NATIONAL NATURAL SCIENCE FOUNDATION OF CHINA

2019 ANNUAL REPORT

FOREWORD

In 2019, under the guidance of President Xi Jinping's Socialist Thoughts with Chinese Characteristics for the New Era, the National Natural Science Foundation of China (hereinafter referred to as NSFC) thoroughly and earnestly implemented the spirits of the 19th National Congress of Chinese Communist Party and its Second, Third and Fourth Plenary Sessions and the important statements of President Xi on basic research. In accordance with the decisions and arrangements of the CPC Central Committee and the State Council on strengthening basic research, NSFC systematically deepened the comprehensive reform on science funding, carefully developed the medium and long-term plan and the 14th Five Year Plan, and successfully completed annual funding work—received a total of approximately 250,700 applications throughout the year, funded 45,200 projects based on merit review with the total amount of about 28.081 billion yuan for the direct cost.

Studying and formulating a systematic reform plan, and comprehensively deepening the reform. After careful research and extensive consultation, on the basis of the pilot reform in 2018, we further formulated a systematic reform plan that has three major tasks (identifying funding categories, improving evaluation mechanisms, and optimizing layout of research areas) at the core, supported by key measures that are to strengthen three aspects (the integrity of the Party and clean government, academic atmosphere and scientific research integrity and ethics, organization and team building), improve six mechanisms (identifying scientific issues addressing major demands, identifying scientific issues at the frontiers of science, planning and organizing major programs, promoting knowledge translation into application, encouraging transdisciplinary and convergent research, and diversifying funding sources), highlight two priorities (original exploratory program, and upgraded talent funding portfolio), and continue optimizing seven areas of funding management (clarifying priorities at all levels, deepening international cooperation systematically, continuously improving rules and regulations, improving project management, regulating funding management, conducting performance evaluation, and strengthening unit management). So far, various aspects of the reform have been advanced in an orderly manner with some of the measures having achieved initial results.

Implementing the Original Exploratory Program to encourage and support originality and innovation. We formulated and implemented the "National Natural Science Foundation Original Exploratory Program Implementation Plan (Trial)" and adopted a new application and review mechanism so as to strongly support original ideas. We also collaborated with the Ministry of Science and Technology and other departments to study and formulate documents such as the "Work Plan for Strengthening Mathematical Science Research", and actively cultivate leading-edge original research results.

Strengthening scientific integrity and purifying the academic ecology. Based on the principles of positive incentives and prudent records, the evaluation mechanism featuring "Responsibility + Credibility + Contribution" was piloted. An "Open Letter from the National Natural Science Foundation of China on Implementation of Commitments by All Parties to Create a Clean and Upright Environment for Review" was issued to achieve full coverage of the "quadripartite commitments" in the review. We have also rigorously enforced review disciplines and strictly implemented on-spot supervision.

Strengthening the fostering of outstanding talents and consolidating the foundation of innovative talents. Focusing on the overall development of science and technology talents, we vigorously cultivated young talents and funded 17,966 young scholars through Young Scientists Fund. The scale of funding for outstanding talents has been moderately expanded with an increase from 200 to 300 for the National Science Fund for Distinguished Young Scholars, and an increase from 400 to 600 for the Excellent Young Scientists Fund. Moreover, we piloted the application for Excellent Young Scientists Fund in the Hong Kong and Macao Special Administrative Regions, and funded 25 excellent young scholars from the two SARs after merit-based selection.

Deepening the reform on the management of Joint Funds Programs and encouraging diversified investment. Four companies including Sinopec joined the Joint Fund for Enterprise Innovation and Development, 16 provinces joined the Joint Fund for Regional Innovation and Development, and 4 ministries joined the Joint Fund for Industry Sectors, attracting a total fund of 6.73 billion yuan. Throughout the year, we funded a total of 925 projects through the Joint Funds with direct costs of 1.851 billion yuan.

Optimizing the fund management of projects and creating an ecology conducive to scientific research. We issued the "Notice of the National Natural Science Foundation of China, the Ministry of Science and Technology and the Ministry of Finance on the Pilot Implementation of Overall Rationing System in the Use of Project Funding for the National Science Fund for Distinguished Young Scholars" to substitute the mechanism of principal investigator accountability and publicize concluding report for budget proposal. We formulated the "Pilot Implementation Plan for Improving the Ratio of Indirect Costs of Knowledge-Intensive and Pure Theoretical Basic Research Projects" to increase the proportion of indirect costs and strengthen incentives for scientific researchers.

Expanding international (regional) cooperation network to a new level of openness and cooperation. We hosted the "Dialogue on Future Directions for Research Funding", and held thorough discussions with partner agencies from 21 countries and regions including the U.K., Russia, the U.S. and Germany and international organizations on how to address the scientific paradigm shift and global challenges. We strengthened support for substantive collaborative research and personnel exchange by funding 1,140 projects with the direct cost of 1.009 billion yuan. And we also initiated the SDG Joint Research Program with an aim to promote scientific development, people-to-people exchanges and win-win cooperation.

Encouraging the sharing of research results and promoting the application and transfer of the results. We continued promoting the publicizing and sharing of research results. The Network for National Natural Science Fund Sharing Service has included and publicized 340,000 concluded projects and 3.94 million research results. We also sought to establish a "green channel" from basic research to technological innovation, and successfully practiced the transfer of research results to serve the need of local economic development in Beijing and Zhejiang Province.

2020 is the year for China to join the rank of innovative countries. It is the final year of the "Thirteenth Five-Year Plan" and the year for preparation for the "Fourteenth Five-Year Plan". NSFC must adhere to Xi Jinping's Socialist Thoughts with Chinese Characteristics for the New Era, thoroughly implement the spirits of the 19th National Congress of the CPC and its Second, Third and Fourth Plenary Sessions, the decisions of the CPC Central Committee and the State Council, and the work arrangements of the Ministry of Science and Technology with the approach of piloting first, active publicity, extensive consultation, and steady advance, systematically deepen the reform, give full play to the unique role of science funding in the national innovation system, and make tangible contributions to building the country into a science and technology power.

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CONTENTS

Part 1

Overview

NSFC

1.1 Steady Progress in NSFC Reform

In accordance with the overall plan for the systematic reform of science funding, NSFC actively responds to the opportunities and challenges brought by the shifts in scientific research paradigm, focuses on the strategic goals of building a scientific funding system for the new era with advanced ideas, standardized systems, fairness and efficiency, and solidly advances all reform tasks.

I. Identifying funding categories

NSFC produced a video that elaborates on the category-specific application and provides further explanation on the four funding categories, i.e. funding creative and timely ideas to achieve excellence in science, focusing on the frontiers of science in unique ways to lead the cutting edges, supporting application-driven basic research to enable breakthroughs, and encouraging transdisciplinary leading-edge research to promote convergence. Moreover, NSFC selected 26,488 projects that cover all from Key Program and 17 disciplines from General Program to pilot the category-specific application and evaluation, developed review criteria, and explored innovative ways of evaluation, which has won acclaim in the scientific community.

II. Improving evaluation mechanisms

Adhering to the principles of positive incentives, simple indicators, prudent records, and strict confidentiality, NSFC has formulated a pilot scheme of the reformed review mechanism that features "Responsibility + Credibility + Contribution", with establishing a reviewers' Credibility record system at the core, a clear code of conduct for reviewing experts as the basis, and a positive incentive mechanism for reviewers as the direction. The preliminary pilot work was carried out at the Department of Management Sciences. At present, the scientific departments have developed respective plans for conducting pilot work in 2020, based on the pilot scheme of the reformed review mechanism.

III. Optimizing layout of research areas

Accurately grasping the development trend of cross-disciplinary integration, integration of knowledge and application, NSFC has followed the principles derived from the logical structure of the knowledge system to promote the integration of knowledge and application, and taken the adjustment of the application code of the Science Fund as the starting point, formulated "Implementation Plan for Stage Work ", optimized the original three-level code system to a two-level code system, and completed the pilot work of adjusting the code system of the Department of Engineering and Materials Sciences and the Department of Information Sciences.

IV. Promoting the Original Exploratory Program

After in-depth and extensive research, NSFC formulated the "Implementation Plan for the Original Exploratory Program (Trial)", and adopted a different selection and implementation approach other than the existing one by setting up a separate funding channel to simplify the review process. Focusing on the originality of research ideas and the leading of expected results during the evaluation, an innovative management mode that includes pre-application, double-blinded review and feedback of review results has also been introduced, which facilitates the establishment of a funding mechanism conducive to the emergence of original results. "2020 NSFC Call for Proposals of the Original Exploratory Program" was released in December 2019.

V. Optimizing program management

In accordance with the requirements in documents such as "Opinions on Deepening Project Review, Talent Evaluation, and Institutional Evaluation Reform", "State Council's Notice on Optimizing Scientific Research Management and Measures to Improve Scientific Research Performance", as well as the requirements for "decentralization and management" reform, NSFC proposed a series of measures to optimize program management. Firstly, it is no longer necessary for applicants of the National Science Fund for Distinguished Young Scholars and the Science Fund for Creative Research Groups to provide recommendations from the academic committee or expert group. Secondly, it is no longer necessary for postdoctoral fellows to provide a letter of commitment from the host institution when applying for General Program, Young Scientists Fund and Fund for Less Developed Regions. Thirdly, participants in the application for Young Scientists Fund are no longer listed, so that reviewers will focus on the capability of the applicant to independently conduct scientific research projects and carry out innovative research. Fourthly, NSFC improved the evaluation system for representative work by reducing the maximum number of representative publications listed in the CV of applicants and participants from 10 to 5, and limiting the maximum number of other research achievements and awards to 10. Lastly, the scope of pilot paperless application was expanded to Young Scientists Fund.

VI. Optimizing talent program portfolio

There has been respective increases of 200 and 100 in the numbers of grants for Excellent Young Scientist Fund and National Science Fund for Distinguished Young Scholars, to further meet the needs of fostering outstanding talents in basic research. Extended funding for Science Fund for Creative Research Groups was canceled, and the number of grants increased from 38 to 46. The number of awards for Basic Science Center Program was also increased with its selection mechanism optimized, so as to further strengthen the support for excellent research teams and cultivate several academic highlands of critical international impacts. NSFC revised the Regulations on the Management of Excellent Young Scientist Fund and National Science Fund for Distinguished Young Scholars, removed restrictions on the applicants of foreign nationalities and non-Chinese origin, and simplified the requirements for application materials and process management. Moreover, NSFC completed the revision of the "Regulation on the Management of Young Scientists Fund", excluded participants and cooperative institutions in the application, and reinforced the management of projects undertaken by postdoctoral fellows.

VII. Regulating funding management

To implement the requirements of the "Government Work Report", NSFC formulated and issued the "Notice of the National Natural Science Foundation of China, the Ministry of Science and Technology and the Ministry of Finance on the Pilot Implementation of 'Overall Rationing System' in the Use of Project Funding for the National Science Fund for Distinguished Young Scholars", piloted the approval and appropriation of the National Science Fund for Distinguished Young Scholars in 2019, abolished budget preparation and implemented the principal investigator (PI) accountability system, allowing the PIs to independently determine the use of fund within the prescribed scope, and giving researchers greater autonomy to use funds.

To implement the requirements of the "State Council's Notice on Several Measures for Optimizing Scientific Research Management and Improving Scientific Research Performance", NSFC promulgated and implemented the "Pilot Implementation Plan for Improving the Indirect Funding Ratio of Intellectually Intensive and Pure Theoretical Basic Research Projects", adjusted the funding structure and increased the proportion of indirect funds to boost the incentives for researchers. In 2019, a total of 364 pilot projects were funded, with indirect costs increased by 48.9 million yuan.

VIII. Expanding diversified investment into basic research

NSFC strengthened the top-down design and overall management, adhered to the problem-oriented and demand-oriented principles, continued deepening the reform of Programs of Joint Funds, and further expanded the Regional Innovation and Development Joint Fund and the Corporate Innovation and Development Joint Fund to more provinces and industries. At present, 16 provinces have joined the Regional Innovation and Development Joint Fund, and the co-sponsors have committed to invest 4.98 billion yuan during the agreement period; 4 enterprises have joined the Corporate Innovation and Development Joint Funds, and the co-sponsors have committed to invest 950 million yuan during the agreement period. NSFC has also established or renewed joint fund agreements with 4 industrial departments, and an investment of 800 million yuan has been committed. A diversified investment mechanism has initially been established, with a total external fund of 6.73 billion yuan attracted under the joint fund model in the new era.

IX. Promoting transfer and application of research achievements

NSFC improved the science fund sharing service network and basic research knowledge database to promote the use of funding results for the benefits of the whole society. Till now, the Network for National Natural Science Fund Sharing Service (Science and Technology Achievements Information System) has included more than 340,000 items of information on concluded projects and 3.94 million items of research results; the basic research knowledge database has collected metadata and full text of 669,498 research papers involving 789,669 authors and 2,052 research institutions. All the information is openly accessible to the whole society, which makes the database an open platform for disseminating cutting-edge scientific and technological knowledge and promoting scientific and technological progress.

NSFC also explored the effective transfer of science funding achievements to serve the needs of local economic development. Through co-hosting the "Beijing Networking Conference for Outstanding Achievements supported by National Natural Science Fund" with Beijing Municipality, NSFC introduced 24 outstanding achievements in 3 areas including artificial intelligence, information technology, and biomedicine to Beijing by on-site display, of which 3 research teams with outstanding achievements signed cooperation agreements with 3 investment companies on site. NSFC also co-organized the "Distinguished Young Scholars' Trip to Zhejiang" with Zhejiang Province. More than 180 scientists funded by NSFC and more than 600 representatives from enterprises, venture capital institutions, incubators, mass innovation spaces and universities and research institutions in Zhejiang participated in the activity; the roadshow for 48 projects was presented, and 11 cooperation agreements were signed on the spot.

X. Reinforcing regulation on host institutions

NSFC thoroughly implemented the "Several Opinions of the National Natural Science Foundation of China on Further Strengthening the Management of Science Fund of at Host Institutions", and made systematic deployments to strengthen the role that host institutions play in science fund management. With due procedures, NSFC approved the registration of 169 host institutions, and that of 8 host institutions in Hong Kong and Macao Special Administrative Regions, and terminated the qualifications of 146 host institutions in accordance with the regulations, in an effort to constantly improve the dynamic "in" and "out" management mechanism. NSFC also emphasized the training of the research management personnel at host institutions, continued managing and supporting the regional networks, helped host institutions to raise the awareness of effectively performing the management responsibilities and to comprehensively improve the management skills, so as to ensure the effectiveness of science fund management.

1.2 Overview of Budget, Outlays and Funding

I. Overview of Budget and Outlays

In 2019, the fiscal budget of NSFC was 31.1 million yuan, of which the budget for project funding was 30.7 million yuan. In 2019, NSFC completed the appropriation of project funds with a total amount of 30.6 million yuan, of which the direct cost was 26.6 million yuan, and the indirect cost was 4.1 million yuan. The fiscal budget statistics of NSFC in 2019 are shown in Table 1-2-1.

Table 1-2-1 NSFC Fiscal Budget and Outlays in 2019

(Unit: 10,000 yuan)

Types	Fiscal Budget	Annual Outlays
National Natural Science Fund	2,976,089.18	2,971,984.62
National Science Fund for Distinguished Young Scholars	90,140.00	87,979.50
Total	3,066,229.18	3,059,964.12

II. Overview of Funding

In 2019, NSFC invested a total of 33,016.9048 million yuan to fund various types of projects, of which the direct cost was 28,080.8589 million yuan, and the indirect costs of 1,454 host institutions were 4,936.0459 million yuan. The project funding statistics of NSFC in 2019 are shown in Table 1-2-2.

Table 1-2-2 NSFC Project Funding Statistics in 2019

(Unit: 10,000 yuan)

No.	Types	Awards	Direct Funding	Indirect Funding	Total
1	General Program	18,995	1,112,699.00	213,632.30	1,326,331.30
2	Key Program	743	221,840.00	41,825.29	263,665.29
3	Major Program	46	88,596.36	16,460.58	105,056.94
4	Major Research Plan	526	100,150.46	17,367.19	117,517.65
5	International (Regional) Joint Research Program	428	88,926.10	15,543.94	104,470.04
6	Young Scientists Fund	17,966	420,795.00	80,260.70	501,055.70
7	Fund for Less Developed Regions	2,960	110,486.00	21,434.49	131,920.49
8	Excellent Young Scientists Fund	625	77,990.00	15,760.00	93,750.00
9	National Science Fund for Distinguished Young Scholars	296	116,120.00	0.00	116,120.00
10	Science Fund for Creative Research Groups (Newly Approved)	45	44,580.00	7,980.00	52,560.00
11	Joint Research Fund for Overseas Chinese Scholars and Scholars in Hong Kong and Macao (Extended Funding Projects)	23	3,920.00	680.00	4,600.00
12	Programs for Joint Funds	925	185,090.00	33,589.18	218,679.18

(continued)

No.	Types	Awards	Direct Funding	Indirect Funding	Total
13	Special Fund for Research on National Major Research Instrument	85	78,340.76	11,342.59	89,683.35
14	Basic Science Center Program	13	102,000.00	12,482.08	114,482.08
15	Special Fund for Emergency Programs	715	41,062.54	4,444.72	45,507.26
16	Tianyuan Fund for Mathematics	89	3,500.00	0.00	3,500.00
17	Research Fund for International Young Scientists	161	4,500.00	801.53	5,301.53
18	International (Regional) Personnel Exchange Program	551	7,489.67	0.00	7,489.67
Total		45,192	2,808,085.89	493,604.59	3,301,690.48

1.3 Overview of Concluded Projects

In 2019, 38,700 projects supported by NSFC were concluded, of which 15,109 were from General Program, 563 from Key Program, 114 from Major Program, 463 from Major Research Plan, 16,163 from Young Scientists Fund, 2,741 from Fund for Less Developed Regions, 397 from Excellent Young Scientists Fund, 41 from Science Fund for Creative Research Groups, 134 from Joint Research Fund for Overseas Chinese Scholars and Scholars in Hong Kong and Macao, 674 from Programs for Joint Funds, 44 from Special Fund for Research on National Major Research Instrument, 1,274 from Special Fund for Emergency Programs, and 983 from International (Regional) Cooperation and Exchange Program. Among the numerous achievements coming out of the concluded projects, 1,044 international patents on invention and 34,102 domestic patents on invention were obtained, and 541 national awards and 3,619 provincial and ministerial awards, including 148 National Natural Science Awards, 290 National Science and Technology Progress Awards, and 103 National Technology Invention Awards were received.

The statistics of research achievements coming out of the concluded projects supported by NSFC in 2019 are shown in Table 1-3-1.

Table 1-3-1 Research Achievements Coming Out of the Concluded Projects Supported by NSFC in 2019

Research Achievements		Program Type												
		General Program	Key Program	Major Program	Major Research Plan	Young Scientists Fund	Fund for Less Developed Regions	Excellent Young Scientists Fund	Science Fund for Creative Research Groups	Joint Research Fund for Overseas Chinese Scholars and Scholars in Hong Kong and Macao	Programs for Joint Funds	Special Fund for Research on National Major Research Instrument	Special Fund for Emergency Programs	International (Regional) Cooperation & Exchange Program
No. of Concluded Projects		15,109	563	114	463	16,163	2,741	397	41	134	674	44	1,274	983
Publications	Keynote Speeches at International Academic Conferences	3,712	1,103	155	329	804	81	405	337	87	260	161	205	584
	Keynote Speeches at Domestic Academic Conferences	4,676	893	127	240	1,007	316	404	128	45	241	96	171	264
	Journal Papers	186,685	24,870	9,397	7,348	100,827	25,026	6,452	4,232	1,175	10,422	2,584	3,141	7,861
	Conference Papers	27,362	3,713	830	863	14,242	2,612	744	561	264	1,635	347	427	1,048
	Included in SCI Index System	120,632	18,026	7,626	5,596	64,111	9,165	5,282	3,574	877	6,841	1,968	1,760	5,743
	Included in EI Index System	22,732	3,053	834	513	13,702	2,628	576	236	195	1,450	261	277	724
	Monographs	2,550	375	76	78	1,542	545	102	66	7	135	13	76	96
Patents	International	472	92	24	22	199	55	31	88	5	16	11	4	25
	Domestic	16,320	1,974	486	430	9,266	2,134	555	929	41	874	415	130	548
Awards	National level	274	62	26	15	44	6	22	34	1	18	8	2	29
	Provincial/ Ministerial level	1,782	209	56	62	962	188	80	55	6	99	17	11	92
Talents Trained	Postdoctoral Fellow	1,180	305	153	115	524	32	80	90	14	102	44	20	113
	PhD	14,847	2,919	955	907	3,578	514	534	831	101	774	342	109	928
	Master	36,977	3,670	900	1,009	11,238	6,414	845	591	87	1,902	450	406	1,345

Note:
1. There were no projects concluded for National Science Fund for Distinguished Young Scholars and Basic Science Center Program in 2019.
2. International (Regional) Cooperation & Exchange Program includes International (Regional) Joint Research Program, Research Fund for International Young Scientists, and International (Regional) Personnel Exchange Program.
3. Statistics of Tianyuan Fund for Mathematics are included in Special Fund for Emergency Programs.

Part 2

Funding and Selected Awards

NSFC

2.1 Application and Funding Statistics

2.1.1 General Program

Function and Positioning: The Program aims at supporting researchers to select topics independently within the funding scope of NSFC, carry out innovative scientific research, and promote the balanced, coordinated and sustainable development of various disciplines.

Table 2-1-1 Application and Funding of General Program Projects in 2019 (by Scientific Department)

(Unit: 10,000 yuan)

Scientific Departments	Applications	Approved						Success Rate② (%)
		Awards	Direct Funding	Percentage of the Total (%)	Average Funding Per Project①	Indirect Funding		
Mathematical and Physical Sciences	6,897	1,750	104,210.00	9.37	59.55	19,456.34		25.37
Chemical Sciences	7,954	1,675	109,120.00	9.81	65.15	20,381.07		21.06
Life Sciences	14,307	3,007	174,470.00	15.68	58.02	34,126.66		21.02
Earth Sciences	7,774	1,887	117,210.00	10.53	62.11	22,421.60		24.27
Engineering and Materials Sciences	17,893	3,261	195,669.00	17.59	60.00	37,165.42		18.23
Information Sciences	11,342	2,024	120,740.00	10.85	59.65	22,582.16		17.85
Management Sciences	5,258	807	39,160.00	3.52	48.53	7,517.28		15.35
Health Sciences	28,659	4,584	252,120.00	22.66	55.00	49,981.77		15.99
Total	100,084	18,995	1,112,699.00	100.00	58.58	213,632.30		18.98

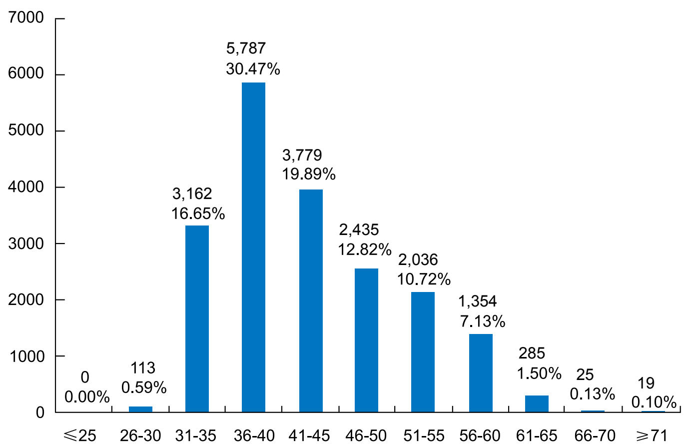


Figure 2-1-1 Age Distribution of Principal Investigators of General Program Projects in 2019

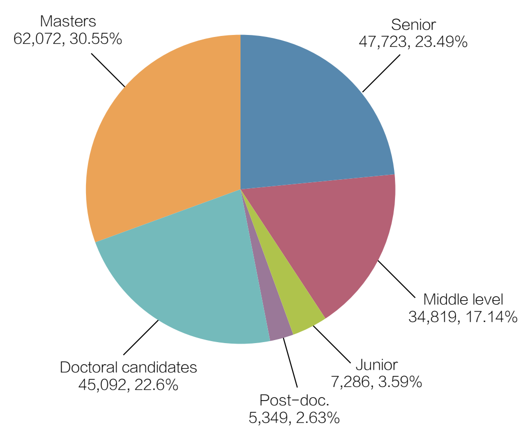


Figure 2-1-2 Professional Structure of Members of Research Groups for General Program Projects in 2019

① average direct funding per project=direct funding/project.
② funding rate =No. of approved/ No. of applications*100.

Table 2-1-2 Statistics of General Program Projects in 2019 (by Region)

(Unit: 10,000 yuan)

No.	Region	Awards	Direct Funding	No.	Region	Awards	Direct Funding
1	Beijing	3,412	201,272.00	16	Chongqing	389	22,382.50
2	Shanghai	2,111	121,656.79	17	Jilin	335	19,926.00
3	Jiangsu	1,992	116,796.91	18	Henan	276	15,944.50
4	Guangdong	1,775	102,780.30	19	Gansu	200	12,113.00
5	Hubei	1,178	69,182.50	20	Shanxi	156	9,312.00
6	Zhejiang	1,019	59,461.00	21	Hebei	151	8,888.00
7	Shaanxi	955	56,515.50	22	Yunnan	122	7,169.00
8	Shandong	820	48,353.00	23	Jiangxi	88	5,082.00
9	Sichuan	667	39,003.00	24	Guangxi	72	4,214.00
10	Liaoning	649	38,205.00	25	Xinjiang	34	2,067.00
11	Hunan	622	36,185.00	26	Guizhou	31	1,884.00
12	Tianjin	546	32,202.50	27	Hainan	19	1,122.00
13	Anhui	476	28,240.00	28	Inner Mongolia	17	1,011.00
14	Fujian	444	26,031.50	29	Qinghai	6	361.00
15	Heilongjiang	430	25,174.00	30	Ningxia	3	164.00

2.1.2 Key Program

Function and Positioning: The Program aims at supporting researchers to carry out in-depth and systematic innovatile research on existing research directions or the new growing points of disciplines, promoting scientific development, and making breakthroughs in several important fields or scientific frontiers.

Table 2-1-3 Application and Funding of Key Program Projects in 2019 (by Scientific Department)

(Unit: 10,000 yuan)

Scientific Departments	Applications	Approved					
		Awards	Direct Funding	Percentage of the Total (%)	Average Funding Per Project	Direct Funding	Success Rate (%)
Mathematical and Physical Sciences	334	90	28,090.00	12.66	312.11	5,155.48	26.95
Chemical Sciences	321	75	22,500.00	10.14	300.00	4,075.50	23.36
Life Sciences	635	115	34,500.00	15.55	300.00	6,647.02	18.11
Earth Sciences	555	98	29,500.00	13.30	301.02	5,672.55	17.66
Engineering and Materials Sciences	595	105	31,500.00	14.20	300.00	5,890.89	17.65
Information Sciences	384	105	31,500.00	14.20	300.00	5,749.62	27.34
Management Sciences	143	30	7,080.00	3.19	236.00	1,355.65	20.98
Health Sciences	758	125	37,170.00	16.76	297.36	7,278.58	16.49
Total	3,725	743	221,840.00	100.00	298.57	41,825.29	19.95

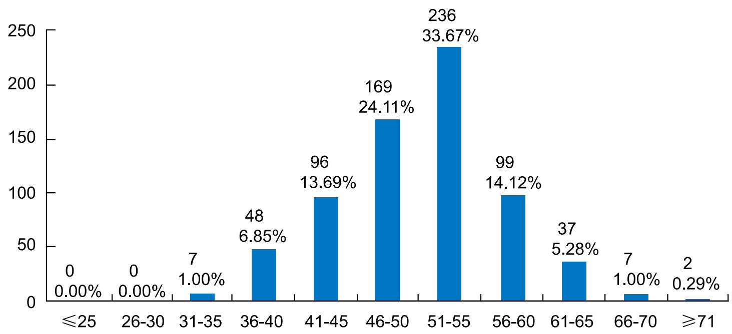


Figure 2-1-3 Age Distribution of Principal Investigators of Key Program Projects in 2019

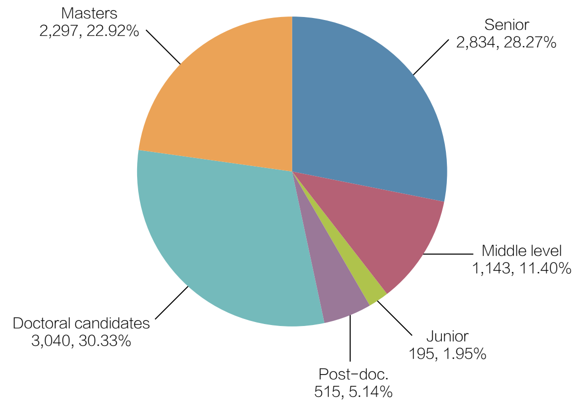


Figure 2-1-4 Professional Structure of Members of Research Groups for Key Program Projects in 2019

2.1.3 Major Program

Function and Positioning: The Program focuses on major scientific issues in the forefront of science and the major needs of national economic, social, technological development and national security. It supports multidisciplinary research and comprehensive research through deploying ahead, gives full play to the supporting and leading role in enhancing China's original innovation ability of basic research.

Table 2-1-4 Funding of Major Program Projects in 2019

(Unit: 10,000 yuan)

No.	Title	PI	Host Institution	Direct Funding	Indirect Funding
1	Artificial intelligence methods for optimizing problems	Yang Xinmin	Chongqing Normal University	1,968.00	364.46
2	Wave energy propagation and control in mechanical metamaterials/metastructures	Hu Gengkai	Beijing Institute of Technology	1,960.00	377.26
3	Reverberation mapping of active galactic nuclei: supermassive black holes and their applications	Wang Jianmin	Institute of High Energy Physics, CAS	1,954.00	358.78
4	Study of noneuilibrium processes in micro- and nano-devices	Wei Suhuai	Beijing Computing Science Research Center	1,944.00	322.47
5	Studies on the mechanism and technique of laser plasma wakefield acceleration	Chen Min	Shanghai Jiao Tong University	1,976.00	317.10
6	In-cell spectral measurement of biomolecular structure and interaction	Liu Maili	Wuhan Institute of Physics and Mathametics, CAS	1,998.00	386.87
7	Catalytic principle and novel processes application of methanol and its coupling reactions	Liu Zhongmin	Dalian Institute of Chemical Physics, CAS	1,991.00	357.16
8	Fundamentals on microchemical engineering towards high-end chemicals production	Luo Guang sheng	Tsinghua University	1,990.00	338.23
9	Development of key reactions and strategies for green manufacture of drugs	Ma Dawei	Shanghai Institute of Organic Chemistry, CAS	2,000.00	372.60
10	Synthesis of high performance perfluoroelastomers resistant to extreme environment	Qing Fengling	Shanghai Institute of Organic Chemistry, CAS	2,000.00	390.00

(continued)

No.	Title	PI	Host Institution	Direct Funding	Indirect Funding
11	Research method and theoretical foundation of catssembly	Tian Zhongqun	Xiamen University	1,987.00	343.36
12	Chemical design and ferroic properties coupling of molecular ferroelectrics	Xiong Rengen	Nanchang University	1,947.40	349.30
13	A fundamental study of new electrochemical interfaces for energy/ matter conversion	Zhuang Lin	Wuhan University	1,998.00	348.84
14	Regulatory mechanism and biological functions of chromatin plasticity	Li Guohong	Institute of Biophysics, CAS	2,000.00	376.33
15	Mechanism underlying regulation of immune cell fate in tumor microenvironment	Dong Chen	Tsinghua University	1,985.00	397.00
16	Molecular basis and genome design of high quality tomato	Huang Erwen	Institute of Agricultural Genomics, CAS	1,990.00	376.62
17	Molecular mechanism and physiological function of ciliogenesis	Ou Guangshuo	Tsinghua University	1,973.00	368.69
18	The molecular mechanisms of cell-cell communication regulation during sexual reproduction in angiosperms.	Qu Lijia	Peking University	1,990.00	377.02
19	Dissection of the molecular basis underlying evolution and domestication of allopolyploid wheat	Sun Qixin	China Agricultural University	1,985.00	379.55
20	Molecular genetic bases for hybrid sterility and reproductive isolation in the Oryza genus	Liu Yaoguang	South China Agricultural University	1,994.00	381.24
21	Ecological-hydrological processes and their impacts on ecosystem services in arid and semi-arid regions of China	Fu Bojie	Beijing Normal University	1,959.40	343.65
22	Anthropocene, a new geological epoch, and its lower boundary, feature and influence	Han Yongming	Institute of Earth Environment, CAS	1,986.70	370.35
23	Study of mechanism, prediction, projection and ecological impacts of extreme climates over mid- and high-latitudes of Asia	Wang Huijun	Nanjing University of Information Science & Technology	1,935.95	366.84
24	Environment-geochemical processes and human health effects of industrial pollutants from typical chemical industrial parks	Tao Peng	Peking University	1,987.00	367.43
25	Modulation mechanism of cenozoic continental weathering	Chen Jun	Nanjing University	1,977.20	377.43
26	Soil combined pollution processes and bioremediation	Luo Yongming	Nanjing Institute of Soil Research, CAS	1,987.00	366.45
27	Sub 10 nm novel semiconductor devices based on two-dimensional materials and their van der waals heterostructures	Zhang Yue	Beijing University of Science and Technology	1,999.51	345.84
28	Principle and method for constructing high-fire-safety polymer materials in confined spaces	Wang Yuzhong	Sichuan University	1,994.00	377.93

(continued)

No.	Title	PI	Host Institution	Direct Funding	Indirect Funding
29	Drilling and exploitation mechanism of natural gas hygrate and regulation method in the South China Sea	Sun Jinsheng	China University of Petroleum (East China)	1,959.00	390.42
30	Research on basic problems of nano-precision surface machining in chip manufacturing	Lu Xinchun	Tsinghua University	1,990.00	368.65
31	Magnetic field modulation theory and design method for high-quality servo motor system	Cheng Ming	Southeast University	2,000.00	400.00
32	Construction and operation hazards and their control measurements of super-long subsea tunnels in adverse geological conditions	Du Yanliang	Shandong University	2,000.00	385.44
33	Basic theory and key technologies of major energy-consuming equipment with intelligent systems	Chai Tianyou	Northeast University	1,939.00	345.63
34	Control theory and application of unmanned surface vehicle cluster in complex sea conditions	Xie Shaorong	Shanghai University	1,985.00	370.21
35	Research on SAR microwave vision three-dimensional imaging theory and application foundation	Ding Chibiao	Institute of Electronics, CAS	1,961.00	355.12
36	Basic theory and key technology of high performance middle and far infrared quantum cascade laser	Chen Yonghai	Institute of Semiconductors, CAS	1,965.00	302.90
37	Energy state manipulation and infrared photoelectric detection mechanism of new quantum structures	Chen Xiaoshuang	Shanghai Institute of Technical Physics, CAS	1,978.80	360.78
38	On the fundamental theory and key techniques for scattering optical imaging in marine environment	Chen Weibiao	Shanghai Institute of Optics and Fine Mechanics, CAS	1,960.00	345.69
39	Research on theories and applications of enterprise operation and service innovation management	Chen Xiaohong	Hunan University of Technology and Business, CAS	1,463.80	283.76
40	Econometrics modeling and prediction at big data era	Fan Jianqing	Fudan University	1,462.40	285.68
41	Strategic and critical mineral resources security and management in the new era	Wang Anjian	Institute of Mineral Resources, CAS	1,500.00	298.60
42	Strategic factors and their underlying regulatory mechanism for modulating vaccine efficacy	Xia Ningshao	Xiamen University	1,781.80	350.85
43	Study on the mechanism for the maintenance and remodeling of periodontal homeostasis	Chen Qianming	Sichuan University	1,793.40	357.46
44	Study on the role and regulatory mechanisms of bone-derived factors in maintaining homeostasis of the body	Bao Xiaochun	South Medical University	1,800.00	347.79
45	Discovery and formation mechanism of marine pharmaceutical molecules	Tan Renxiang	Nanjing University of Traditional Chinese Medicine	1,800.00	360.00
46	Development and spread of bacterial resistance	Wang Minggui	Fudan University	1,800.00	352.80
Total				88,596.36	16,460.58

2.1.4 Major Research Plan

Function and Positioning: The Plan follows the basic principles of limited goals, stable support, integrated sublimation, and leapfrog development. It focuses on major national strategic needs and major scientific frontiers, strengthens top-level design, consolidates scientific goals, and gathers superior strengths to form relatively unified goals, thus forming project clusters with common goals or direction. It promotes the intersection and integration of disciplines, cultivates innovative talents and teams, enhances the original innovation ability of China's basic research, and provides scientific support for national economy, social development and national security.

Table 2-1-5 Applications and Funding of Major Research Plan Projects in 2019

(Unit: 10,000 yuan)

No.	Title	Applications	Approved	Direct Funding	Indirect Funding
1	Mechanism and manipulation of mesoscales in multi-phase reaction processes	13	4	3,300.00	451.16
2	Project-dissection of genetic networks controlling yield traits in major crops	8	6	5,580.00	841.33
3	Precision measurement physics	1	1	213.46	0.00
4	Tibetan Plateau land-air coupled system change and its impact on global climate	4	3	2,080.00	265.85
5	Fundamental theory and key technology of spatial information network	13	7	1,600.00	249.80
6	Regulation of vascular homeostasis and remodeling	152	15	1,138.00	226.15
7	Mechanism of regulatory of noncoding RNA in gene information transmission	18	7	5,800.00	910.00
8	Basic research on turbulent combustion for engines	36	7	2,000.00	295.12
9	Tissue and organ regional immunity and disease	80	15	3,750.00	747.20
10	Toxicology and health effects of fine particulate matter in the atmosphere	1	1	1,200.00	193.20
11	Catalytic science of carbon-based energy conversion and utilization	5	3	3,100.00	439.28
12	Research on the basic theory and key technology of Tri-Co robots	30	7	5,000.00	811.82
13	Mechanism of organ senescence and organ degeneration	393	39	3,800.00	746.98
14	New light field control physics and application	127	29	4,734.00	788.10
15	Driving mechanism of hydrosphere microbes towards the circulation of earth's elements	147	32	4,918.00	893.34
16	Formation, evolution and mechanism of turbulence structure	76	19	4,800.00	836.12
17	Dynamic modification and chemical intervention of biomacromolecules	138	27	2,480.00	437.78
18	Organelle interaction networks and their functions	121	34	4,220.00	779.75

(continued)

No.	Title	Applications	Approved	Direct Funding	Indirect Funding
19	Tethys geodynamic system	43	11	3,599.00	704.01
20	Accurate construction of multi-level chiral substances	220	34	3,600.00	613.88
21	Spatio-temporal network regulation of glucose and lipid metabolism	202	35	5,000.00	984.82
22	Multi-ring interaction of the earth system in the western Pacific	75	26	5,000.00	932.45
23	Molecular functional visualization of tumor evolution and diagnosis and treatment	347	39	5,000.00	927.89
24	Scientific basis of high-temperature materials for aeroengines/ advanced manufacturing and fault diagnosis	81	14	1,800.00	351.66
25	Structural function and multistage evolution of clusters	209	30	3,658.00	658.97
26	Strategic key metal supernormal enrichment ore dynamics	133	24	5,280.00	931.11
27	Basic research on high-performance materials with functional element order	381	42	5,400.00	980.36
28	Basic research on new devices in post-Moore era	91	15	2,100.00	369.06
Total		3,145	526	100,150.46	17,367.19

2.1.5 International (Regional) Cooperative Research Program

Function and Positioning: The Program funds researchers to base on the forefront of international science, effectively use international scientific and technological resources, conduct substantive international research on the principle of equal cooperation, mutual benefit and sharing of results, so as to improve the scientific research and international competitiveness of China. The Program includes Key International (Regional) Cooperative Research Program and MoU-Based Cooperative Research Program.

The Key International (Regional) Cooperative Research Program funds scientific and technical personnel to research on priority funded areas of the National Science Fund, the research areas that China urgently needs to develop, the international large-scale scientific research projects or programs that Chinese scientists organize or participate in, and large international (regional) collaborative research by use of large international scientific facilities and partners.

The MoU-Based Cooperative Research Program supports bilateral and multilateral cooperation within the framework of inter-organizational agreements, makes full use of the coordination mechanism of international scientific and technological organizations in transnational cross-border scientific research programs, promotes Chinese scientists to participate in, plan and carry out regional cross-border research projects with important scientific significance, actively advances cooperation with countries and regions along the “Belt and Road” area, implements the central government’s “one country, two systems” policy, and continues to strengthen cooperation and exchanges with scientists from Hong Kong, Macao and Taiwan.

Table 2-1-6 Application and Funding of Key International (Regional) Cooperative Research Program Projects in 2019

(Unit: 10,000 yuan)

Scientific Departments	Applications	Approved					Success Rate (%)
		Awards	Direct Funding	Percentage of the Total (%)	Average Funding Per Project	Indirect Funding	
Mathematical and Physical Sciences	28	5	1,050.00	4.20	210.00	202.20	17.86
Chemical Sciences	38	7	1,610.00	6.44	230.00	285.26	18.42
Life Sciences	88	16	4,080.00	16.32	255.00	777.22	18.18
Earth Sciences	40	10	2,310.00	9.24	231.00	444.54	25.00
Engineering and Materials Sciences	92	14	3,440.00	13.76	245.71	637.40	15.22
Information Sciences	80	14	3,480.00	13.92	248.57	643.51	17.50
Management Sciences	20	4	850.00	3.40	212.50	162.52	20.00
Health Sciences	171	33	8,180.00	32.72	247.88	1,607.96	19.30
Total	557	103	25,000.00	100.00	242.72	4,760.61	18.49

Table 2-1-7 Application and Funding of MoU-Based Cooperative Research Program Projects in 2019

(Unit: 10,000 yuan)

Scientific Departments	Applications	Approved					
		Awards	Direct Funding	Percentage of the Total (%)	Average Funding Per Project	Indirect Funding	Success rate (%)
Mathematical and Physical Sciences	79	33	8,882.00	13.89	269.15	1,496.98	41.77
Chemical Sciences	175	41	7,001.00	10.95	170.76	1,287.24	23.43
Life Sciences	308	73	15,965.12	24.97	218.70	3,046.06	23.7
Earth Sciences	174	39	7,611.00	11.91	195.15	1,443.70	22.41
Engineering and Materials Sciences	315	60	11,100.99	17.37	185.02	2,041.24	19.05
Information Sciences	124	24	3,026.00	4.73	126.08	533.76	19.35
Management Sciences	123	16	3,030.00	4.74	189.38	583.46	13.01
Health Sciences	379	39	7,309.99	11.44	187.44	350.89	10.29
Total	1,677	325	63,926.10	100.00	196.70	10,783.33	19.38

2.1.6 Young Scientists Fund

Function and Positioning: The Fund supports young science and technology personnel to select topics independently within the funding scope of the National Science Fund, conduct basic research, train young science and technology talents to independently carry out research projects, conduct innovative research, and cultivate basic research talents.

Table 2-1-8 Application and Funding of Young Scientists Fund Projects in 2019 (by Scientific Department)

(Unit: 10,000 yuan)

Scientific Departments	Applications	Approved					Success rate (%)
		Awards	Direct Funding	Percentage of the Total (%)	Average Funding Per Project	Indirect Funding	
Mathematical and Physical Sciences	6,774	1,800	45,000.00	10.69	25.00	8,243.14	26.57
Chemical Sciences	8,015	1,566	39,260.00	9.33	25.07	7,320.24	19.54
Life Sciences	13,519	2,428	58,240.00	13.84	23.99	11,493.84	17.96
Earth Sciences	7,481	1,727	43,220.00	10.27	25.03	8,149.16	23.09
Engineering and Materials Sciences	16,460	3,121	78,011.00	18.54	25.00	14,716.88	18.96
Information Sciences	8,837	2,134	52,154.00	12.39	24.44	9,587.64	24.15
Management Sciences	5,817	865	16,230.00	3.86	18.76	3,091.07	14.87
Health Sciences	33,473	4,325	88,680.00	21.07	20.50	17,658.73	12.92
Total	100,376	17,966	420,795.00	100.00	23.42	80,260.70	17.90

Note: 48,704 proposals from male PIs and 10,576 granted; 51,672 from female and 7,390 granted.

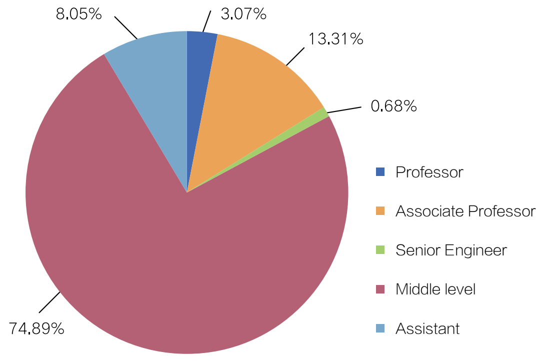


Figure 2-1-5 Professional Structure of Principal Investigators of Research Groups for Young Scientists Fund in 2019

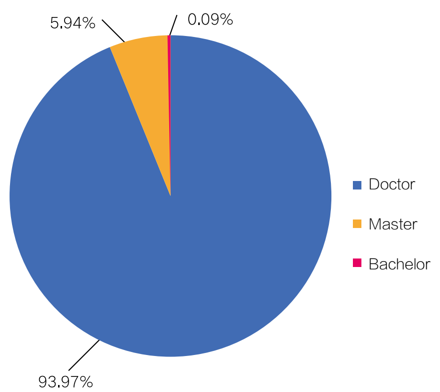


Figure 2-1-6 Academic Degree of Principal Investigators of Young Scientists Fund in 2019

Table 2-1-9 Application and Funding of Young Scientists Fund Projects in 2019 (by Region)

(Unit: 10,000 yuan)

No.	Region	Applications	Awards	Direct Funding	Percentage of the Total (%)	Average Funding Per Project	Indirect Funding	Success Rate (%)
1	Beijing	10,242	2,419	56,858.20	13.51	23.50	10,785.60	23.62
2	Guangdong	9,955	2,055	47,603.70	11.31	23.16	9,102.52	20.64
3	Jiangsu	9,669	1,840	43,103.70	10.24	23.43	8,193.43	19.03
4	Shanghai	7,924	1,610	36,422.30	8.66	22.62	6,973.74	20.32
5	Shaanxi	5,526	1,112	26,811.10	6.37	24.11	5,073.81	20.12
6	Hubei	5,650	1,084	25,306.00	6.01	23.35	4,896.45	19.19
7	Shandong	6,589	1,038	24,738.10	5.88	23.83	4,734.03	15.75
8	Zhejiang	5,813	913	21,140.50	5.02	23.15	4,067.81	15.71
9	Sichuan	4,512	753	17,574.30	4.18	23.34	3,360.83	16.69
10	Hunan	3,333	657	15,401.10	3.66	23.44	2,894.02	19.71
11	Henan	4,583	566	13,312.00	3.16	23.52	2,567.44	12.35
12	Liaoning	3,058	507	11,884.50	2.82	23.44	2,257.54	16.58
13	Tianjin	2,532	439	10,270.30	2.44	23.39	1,932.16	17.34
14	Anhui	2,491	415	9,883.90	2.35	23.82	1,864.04	16.66
15	Chongqing	2,531	425	9,721.50	2.31	22.87	1,878.35	16.79
16	Fujian	2,132	364	8,519.50	2.02	23.41	1,623.92	17.07
17	Heilongjiang	1,887	306	7,241.50	1.72	23.67	1,389.53	16.22
18	Jilin	1,746	263	6,252.50	1.49	23.77	1,196.17	15.06
19	Shanxi	1,765	223	5,299.50	1.26	23.76	1,007.41	12.63
20	Jiangxi	1,407	186	4,439.50	1.06	23.87	844.62	13.22
21	Gansu	991	176	4,347.00	1.03	24.70	812.89	17.76
22	Hebei	1,643	165	3,943.00	0.94	23.90	746.17	10.04
23	Yunnan	1,039	138	3,312.10	0.79	24.00	637.97	13.28
24	Guangxi	1,077	90	2,106.50	0.50	23.41	408.70	8.36
25	Guizhou	836	78	1,852.10	0.44	23.74	352.44	9.33
26	Inner Mongolia	461	50	1,201.00	0.29	24.02	231.40	10.85
27	Xinjiang	359	35	861.60	0.20	24.62	167.11	9.75
28	Hainan	334	36	857.50	0.20	23.82	160.26	10.78
29	Qinghai	129	12	282.00	0.07	23.50	54.06	9.30
30	Ningxia	150	10	228.50	0.05	22.85	42.48	6.67
31	Tibet	12	1	20.00	0.00	20.00	3.80	8.33
Total		100,376	17,966	420,795.00	100.00	23.42	80,260.70	17.90

2.1.7 Fund for Less Developed Regions

Function and Positioning: The Fund supports scientific and technical personnel of host institutions in specific regions to carry out innovative scientific research within the scope of the National Science Fund, cultivates and supports scientific and technical personnel in the region, and stabilizes and unites outstanding talents for the region, and serves the development of the innovation system and economic and social development.

Table 2-1-10 Application and Funding of Fund for Less Developed Regions Projects in 2019 (by Funding)

(Unit: 10,000 yuan)

Region		Applications	Approved					Success rate (%)
			Awards	Direct Funding	Percentage of the Total (%)	Average Funding Per Project	Indirect Funding	
Jiangxi		3663	617	22,890.90	20.72	37.10	4,441.97	16.84
Yunnan		3156	485	17,954.20	16.25	37.02	3,499.65	15.37
Guangxi		2996	430	16,080.80	14.55	37.40	3,087. 92	14.35
Xinjiang		1778	264	9,947.80	9.00	37.68	1,939.20	14.85
Guizhou		2409	306	11,190.00	10.13	37.57	2,169.75	12.70
Gansu		1886	234	8,925.70	8.08	38.14	1,727.34	12.41
Inner Mongolia		1484	231	8,785.90	7.95	38.03	1,700.41	15.57
Ningxia		765	123	4,567.60	4.13	37.13	895.67	16.08
Hainan		666	121	4,519.10	4.09	37.35	876.32	18.17
Qinghai		354	53	2,066.00	1.87	38.98	407.33	14.97
Tibet		109	22	811.00	0.73	36.86	158.96	20.18
Shaanxi	Yan'an	82	10	364.50	0.33	36.5	68.27	12.2
	Yulin	115	10	391.00	0.35	39.1	75. 36	8.7
Jilin	Yanbian	227	25	901.00	0.82	36.04	177.10	11.01
Hunan	Xiangxi	87	12	443.00	0.40	36.92	84.88	13.79
Hubei	Enshi	67	13	500.50	0.45	38.5	96.06	19.40
Sichuan	Liangshan	42	4	147.00	0.13	36.75	28.30	9.52
	Ganzi	0	0	0.00	0.00	0.00	0.00	0.00
	Aba	10	0	0.00	0.00	0.00	0.00	0.00
Total		19896	2960	110,486.00	100	37.33	21,434.49	14.88

Note: there were 12,704 applications from male applicants, of which 1,923 were funded, and 7,192 from female applicants, of which 1,037 were funded.

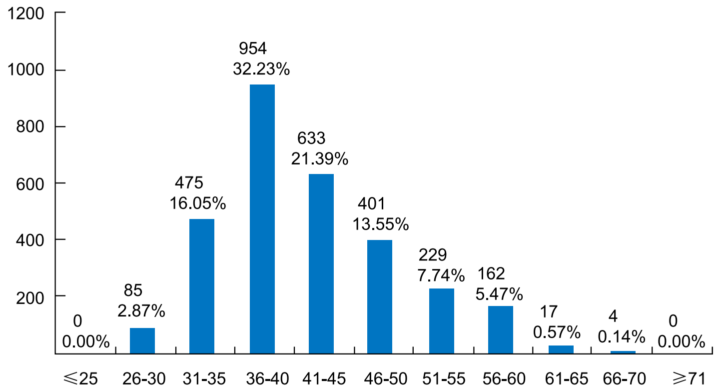


Figure 2-1-7 Age Distribution of Principal Investigators of Projects of the Fund for Less Developed Regions in 2019

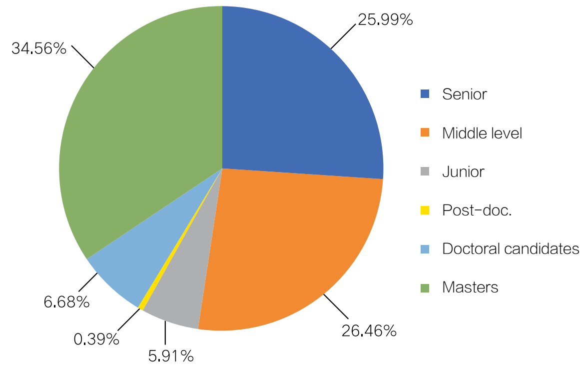


Figure 2-1-8 Professional Structure of Members of Research Groups for the Fund for Less Developed Regions in 2019

2.1.8 Excellent Young Scientists Fund

Function and Positioning: The Fund supports young scholars who have achieved good results in basic research to independently conduct innovative research, promotes the rapid growth of young science and technology talents, and cultivates a group of excellent academic talents who are expected to enter the forefront of world science and technology.

To support the technological innovation and development of the Hong Kong and Macao Special Administrative Regions, to encourage high-quality scientific and technological talents from Hong Kong and Macao to participate in the central financial science and technology plan, and to contribute the construction of a strong science and technology country, NSFC launched a pilot program and opened the Excellent Young Scientists Fund to the scientific and technological talents of Hong Kong and Macao in 2019.

Table 2-1-11 Application and Funding of Excellent Young Scientists Fund Projects in 2019 (by Scientific Department)

(Unit: 10,000 yuan)

Scientific Departments	Applications	Approved					Success rate (%)
		Awards	Direct Funding	Percentage of the Total (%)	Average Funding Per Project	Indirect Funding	
Mathematical and Physical Sciences	672	71	8,840.00	11.83	124.51	1,810.00	10.57
Chemical Sciences	805	86	10,640.00	14.24	123.72	2,260.00	10.68
Life Sciences	815	86	10,770.00	14.41	125.23	2,130.00	10.55
Earth Sciences	576	59	7,380.00	9.87	125.08	1,470.00	10.24
Engineering and Materials Sciences	1,080	110	13,720.00	18.36	124.73	2,780.00	10.19
Information Sciences	876	90	11,250.00	15.05	125.00	2,250.00	10.27
Management Sciences	192	22	2,720.00	3.64	123.64	580.00	11.46
Health Sciences	607	76	9,420.00	12.60	123.95	1,980.00	12.52
Total	5,623	600	74,740.00	100.00	124.57	15,260.00	10.67

Note: there were 4,468 applications from male applicants, of which 471 were funded, and 1,155 from female applicants, of which 129 were funded.

Table 2-1-12　Application and Funding of Excellent Young Scientists Fund for Hong Kong and Macao Projects in 2019 (by Scientific Department)

(Unit: 10,000 yuan)

Scientific Departments	Applications	Approved					Success rate (%)
		Awards	Direct Funding	Percentage of the Total (%)	Average Funding Per Project	Indirect Funding	
Mathematical and Physical Sciences	34	3	390.00	12.00	130.00	60.00	8.82
Chemical Sciences	24	2	260.00	8.00	130.00	40.00	8.33
Life Sciences	40	4	520.00	16.00	130.00	80.00	10.00
Earth Sciences	16	1	130.00	4.00	130.00	20.00	6.25
Engineering and Materials Sciences	38	4	520.00	16.00	130.00	80.00	10.53
Information Sciences	42	3	390.00	12.00	130.00	60.00	7.14
Management Sciences	27	2	260.00	8.00	130.00	40.00	7.41
Health Sciences	73	6	780.00	24.00	130.00	120.00	8.22
Total	294	25	3,250.00	100.00	130.00	500.00	8.50

Note: there were 206 applications from male applicants, of which 17 were funded, and 88 from female applicants, of which 8 were funded.

2.1.9 National Science Fund for Distinguished Young Scholars

Function and Positioning: The Fund supports young scholars who have achieved outstanding results in basic research to independently conduct innovative research, promotes the growth of young scientific and technological talents, attracts overseas talents, and cultivates a group of academic leaders to enter the forefront of the international science and technology community.

In 2019, we received 3,159 applications for the Fund. After review, we funded 296 people. The total direct funding was 1.1612 billion yuan.

Table 2-1-13　Awardees of National Science Fund for Distinguished Young Scholars in 2019

(Unit: 10,000 yuan)

No.	PI	Title	Host Institution
1	Lu Shuai	Computational methods and mathematical theory of inverse problems	Fudan University
2	Yuan Donghua	Physics of bacterial motility	University of Science and Technology of China
3	Lin Wei	Methodology and theory in modern mathematical biology and their applications to interdisciplinary research	Fudan University
4	Fang Deqing	Radioactive ion beam physics	Fudan University
5	Wang Jizeng	Solid mechanics	Lanzhou University
6	Gu Weimin	Black-hole accretion and outflows	Xiamen University

(continued)

No.	PI	Title	Host Institution
7	Xiang Dao	Physics and key technologies for accelerator-based ultrafast science facilities	Shanghai Jiao Tong University
8	Li Jing	THz detecting, radio astronomy	Purple Mountain Observatory, CAS
9	Shao Chenggang	Noise analysis in precise gravitational experiments	Huazhong University of Science and Technology
10	Lu Haizhou	Theories of electronic transport in topological matter under magnetic fields	Southern University of Science and Technology
11	Liu Yi	Topology and geometry of 3-manifolds	Peking University
12	Yang Zhenwei	Experimental studies of hadron spectroscopy and production	Tsinghua University
13	Yang Yue	Turbulence and transition	Peking University
14	Tian Chushun	The quantum principle-based studies of the foundations of statistical physics	Institute of Theoretical Physics, CAS
15	Zou Changliang	Statistical inference in massive dataset	Nankai University
16	Sun Mingbo	Supersonic combustion	PLA National University of Defense Technology
17	Lyu Chaofeng	Mechanics of heterogeneous materials and structures	Zhejiang University
18	He Feng	Ultrafast dynamics of atoms and molecules in strong laser fields	Shanghai Jiao Tong University
19	Wang Chunpeng	Partial differential equations	Jilin University
20	Liu Rui	Solar physics	University of Science and Technology of China
21	Sun Luyan	Superconducting quantum computing	Tsinghua University
22	Chen Shuqi	Physics of light field regulation with few layers of artificial microstructures	Nankai University
23	Yao Xiaohu	Explosion and shock dynamic	South China University of Technology
24	Weng Hongming	Computational condensed matter physics	Institute of Physics, CAS
25	Wang Zhengxiong	Instabilities in magnetic fusion plasmas	Dalian University of Technology
26	Wang Lifeng	Dynamics in nano systems	Nanjing University of Aeronautics and Astronautics
27	Pan Bing	Experimental solid mechanics	Beihang University
28	Luo Junwei	Semiconductor physics and device physics	Institute of Semiconductors, CAS
29	Jia Yu	Perturbative higher-order calculation in quantum chromodynamics and effective field theory	Institute of High Energy Physics, CAS
30	Li Chanying*	Adaptive control of nonlinear parametrized systems	Academy of Mathematics and Systems Sciences, CAS
31	Wu Haibin	Ultracold quantum gases	East China Normal University
32	Yan Zhenya	Mathematical theory and interdisciplinary applications of integrable systems and complex nonlinear waves	Academy of Mathematics and Systems Sciences, CAS

(continued)

No.	PI	Title	Host Institution
33	Liu Jinsong	Teichmuller space and related topics	Academy of Mathematics and Systems Sciences, CAS
34	Liu Zhenxin	Random dynamical systems	Dalian University of Technology
35	Zhao Gongbo	Cosmology with large galaxy surveys	National Astronomical Observatory of China
36	Zhang Fuxiang	Photocatalytic overall water splitting for hydrogen production	Dalian Institute of Chemical Physics, CAS
37	Wang Lin	Atmospheric pollution chemistry	Fudan University
38	Li Weihua	Molecular design of block copolymers for desired nanostructures from microphase Separation	Fudan University
39	Zhang Wenbin	Design, synthesis, and assembly of precise macromolecules	Peking University
40	Wang Chu	Chemical biology	Peking University
41	Chen Chen	Rational design and precise manipulation of nano-catalysts	Tsinghua University
42	Zhu Ting	Mirror-image chemical biology	Tsinghua University
43	Zhang Zhengbiao	Precision polymer synthesis	Soochow University
44	Tang Pingping	Organic fluorine chemistry	Nankai University
45	Che Yanke	Environmental analysis	Institute of Chemistry, CAS
46	Shi Bingfeng	Organic synthetic chemistry	Zhejiang University
47	Zhao Huazhang	Environmental and chemical engineering	Peking University
48	Zhao Dahui*	Functional organic & polymer materials chemistry	Peking University
49	Ye Shuji	Physics and chemistry of complex molecular systems at the interface	University of Science and Technology of China
50	Wang Wei	Chemical imaging and measurements of single nanoparticles	Nanjing University
51	Jia Yanxing	Natural product total synthesis	Peking University
52	Wu Changzheng	Inorganic synthesis chemistry	University of Science and Technology of China
53	Lu Xing	Chemistry of metallofullerenes	Huazhong University of Science and Technology
54	Li Xianfeng	Flow battery membranes and application	Dalian Institute of Chemical Physics, CAS
55	Wang Tie	In vitro analysis for detecting diseases	Institute of Chemistry, CAS
56	Luan Xinche	Synthetic organic chemistry	Northwest University
57	Zeng Jie	Catalytic regulation mechanism for surface/interface coordination	University of Science and Technology of China
58	Huang Hanmin	Metal-catalyzed synthetic organic chemistry	University of Science and Technology of China
59	Jiao Liying*	Chemistry and electronic devices of two-dimensional crystals	Tsinghua University

(continued)

No.	PI	Title	Host Institution
60	Li Jianfeng	Electrochemical raman spectroscopic analysis	Xiamen University
61	Zhong Yuwu	Photofunctional organometallic complexes and optoelectronic chemistry	Institute of Chemistry, CAS
62	Cheng Fangyi	Nonstoichiometric electrode materials chemistry	Nankai University
63	Kuang Hua*	Cell analysis based on optical activity of chiral nanostructure	Jiangnan University
64	Ge Ziyi	Organic solar cells	Ningbo Institute of Materials Technology and Engineering, CAS
65	Jiang Zhiyong	Novel asymmetric hydrogen-bonding catalysis	Henan Normal University
66	Xu Weilin	Basic research of the energy-chemical process at single-molecule single-particle level	Changchun Institute of Applied Chemistry, CAS
67	Yuan Quan*	Chemical and biological sensing	Hunan University
68	Du Jianzhong	Polymer vesicles	Tongji University
69	Liu Bo	Total synthesis of natural products	Sichuan University
70	You Yumeng	Molecular piezoelectric materials	Southeast University
71	Wu Zhikun	Structure chemistry	Hefei Institute of Physical Science, CAS
72	Huang Yanqiang	Carbon dioxide reduction in closed ecological system	Dalian Institute of Chemical Physics, CAS
73	Shi Feng	Heterogeneous catalysis	Lanzhou Institute of Chemical Physics, CAS
74	Shi Weiqun	Basic Research on spent nuclear fuel reprocessing	Institute of High Energy Physics, CAS
75	Pan Bingcai	Water pollution control chemistry	Nanjing University
76	Yang Ning	Development and engineering application of mesoscale models for multiphase reactors	Institute of Process Engineering, CAS
77	Fan Jiangli*	Dye fine chemistry	Dalian University of Technology
78	Liu Peinian	On-surface chemistry	East China University of Science and Technology
79	Li Conggang	Nuclear magnetic resonance spectroscopy	Wuhan Institute of Physics and Mathematics, CAS
80	Zhang Hengquan	Emulsion interface catalysis	Shanxi University
81	Lan Fei	Dynamic regulation of histone methylation	Fudan University
82	Cai Shiqing	Molecular and neuronal mechanisms of aging	Shanghai Institute of Life Sciences, CAS
83	Yu Li*	Mammalian molecular phylogenetics and adaptive evolution	Yunnan University
84	Xiang Ye	Molecular biophysics	Tsinghua University
85	Qin Guozheng	Postharvest biology of horticultural crops	Institute of Botany, CAS

(continued)

No.	PI	Title	Host Institution
86	Shen Xiaohua	Noncoding RNA-mediated transcription and chromatin regulation in cell-fate determination	Tsinghua University
87	Bi Yanchao*	Cognitive psychology and cognitive neuroscience	Beijing Normal University
88	Wang Xiaowei	Insect transmission of plant viruses	Zhejiang University
89	Yan Xianghua	Animal molecular nutrition	Huazhong Agricultural University
90	Wang Yingxiang	Plant reproductive biology	Fudan University
91	Zhang Long	Tumor cell metastasis and the tumor-derived exosome	Zhejiang University
92	Cong Yongrui	Maize endosperm development and the genetic improvement	Shanghai Institute of Life Sciences, CAS
93	Jiang Changtao	Sphingolipid ceramide and metabolic diseases	Peking University
94	Chu Chengjin	Community ecology	Sun Yat-sen University
95	Yang Li	Computational biology	Shanghai Institute of Life Sciences, CAS
96	Yang Hui	Gene editing	Shanghai Institute of Life Sciences, CAS
97	Pan Weijun	Study on hematopoietic stem cell homing and proliferative microenvironment	Shanghai Institute of Life Sciences, CAS
98	Chen Xiaowei	Systems neuroscience	Army Medical University
99	Xu Qiang	Citrus genomics and genetic improvements	Huazhong Agricultural University
100	Yu Haipeng	Biorefinery and utilization of lignocellulose	Northeast Forestry University
101	Tan Anjiang	Insect physiology and biochemistry	Shanghai Institute of Life Sciences, CAS
102	Tan Mingqian	Encapsulation and delivery mechanism of food nutrition components	Dalian Polytechnic University
103	Cao Peng	Neurobiology of behavior	National Institute of Biological Sciences, Beijing
104	Tao Xiaorong	Plant virus disease	Nanjing Agricultural University
105	Liu Zhenfeng	Structural biology of membrane proteins	Institute of Biophysics, CAS
106	Guo Yalong	Plant adaptive evolution	Institute of Botany, CAS
107	Sun Fei	Advanced technology of biological electron microscopy	Institute of Biophysics, CAS
108	Zhu Zuofeng	Rice germplasm innovation and favorable gene exploitation	China Agricultural University
109	Cheng Hong*	Mechanism and function of RNA nuclear export and degradation	Shanghai Institute of Life Sciences, CAS
110	Yang Chen*	Regulation and control of metabolic fluxes in microbes	Shanghai Institute of Life Sciences, CAS
111	Zhao Jianguo	Pig functional genomics and genome editing	Institute of Zoology, CAS
112	Cui Zongqiang	Single virus tracking	Wuhan Institute of Virology, CAS

(continued)

No.	PI	Title	Host Institution
113	Yao Hongjie	Epigenetic mechanism in cell fate determination	Guangzhou Institute of Biomedicine and Health, CAS
114	Chen Shi	Microbiological epigenetics	Wuhan University
115	Liu Ying*	Cellular stress response and homeostatic regulation	Peking University
116	Li Yulong	Neurobiology	Peking University
117	Kong Zhaosheng	Cytoskeleton and plant cell morphogenes	Institute of Microbiology, CAS
118	Zhou Zhigang	Fish-gastrointestinal microbiota interaction	Institute of Feed Research, Chinese Academy of Agricultural Sciences
119	Cheng Hao	Metamorphic petrochronology	Tongji University
120	Yuan Wenping	Carbon cycle model of terrestrial ecosystem	Sun Yat-sen University
121	Wu Zhongqing	First-principles calculations of minerals properties at high temperature and high pressure	University of Science and Technology of China
122	Zhao Pengjun	Transport geography	Peking University
123	Yuan Zhigang	Coupling between the inner magnetosphere and ionosphere	Wuhan University
124	Wu Huaichun	Paleozoic cyclostratigraphy and astrochronology	China University of Geosciences (Beijing)
125	Zhao Chuanfeng	Cloud physics	Beijing Normal University
126	Zhou Shungui	Soil bioelectrochemistry	Fujian Agriculture and Forestry University
127	Zhang Liqiang	Remote sensing image/point cloud recognition and understanding	Beijing Normal University
128	Li Siliang	Weathering and biogeochemical processes in the riverine system	Tianjin University
129	Yuan Zengwei	Resource flow and the environmental effect	Nanjing University
130	Wang Aihui*	Land-atmosphere interaction and climate change	Institute of Atmospheric Physics, CAS
131	Cheng Xiao	Polar remote sensing	Beijing Normal University
132	Tang Chaosheng	Extreme climatic engineering geology	Nanjing University
133	Wang Minghuai	Aerosols, clouds and climate interactions	Nanjing University
134	Shi Tailin	Marine biogeochemistry and global change	Xiamen University
135	Gao Yanzheng	Process and control of organic contamination in soil	Nanjing Agricultural University
136	Wang Xin	Physical oceanography	South China Sea Institute of Oceanology, CAS
137	Huang Diying	Mesozoic insects	Nanjing Institute of Geology and Palaeontology, CAS
138	Wang Lin	Variability of the East Asian winter monsoon and its mechanism	Institute of Atmospheric Physics, CAS

(continued)

No.	PI	Title	Host Institution
139	Tian Hui	Oil and gas geochemistry	Guangzhou Institute of Geochemistry, CAS
140	Wang Lizhe	Theory and method for remote sensing data processing	China University of Geosciences (Wuhan)
141	Wang Xiaoping*	Regional cycling of persistent organic pollutants	Institute of Tibetan Plateau Research, CAS
142	Lin Xiaopei	Ocean circulation dynamics	Ocean University of China
143	Fu Qiaomei*	Ancient human genomics	Institute of Vertebrate Paleontology and Paleoanthropology, CAS
144	Li Zhengqiang	Remote sensing and detection of atmospheric aerosol	Institute of Remote Sensing And Digital Earth, CAS
145	Zheng Hua	Ecosystem services	Center for Ecological and Environmental Studies, CAS
146	Zhao Xiaoli*	Environmental geochemical behavior of nano-pollutants	Chinese Research Academy of Environmental Sciences
147	Li Zhiwei	High precision and three-dimensional deformation monitoring by InSAR	Central South University
148	Chen Xiaoqing	Formation mechanism and mitigation of mountain hazards	Chengdu Institute of Mountain Hazards and Environment, Ministry of Water Resources, CAS
149	Xie Guiqing	mineral deposits	Institute of Mineral Resources, CAS
150	Huang Wenbin	Organic aerosol	Institute of Earth Environment, CAS
151	Li Feng	Organic electroluminescent materials and devices	Jilin University
152	Zhang Guangqing	Rock mechanics in petroleum engineering	China University of petroleum (Beijing)
153	Gong Zheng	Coastal dynamic geomorphology: a study on the evolution mechanism of multi-factor tidal flat systems	Hohai University
154	Wu Dingcai	Porous polymer and carbon materials	Sun Yat-sen University
155	Zhao Hongwei	In situ testing principle and technology of materials' microscopic mechanical properties	Jilin University
156	Xie Xiaorong	Analysis and control of power system oscillations	Tsinghua University
157	Li Wuhua	Power converters and controls of renewable energy systems	Zhejiang University
158	Li Jianshu	Biomedical polymers	Sichuan University
159	Luo Kun	Multiphase turbulent combustion	Zhejiang University
160	Zhang Chi	System analysis and utilization of water resources	Dalian University of Technology
161	Zhang Yanfeng*	Two-dimensional carbon-based materials and their heterostructures	Peking University
162	Wang Jianjun	Study on the surface and interface of polymer materials	Institute of Chemistry, CAS

(continued)

No.	PI	Title	Host Institution
163	Sun Weiling*	Migration and transformation of complex pollution and its ecological effects in water and sand systems	Peking University
164	Wang Gang	Fracture mechanism of metallic glasses	Shanghai University
165	Wu Shuilin	Surface modification and coatings of metallic biomaterials	Tianjin University
166	Wang Huaiyuan	Storage and transportation of oil and gas resources in extreme environment	Tianjin University
167	Yu Yan*	Sodium ion batteries	University of Science and Technology of China
168	Wang Fazhou	Advanced concrete materials	Wuhan University of Technology
169	Zhang Chenhui	Research on the mechanism and application of liquid superlubricity	Tsinghua University
170	Yan Junmin*	Metallic energy materials for hydrogen fuel cell vehicles	Jilin University
171	Cui Hongzhi	Concrete with function of energy storage	Shenzhen University
172	Zhu Jia	Nanostructured solar thermal conversion: materials design and device Applications	Nanjing University
173	Fu Jiyang	Structural wind engineering	Guangzhou University
174	Yang Shangfeng	Fullerene functional materials	University of Science and Technology of China
175	Chen Rong	Transport and conversion of energy and mass in optofluidics	Chongqing University
176	Huang Yongan	Technology and equipment of flexible electronics manufacturing	Huazhong University of Science and Technology
177	Liu Guangyi	Flotation reagents	Central South University
178	Chen Yifeng	Geomechanics and geotechnical engineering	Wuhan University
179	Ding Bin	Polymeric nanofibrous materials	Donghua University
180	Liu Xinhua	Basic research on short process preparation and processing of metals by controlled solidification and controlled forming	University of Science and Technology Beijing
181	Zhao Lidong	Thermoelectric materials	Beihang University
182	Zhang Jian	Biological treatment and resource utilization of wastewater	Shandong University
183	Wang Zhiwei	Wastewater treatment and reclamation	Tongji University
184	Wen Bin	Mechanism of materials mechanical behavior	Yanshan University
185	Lyu Youjun	Multiphase flow thermochemistry	Xi'an Jiaotong University
186	Dong Biqin	Degradation control of marine concrete structure	Shenzhen University
187	Han Bangcheng	Optimization, control and application of the high-speed magnetically suspended rotor system	Beihang University

(continued)

No.	PI	Title	Host Institution
188	Zi Bin	Theory, technology and equipment on intelligent flexible driving robots	Hefei University of Technology
189	Zhang Yu	Inorganic new energy materials	Beihang University
190	Liu Pan	Road safety design	Southeast University
191	Shao Tao	Pulse gas discharge plasma at atmospheric pressure	Institute of Electrical Engineering, CAS
192	Li Yingguang	Digital manufacturing and intelligent manufacturing	Nanjing University of Aeronautics and Astronautics
193	Tian Huayu	Biomedical polymer materials	Changchun Institute of Applied Chemistry, CAS
194	Dai Qing	Carbon nanomaterials for nanophotonics	The National Center for Nanoscience and Technology
195	Liu Ruiping	Toxic inorganic pollutants control and resources recovery	Center for Ecological and Environmental Studies, CAS
196	Shen Jun*	Research on thermodynamic cycle of magnetic refrigeration	Technical Institute of Physics and Chemistry, CAS
197	Shi Feng	Heterogeneous catalysis	Beijing University of Chemical Technology
198	Zhang Aman	Underwater explosion and ship damage	Harbin Engineering University
199	Jiang Jinyang	Marine concrete metamaterial	Southeast University
200	Zhai Cheng	Fracturing and permeability enhancement and high efficiency gas drainage in low permeability coal seam	China University of Mining and Technology
201	Lu Junyong	Shipboard electromagnetic launch technology	Naval University of Engineering
202	Chen Haisheng	Research on key fundamental issues of compressed air energy storage system	Institute of Engineering Thermophysics, CAS
203	He Xuhui	Bridge wind resistance and traffic safety	Central South University
204	Di Zengfeng	Semiconductor-on-insulator (SOI) materials for integrated circuits	Shanghai Institute of Microsystem and Information Technology, CAS
205	Huang Hui	Organic/polymeric semiconductors	University of Chinese Academy of Sciences
206	Feng Guorui	Mining of residual coal resource and preventing of disasters	Taiyuan University of Technology
207	Xu Fei	Fiber devices	Nanjing University
208	Liu Shengli*	Design and security proof of public-key algorithms in sophisticated scenarios	Shanghai Jiao Tong University
209	Yang Jun	Fiber optic white-light interferometry	Guangdong University of Technology
210	Chen Yunji	Processor architecture	Institute of Computing Technology, CAS
211	Li Gang	Radar imaging and detection of moving targets	Tsinghua University
212	Xu Wenyuan*	Multi-factor security analysis and defense of smart systems	Zhejiang University
213	Li Guoliang	Database theory and system	Tsinghua University
214	Liu Yunhuai	Mobile crowdsensing and applications	Peking University

(continued)

No.	PI	Title	Host Institution
215	Pan Gang	Brain-machine integrated intelligence	Zhejiang University
216	Liu Yang	Machine translation	Tsinghua University
217	Chi Nan*	High spectrum efficiency optical modulation and optical transmission	Fudan University
218	Yang Yuchao	Memristive neuromorphic devices for brain inspired computing	Peking University
219	Zhang Jianhua*	Theoretical and experimental research of radio mobile channel property and modeling	Beijing University of Posts and Telecommunications
220	Hua Qinghua	Uncertainty in artificial intelligence	Tianjin University
221	Tao Xiaomin	Multimedia computational communications	Tsinghua University
222	Ding Guiguang	Multimedia searching and analysis	Tsinghua University
223	Zhou Penghuang	Novel storage and logic integration	Fudan University
224	Peng Yuxin	Cross-media analysis	Peking University
225	Peng Mugen	Theory and technologies of cooperative networking for radio communications	Beijing University of Posts and Telecommunications
226	Long Shibing	Wide band-gap power electronics	University of Science and Technology of China
227	Huang Lei	Robust array signal processing	Shenzhen University
228	Li Ming	Optical analog signal processing	Institute of Semiconductors, CAS
229	Tang Jinhui	Multimedia analysis and retrieval	Nanjing University of Science and Technology
230	Xie Hui	Micro and nanorobotics	Harbin Institute of Technology
231	Cheng Xinbin	High power/energy laser coatings	Tongji University
232	Liao Lei	The heterostructure integration and devices fabrication of novel semiconductors	Hunan University
233	Lu Weibing	Computational electromagnetic and its application	Southeast University
234	Wang Guangcheng	Optimal control theory of forward and backward stochastic system	Shandong University
235	Quan Wei	Quantum precision inertial measurement and navigation technology	Beihang University
236	Ma Shuai	Approximate computation for big data analytics	Beihang University
237	Jia Xiaojun	Quantum information network and quantum optics	Shanxi University
238	Zhong Weimin	Chemical process modeling and operation optimization	East China University of Science and Technology
239	Zhang Jincheng	Wide bandgap semiconductor electronic devices	Xidian University
240	Chen Haibo	Operating systems	Shanghai Jiao Tong University
241	Lu Xiaoqiang	Optical remote sensing image data intelligent analysis	Xi’an Institute of Optics and Fine Mechanics, CAS

(continued)

No.	PI	Title	Host Institution
242	You Jingbi	Perovskite semiconductor based optoelectronic devices	Institute of Semiconductors, CAS
243	Su Liangbi	Laser crystal materials	Shanghai Institute of Ceramics, CAS
244	Liu Lianqing	Micro/nano manipulation enabled biosyncretic robot research	Shenyang Institute of Automation, CAS
245	Dong Hairong*	Intelligent train operation and optimization under complex circumstance	Beijing Jiaotong University
246	Sun Jian	Analysis and control of networked fire control systems	Beijing Institute of Technology
247	Leng Yuxin	Ultra-intense and ultra-short laser technology	Shanghai Institute of Optics and Fine Mechanics, CAS
248	Zhang Long	IR optical materials	Shanghai Institute of Optics and Fine Mechanics, CAS
249	Lin Xiao	Epitaxial growth and electrical characterization of two-dimensional atomic crystal heterostructures	University of Chinese Academy of Sciences
250	Zhou Wenhou	Economics of queues and service operations management	South China University of Technology
251	Zhou Yuexin*	Emotion and consumer behavior	Zhejiang University
252	Liu Chengfang*	Education management and policy studies in rural China	Peking University
253	Yu Jihai	Spatial econometrics	Peking University
254	Long Jiancheng	Urban dynamic travel optimization	Hefei University of Technology
255	Wu Libo*	Energy and environmental economics and policy analysis	Fudan University
256	Zhang Ying	Consumer behavior	Peking University
257	Zhang Xinyu	Research on econometric theory and application	Academy of Mathematics and Systems Sciences, CAS
258	Fang Zheng	Marketing based on artificial intelligence	Sichuan University
259	Liao Hua	Research on energy economics and climate policy	Beijing Institute of Technology
260	Zhang Jian	Drug design and lead discovery	Shanghai Jiao Tong University
261	Zhou Hongwei	Methodology development for clinical diagnosis with human microbiome	Southern Medical University
262	Lu Boxun	Neurodegenerative disorders	Fudan University
263	Huang Yongzhuo	Molecular pharmaceutics	Shanghai Institute of Materia Medica, CAS
264	Ding Fusen	Vascular remodeling in organ repair	Sichuan University
265	Li Rong*	Reproductive endocrine disorder regulates the endometrial receptivity	Peking University
266	Xue Tian	Biomedical study of the visual nervous system	University of Science and Technology of China
267	LjuJicheng	IgA nephropathy mechanism and treatment	Peking University

(continued)

No.	PI	Title	Host Institution
268	Zhu Yongqun	Molecular mechanisms of bacterial pathogenesis	Zhejiang University
269	Chen Liangyi	Biomedical photonics	Peking University
270	Chen Lanfen*	Hippo signaling in immunity and diseases	Xiamen University
271	Wang Jinyong	Blood cell regeneration and anti-leukemia	Guangzhou Institute of Biomedicine and Health, CAS
272	Li Bin	Orthopaedic biomaterials and regenerative medicine	Soochow University
273	Li Yu	Hepatic nutrient sensing and metabolic regulation	Shanghai Institute of Life Sciences, CAS
274	Ai Ding*	Pathogenesis of metabolic cardiovascular disease	Tianjin Medical University
275	Liu Gang	Molecular imaging probes	Xiamen University
276	Li Wei	Pathogenesis of male infertility	Institute of Zoology, CAS
277	Miao Xiaoping	Cancer molecular epidemiology	Huazhong University of Science and Technology
278	Zheng Hongting	Pathogenesis and intervention for diabetic complications and comorbidities	Army Medical University
279	Zhao Qiang	Cardiovascular biomaterials	Nankai University
280	Xu Jinfu	Bronchiectasis and the respiratory infection	Tongji University
281	Li Lei	Therapeutic resistance of tumor (urinary system tumor)	Xi'an Jiaotong University
282	Liu Zaiyi	Radiomics in colorectal cancer	Guangdong Provincial People's Hospital
283	Sun Xun*	Biomacro molecular drugs targeted delivery	Sichuan University
284	Gao Daming	Signaling transduction of tumor cell	Shanghai Institute of Life Sciences, CAS
285	Wang Qiang	Maternal environment and reproductive health	Nanjing Medical University
286	Ge Huiming	Natural product chemistry	Nanjing University
287	Zhang Jie	Investigation on molecular mechanism of Alzheimer's disease	Xiamen University
288	Li Tao	Innate immunity	Academy of Military Medical Sciences
289	Tang Yamei*	Mechanism and treatment of radiation-induced nervous system injury	Sun Yat-sen University
290	Ming Dong	Neural engineering	Tianjin University
291	Qin Chengfeng	Infection and pathogenesis of vector-borne flaviviruses	Academy of Military Medical Sciences
292	Zhou Jie*	Mucosal immunity and diseases	Tianjin Medical University
293	Lin Zhuofeng	Adipocytokines and cardiovascular disease	Wenzhou Medical University
294	Gao Hao	Effective substances of common traditional Chinese medicines	Jinan University

(continued)

No.	PI	Title	Host Institution
295	Zhu Bo	Cellular and molecular mechanisms of anti-tumor immunity modulation	Army Medical University
296	Zhang Chen	Neuroscience	Capital Medical University

Note: there were 2,797 applications from male applicants, of which 259 were funded, and 362 from female applicants, of which 37 were funded.

2.1.10 Science Fund for Creative Research Groups

Function and Positioning: The Fund supports outstanding young and middle-aged scientists as academic leaders and research backbones to work together on an important research direction to conduct innovative research, so as to cultivate and build a research community that has a role to play in the forefront of international science.

In 2019, we received 240 applications. After review, we supported 45 groups, with a total direct funding of 445.8 million yuan and indirect funding of 79.8 million yuan. From 2019, the continued funding for creative research groups is canceled. Please refer to the following table for details.

Table 2-1-14 Awardees of Science Fund for Creative Research Groups in 2019

(Unit: 10,000 yuan)

No.	Group Leader	Research Direction	Host Institution	Direct Funding	Indirect Funding
1	Sun Qingfeng	Quantum transport in low-dimensional topological systems	Peking University	1,000.00	200.00
2	Yan Xueqing	Laser particle accelerator and applications	Peking University	1,000.00	200.00
3	Chang Jin	Space astronomy	Purple Mountain Observatory, CAS	1,050.00	150.00
4	Feng Xiqiao	Mechanics of soft materials and flexible structures	Tsinghua University	1,000.00	200.00
5	Chen Yongchuan	Combinatorics	Tianjin University	670.00	170.00
6	Jin Changqing	Maters states & quantum emergent phenomena at extreme conditions	Institute of Physics, CAS	1,000.00	200.00
7	Qin Yong	Synthetic chemistry	Sichuan University	1,000.00	200.00
8	Li Zhanting	Synthetic chemistry of biologically active molecules and supramolecules	Fudan University	1,000.00	200.00
9	Zhang Suojiang	Microenvironment regulation of ionic liquids and green engineering	Institute of Process Engineering, CAS	1,050.00	150.00
10	Guo Guocong	Nonlinear optical crystal materials	Fujian Institute of Material Structure, CAS	1,050.00	150.00
11	Xing Weihong	Special separation membrane	Nanjing Tech University	1,050.00	150.00
12	Zhou Xin	NMR and MRI for life science	Wuhan Institute of Physics and Mathematics, CAS	1,050.00	150.00
13	Wang Haiyang	Utilization of hybrid vigor between indica and japonica subspecies	South China Agricultural University	1,050.00	150.00

(continued)

No.	Group Leader	Research Direction	Host Institution	Direct Funding	Indirect Funding
14	Fu Xiangdong	Molecular basis of complex traits towards understanding genome interaction in wheat	Institute of Genetics and Development Biology, CAS	1,000.00	200.00
15	Guo Yan	Perception and responses of abiotic stress in plants	China Agricultural University	1,000.00	200.00
16	Tan Chongjun	Synthetic microorganisms and new functions	Shanghai Institute of Life Sciences, CAS	1,000.00	200.00
17	Xu Zhiheng	Brain development	Institute of Genetics and Development Biology, CAS	1,000.00	200.00
18	Hu Zhian	Dasic and clinical research of arousal-promoting system in regulating learning and memory	Army Medical University	1,050.00	150.00
19	He Hongping	Mineral evolution	Guangzhou Institute of Geochemistry, CAS	1,050.00	150.00
20	Zhang Qiang	Atmospheric composition change and its impact on climate and environment	Tsinghua University	1,000.00	200.00
21	Yuan Xunlai	Origin and early evolution of multicellular life	Nanjing Institute of Geology and Palaeontology, CAS	1,050.00	150.00
22	Feng Xinbin	Biogeochemistry	Institute of Geochemistry, CAS	1,050.00	150.00
23	Xiao Xiang	Deep-sea and deep biosphere	Shanghai Jiao Tong University	1,000.00	200.00
24	Li Zhaoliang	Mechanism and methodology of agricultural remote sensing	Institute of Agricultural Resources and Zoning, Chinese Academy of Agricultural Sciences	1,050.00	150.00
25	He Jinliang	High voltage and electrical insulation technology	Tsinghua University	1,000.00	200.00
26	Yang Huai	Functional liquid crystalline materials	Peking University	1,000.00	200.00
27	Yao Mingfa	Engineering thermal physics problems of high-efficiency low-carbon cleaning utilization of mobile power energy	Tianjin University	1,000.00	200.00
28	Li Hui	Disaster resilience of urban engineering structures and intelligent disaster prevention and mitigation	Harbin Institute of Technology	1,050.00	150.00
29	Lyu Zhaoping	High-performance metallic materials	University of Science and Technology Beijing	1,050.00	150.00
30	Yuan Shenfang	Manufacture and monitoring of aircraft monolithic structures	Nanjing University of Aeronautics and Astronautics	1,050.00	150.00
31	Zhou Zhihua	Machine learning for open dynamic environments	Nanjing University	1,000.00	200.00
32	Gong Yubin	Vacuum electronics	University of Electronic Science and Technology of China	1,000.00	200.00
33	Xu Jun	Energy efficient semiconductor materials and information devices	Nanjing University	1,000.00	200.00

(continued)

No.	Group Leader	Research Direction	Host Institution	Direct Funding	Indirect Funding
34	Li Xiang	Research of information processing and target recognition in space countermeasure	National University of Defense Technology	1,050.00	150.00
35	Sun Changyin	Theory and applications of autonomous cooperative control for unmanned systems	Southeast University	1,050.00	150.00
36	Ma Huadong	Basic theories and key technologies of the internet of things	Beijing University of Posts and Telecommunications	1,050.00	150.00
37	Yu Yugang	Platform-based supply chain operations management research	University of Science and Technology of China	670.00	170.00
38	Bi Jun	Environmental risk management	Nanjing University	670.00	170.00
39	Li Gang	Information resources management	Wuhan University	670.00	170.00
40	Jiang Xinquan	Oral and maxillofacial bone regeneration and functional restoration	Shanghai Jiao Tong University	1,000.00	200.00
41	Kong Wei	Vascular microenvironment and atherosclerosis-related vascular pathology	Peking University	1,000.00	200.00
42	Kong Deling	Repair and regeneration of damaged tissues and organs	Nankai University	1,050.00	150.00
43	Gao Guangxia	Viruses, viral infection and immunity	Institute of Biophysics, CAS	1,000.00	200.00
44	Fan Zusen	Non-coding RNAs and cancer	Institute of Biophysics, CAS	1,000.00	200.00
45	Liu Guanghui	Aging mechanism and regulation	Institute of Zoology, CAS	1,000.00	200.00
Total				44,580.00	7,980.00

2.1.11 Joint Research Fund for Overseas Chinese Scholars and Scholars in Hong Kong and Macao

Function and Positioning: The Fund supports overseas Chinese scholars and Chinese scholars in Hong Kong and Macao under the age of 50 to work with Chinese mainland partners to conduct high-level collaborative research.

The Fund adopts “2+4” funding model, which means that those 2-year projects with substantial cooperation and clear potential for future development will be renewed to another 4 years. Since 2019, the 2-year projects were canceled.

Table 2-1-15 Application and Funding of Joint Research Fund for Overseas Chinese Scholars and Scholars in Hong Kong and Macao Projects in 2019 (4-year Continued Funding)

(Unit: 10,000 yuan)

Scientific Departments	Applications	Approved					Success rate (%)
		Awards	Direct Funding	Percentage of the Total (%)	Average Funding Per Project	Indirect Funding	
Mathematical and Physical Sciences	5	2	340.00	8.67	170.00	60.00	40.00
Chemical Sciences	7	2	360.00	9.18	180.00	40.00	28.57
Life Sciences	10	3	480.00	12.24	160.00	120.00	30.00
Earth Sciences	5	2	340.00	8.67	170.00	60.00	40.00
Engineering and Material Sciences	13	4	700.00	17.86	175.00	100.00	30.77
Information Sciences	14	4	640.00	16.33	160.00	160.00	28.57
Management Sciences	5	2	340.00	8.67	170.00	60.00	40.00
Health Sciences	11	4	720.00	18.37	180.00	80.00	36.36
Total	70	23	3,920.00	100.00	170.43	680.00	32.86

Note: there were 60 applications from male applicants, of which 22 were funded, and 10 from female applicants, of which 1 were funded.

2.1.12 Joint Funds

Function and Positioning: The strategic positioning of the Funds is "to face the needs of the country, guide diversified investment, promote resource sharing, and promote multi-party cooperation", which aim to give play to the guiding role of the NSFC, guide and integrate social resources such as government, industry, enterprises and individuals into basic research, attract and gather the strengths of scientific research in the country in view of the urgent needs of regions, industries and enterprises. The Funds focus on core and major scientific issues in the emerging frontier cross-cutting fields, forward-looking basic research, and the cultivation of scientific and technical talents, so as to jointly promote the construction of regional innovation systems, and improve the independent innovation capability of industries and important fields.

Table 2-1-16 Applications and Funding of Joint Funds Projects in 2019

(Unit: 10,000 yuan)

No.	Joint Funds	Applications	Approved				Success Rate (%)
			Awards	Direct Funding	Average Funding Per Project	Indirect Funding	
1	Joint Fund for Regional Innovation and Development	575	113	27,917	247.05	5,341.95	19.65
2	Joint Fund for Corporate Innovation and Development	255	47	20,291	431.72	3,337.97	18.43
3	NSAF Joint Fund	171	38	11,340	298.42	1,691.63	22.22
4	Joint Fund for Iron and Steel	148	20	2,520	126.00	493.80	13.51

(continued)

No.	Joint Funds	Applications	Approved				Success Rate (%)
			Awards	Direct Funding	Average Funding Per Project	Indirect Funding	
5	Joint Fund of Astronomy	217	52	5,040	96.92	902.92	23.96
6	NSFC-Guangdong Joint Fund	111	25	8,100	324.00	1,495.75	22.52
7	NSFC-Yunnan Joint Fund	182	22	4,914	223.36	962.51	12.09
8	Joint Fund of Large Science Facilities	380	88	10,080	114.55	1,848.33	23.16
9	NSFC-Xinjiang Joint Fund	514	56	6,720	120.00	1,262.19	10.89
10	NSFC-Henan Joint Fund	1,404	116	8,352	72.00	1,628.50	8.26
11	Joint Fund for Promoting S&T Cooperation between Both Sides of the Strait	133	17	3,863	227.24	744.86	12.78
12	NSFC-Shandong Joint Fund	212	34	8,400	247.06	1,594.69	16.04
13	NSFC-General-Tec Joint Fund for Basic Research	181	42	6,720	160.00	1,231.51	23.20
14	Joint Fund of Advanced Aerospace Manufacturing Technology Research	25	11	4,200	381.82	768.29	44.00
15	NSFC-Liaoning Joint Fund	97	33	8,410	254.85	1,562.54	34.02
16	NSFC-Zhejiang Joint Fund for Industrialization and Informatization	66	21	4,200	200.00	809.66	31.82
17	Joint Fund for the Innovation-driven Development of China's Auto industry	107	7	1,590	227.14	297.82	6.54
18	NSFC-Shanxi Joint Fund of Coal-Based Low Carbon	95	16	4,120	257.50	776.74	16.84
19	NSFC-Guangdong Big Data Science Research Center Project	11	6	5,410	901.67	878.49	54.55
20	Joint Fund of Civil Aviation Research	240	37	1,680	45.41	317.36	15.42
21	NSFC-Shenzhen Robotics Research Center Project	95	19	7,300	384.21	1,264.33	20.00
22	High-Speed Railway Joint Fund	183	22	5,083	231.05	963.90	12.02
23	Yalong River Joint Fund	53	17	2,520	148.24	472.75	32.08
24	Smart Grid Joint Fund	81	16	6,720	420.00	1,134.79	19.75
25	Joint Fund for Space Science Satellite	36	18	1,200	66.67	213.37	50.00
26	Seismological Science Joint Fund	50	10	2,520	252.00	482.79	20.00
27	Nuclear Technology Innovation Joint Fund	107	22	5,880	267.27	1,109.74	20.56
Total		5,729	925	185,090		33,589.18	

2.1.13 Special Fund for Development of National Major Research Instruments and Facilities

Function and Positioning: The Fund is oriented toward frontier of science and national needs, and is guided by scientific goals. It supports the development of original scientific research instruments and core components that play an important role in promoting scientific development, and exploring natural laws and research fields, thus enhancing the country's original ability to innovate.

In 2019, we received 671 applications for the Fund. After expert review, we funded 82 applications, with direct funding of 583.5068 million yuan and indirect funding of 91.0443 million yuan. The receiving departments recommended 48 applications. After review, we supported 3 projects, with total funding of 199.9008 million yuan and indirect funding of 22.3816 million yuan.

Table 2-1-17 Funding of Special Fund for Development of National Major Research Instruments and Facilities Projects (Open Application) in 2019

(Unit: 10,000 yuan)

No.	Title	PI	Host Institution	Direct Funding	Indirect Funding
1	Development of high-resolution X-ray imaging spectrometer for the HUBS mission	Cui Wei	Tsinghua University	645.25	113.84
2	Science requirement and construction of a new generation broad band high throughput optical spectrograph	Wu Xuebing	Peking University	583.25	106.49
3	Integrated flexible array electromagnetic acoustic NDE instrument for thermal barrier coating system of heavy-duty gas turbines	Chen Zhenmao	Xi'an Jiaotong University	760.00	133.24
4	Development of an ultralow-field nuclear magnetic resonance spectrometer with high-sensitivity atomic magnetometers	Peng Xinhua	University of Science and Technology of China	606.68	106.78
5	Development of an instrument to measure angle-resolved specific heat at low temperature and high magnetic field	Wen Haihu	Nanjing University	595.00	103.45
6	Development of ultrafast THz low-temperature scanning tunneling microscopy	Wu Kehui	Institute of Physics, CAS	808.00	110.35
7	Development of micro-newton thruster for space borne gravitational wave detection	Tu Liangcheng	Huazhong University of Science and Technology	595.00	90.70
8	Time of flight multi-channel spin-resolved photoelectron spectrometer	Qiao Shan	Shanghai Institute of Microsystems and Information Technology, CAS	804.00	73.20
9	Accurate optical frequency synthesizer	Ma Longsheng	East China Normal University	730.20	85.04
10	High-throughput growth of superconducting thin films and in-situ multi-parameter characterization system	Huan Qing	Institute of Physics, CAS	748.00	102.85
11	High-frequency dynamic measurement system for key flow-field parameters of spray combustion within aeronautics and astronautics engines	Yang Lijun	Beihang University	656.00	78.80

(continued)

No.	Title	PI	Host Institution	Direct Funding	Indirect Funding
12	A scientific experimental system for research on electromagnetic scattering and transmission characteristics of a hypersonic vehicle	Yu Xilong	Institute of Mechanics, CAS	673.66	101.95
13	Magnetic field controlled polarized photoacoustic imaging system for ‘background free’ in vivo imaging	Liu Zhuang	Soochow University	770.00	126.87
14	An adiabatic accelerating rate calorimetric system with accurate analysis of thermal hazard characteristics solving for safety assessment of self-reactive chemicals	Jiang Juncheng	Changzhou University	526.00	98.26
15	Contamination-free, loss-less, and in-situ 3D counting digital PCR system	Huang Yanyi	Peking University	653.51	104.88
16	Instrument development of the cryogenic ion trap mass spectrometry for infrared photo dissociation spectroscopy	Ding Chuanfan	Ningbo University	721.00	115.90
17	High mass resolution in situ liquid secondary ion mass spectrometry system	Wang Fuyi	Institute of Chemistry, CAS	800.00	124.30
18	240 GHz stable high field superconducting electron spin resonance instrument construction for electron dynamic property studies in biological systems	Tian Changlin	University of Science and Technology of China	775.00	85.20
19	Structure-electricity-optics multiple-mode ultrafast scanning electron microscopy	Zhong Dongping	Shanghai Jiao Tong University	754.10	115.44
20	Single cell multi-omic analytical system	Yang Chaoyong	Xiamen University	645.00	100.45
21	A new type of mass spectrometry device for organic compound analysis in haze	Pan Yuanjiang	Zhejiang University	592.00	90.20
22	Development of a new in situ fluorescence imaging spectrometer for free radicals at single particles	Tang Bo	Shandong Normal University	813.68	127.82
23	Development of an ultra-sensitive mass spectrometer for accurate analysis of single-cell metabonomic toxicology	Fang Xiang	National Institute of Metrology, China	780.00	114.51
24	High-throughput two-photon fluorescent protein screening and the whole brain functional imaging system	Xu Pingyong	Institute of Biophysics, CAS	762.03	77.21
25	Apparatus for electric field manipulation of single molecules and its applications for protein-DNA interaction study	Wang Hailin	Center for Ecological And Environmental Studies	790.00	114.70
26	Establishment of high-sensitivity proton-detection solid-state NMR spectrometer for structure determination of mass-limited proteins	Yang Jun	Wuhan Institute of Physics and Mathematics, CAS	695.02	120.43
27	Instrumentation for mass spectrometric imaging and in situ analysis of metabolites	ZaipaerAbulizi	Minzu University of China	722.00	104.52
28	Development of a 3D cell-printing equipment associated with OCT/ODT imaging and monitoring	Xu Mingen	Hanzhou Electronic Science and Technology University	748.79	122.99

(continued)

No.	Title	PI	Host Institution	Direct Funding	Indirect Funding
29	Development of a universal protein and nucleic acid digital multiplex bio-detection system	Gu Hongchen	Shanghai Jiao Tong University	622.00	107.05
30	Development of central fluid processing unit and platform based on digital microfluidics	Cheng Xin	Southern University of Science and Technology	701.00	113.46
31	Single-line-extracted pure rotational Raman lidar to accurately measure atmospheric temperature and aerosol profiles	Yi Fan	Wuhan University	667.10	98.56
32	An analogue modelling experimental device for continental lithosphere tectonic deformation in the hypergravity environment	Jia Dong	Nanjing University	612.60	90.84
33	In-situ testing system of engineering geological information with self-adaption and coordinated control for complex loess slopes	Lan Hengxing	Institute of Geographical Sciences and Resources, CAS	700.38	124.75
34	Research and development of an underwater optical high-resolution 3D imaging system	Dong Junyu	Ocean University of China	620.00	103.09
35	System of laser in situ microanalysis of oxygen isotope and elimination of oxide interference	Liu Yongsheng	China University of Geosciences, Wuhan	823.00	100.00
36	Key parameter test and intelligent evaluation system for shale gas	Zhang Jinchuan	China University of Geosciences, Beijing	779.51	135.00
37	Ground hardware-in-the-loop simulator of space manipulator contact operation	Gao Feng	Shanghai Jiao Tong University	808.00	113.22
38	An integrated system with high resolution magnetic force microscope and high sensitivity electrical transport measurement working in multi-fields	Jiang Yong	University of Science and Technology Beijing	717.00	114.85
39	Development of a new type of rheometer for multiple parameters of magnetic fluid with high precision based on in-situ characterization	Li Decai	Tsinghua University	752.17	123.73
40	Joint full-process simulation test system for large-span space structures integrating wind, rain, heat and snow module	Fan Feng	Harbin Institute of Technology	789.11	63.32
41	In situ synchrotron radiation X-ray Laue microdiffraction system for the materials microscopic structure/stress study under multivariate environments	Wang Tongmin	Dalian University of Technology	729.32	127.80
42	Development of the instruments for measuring flow and heat transfer of liquid metal under extreme conditions of a magnetic confinement fusion reactor	Ni Mingjiu	University of Chinese Academy of Sciences	775.00	104.97
43	Developing a super-resolution optical system for cross-scale micron/nano structure fast manufacture	Bai Jintao	Northwest University	828.78	135.07

(continued)

No.	Title	PI	Host Institution	Direct Funding	Indirect Funding
44	Study on an experimental roll to roll processing instrument system and the regulation mechanism of the electro-optical properties for the ultra-thin liquid crystal/polymer composite film prepared by this system	Yang Huai	Peking University	825.00	124.44
45	Study on all-optical point-of-care testing device for protein bio-markers BNP/NT-proBNP	Yu Yanlei	Fudan University	600.70	97.40
46	Development of the test system for inducing the change of disaster-causing energy in rock mass under the multi-field couplings in deep properties and mechanism	Li Xibing	Central South University	700.30	96.52
47	Flexible automatic 3D scanning technique and system for airborne conformal array antennas	Yu Liandong	Hefei University of Technology	834.04	132.80
48	Design and fabrication of in-situ liquid-cryogenic-heating TEM holders for electrochemistry investigations	Cheng Huiming	Institute of Metal Research, CAS	693.52	100.62
49	An in-situ testing system for the resilient modulus of subgrade	Zheng Jianlong	Changsha University of Science & Technology	766.05	133.52
50	Hydro-mechanical coupling simulation testing equipment for rock masses during operation of reservoir with high dam	Wu Aiqing	Changjiang River Scientific Research Institute of Changjiang Water Resources Commission	623.90	113.28
51	Experiment system for modeling fault-slip coal burst in underground coal roadways	Kang Hongpu	CCTEG China Coal Research Institute	815.00	135.10
52	Photonic millimeter-wave noise generator	Wang Yuncai	Guangdong University of Technology	795.45	137.36
53	High energy, high repetition frequency laser peening system using homogeneously combined rectangular pulses	Deng Xiaoxu	Shanghai Jiao Tong University	623.69	79.30
54	Development of hundred-joule compact solid-state laser operating at repetition rate	Lyu Zhiwei	Hebei University of Technology	672.38	109.17
55	A high-throughput analyzer and multi-target combined detection method for trace nucleic acids in micro-nanoliter reaction assays	Huang Guoliang	Tsinghua University	656.00	112.41
56	Precise interface modification of two-dimensional materials by organic molecules and in-situ device integration	Wang Xinran	Nanjing University	746.29	100.19
57	Two-photon light field computational microscopy instrument	Fan Jingtao	Tsinghua University	779.05	141.86
58	A label-free far-field super-resolution optical microscope system based on super-oscillation	Chen Gang	Chongqing University	701.50	115.57
59	Study of time and space resolved deep ultra-violet hydrostatic pressure spectrum system	Shen Bo	Peking University	792.00	60.00

(continued)

No.	Title	PI	Host Institution	Direct Funding	Indirect Funding
60	Terahertz trace detection analyzer	Zheng Xiaoping	Tsinghua University	715.00	127.45
61	Advanced in-well fiber-optic instrumentation for oil and gas seismic exploration	Qiao Xueguang	Northwest University	841.00	149.80
62	In-situ pump-prob system for precise controlling the physical properties during femtosecond laser microfabricationnetworks	Wu Dong	University of Science and Technology of China	790.00	111.25
63	High resolution THz spectrum analyzer with 50MHz frame rate	Zhang Xinliang	Huazhong University of Science and Technology	667.20	125.08
64	Wide-field and label-free surface plasmon resonance holographic microscope for dynamic measurement of multi-parameter	Zhao Jianlin	Northwestern Polytechnical University	587.15	102.65
65	Self-calibrated multi-dimension optoelectronic frequency response analyzer based on frequency-shifted optical heterodyne	Liu Yong	Hanzhou Electronic Science and Technology University	600.90	105.24
66	Energy transportation observation device for proton beam in biological tissues	Xie Qingguo	Huazhong University of Science and Technology	835.00	148.38
67	Ice lithography nanofabrication system for 3D micro/nano-optoelectronic devices	Qiu Min	Xihu University	600.88	88.31
68	2D/3D microscope having large field and continuous optical zoom	Wang Qionghua	Beihang University	780.00	130.63
69	Endoscopic volume data monitor based on composite narrow spectrum synergy for industrial furnaces and kilns	Jiang Zhaohui	Central South University	686.85	116.56
70	Synchronized temporal/spatial/spectral-domain full-field real-time continuous-recording ultrafast measurement system	Yang Zhongmin	South China University of Technology	713.29	121.16
71	Research on 3D ultrasound ct imaging system for breast diagnosis based on high density CMUT cylindrical array	Zhang Wendong	North University of China	700.00	123.43
72	Synchronized multiprobe measurement system for nanoscale signal propagation in live muscle cells of biosyncretic robotic	Su Quanmin	Shenyang Institute of Automation, CAS	750.00	132.93
73	Ultrafast time resolved terahertz near-field scanning tunneling microscopy	Cao Juncheng	Shanghai Institute of Microsystems and Information Technology, CAS	765.00	121.74
74	Development of an artificial intelligence guided adaptive full-ring SPECT/CT system	Wang Fan	Peking University	800.21	145.03
75	Development of ultrasound-based continuous and dynamic imaging and monitoring apparatus for traumatic brain injury	Yu Wenkui	Nanjing University	655.00	118.68
76	Development of intravascular laser atherectomy system integrated with the features of real-time feedback and low-loss conductivity	Tao Ling	Airforce Medical University	718.65	119.33

(continued)

No.	Title	PI	Host Institution	Direct Funding	Indirect Funding
77	Optical/ultrasonic/magnetic multimodality imaging system for morphology and function research of early prostate cancer	Zhang Xiaoping	Huazhong University of Science and Technology	740.00	136.00
78	Technology and instrument research on non-invasive deep brian focused stimulation by accurate positioning based on magneto-acoustic coupling effect	Liu Zhipeng	Chinese Academy of Medical Sciences	545.00	99.40
79	Development of an ultrasound-OCT biomechanical imaging instrument for skin diseases	Xu Huixiong	Tongji University	777.54	115.74
80	Development of phase control multiple input capacitively coupled contactless conductivity detector for ion chromatography in clinical analysis	Xiao Dan	Sichuan University	412.00	65.30
81	Optical microscopy system for in vivo multi-region imaging of neuronal activity	Zheng Wei	Shenzhen Institute of Advanced Technology, CAS	677.00	84.80
82	Synchronous and high-resolution acquisition system of electrophysiological and blood microcirculation signals of neuromuscular activities	Li Guanglin	Shenzhen Institute of Advanced Technology, CAS	690.00	119.92
Total				58,350.68	9,104.43

Table 2-1-18 Funding of Special Fund for Development of National Major Research Instruments and Facilities Projects (by Recommendation) in 2019

(Unit: 10,000 yuan)

No.	Title	PI	Host Institution	Direct Funding	Indirect Funding
1	Research and development of CSR external-target experiment	Xu Nu	Institute of Modern Physics, CAS	7,452.41	872.56
2	An ultrahigh spatio-temporal resolution setup for ion chemistry	Wu Kai	Peking University	7,352.68	810.50
3	In-situ characterization system for oxide defect evolution in semiconductor devices	Huang Ru	Peking University	5,184.99	555.10
Total				19,990.08	2,238.16

2.1.14 Basic Science Center Project

Function and Positioning: The Project aims to concentrate and integrate domestic superior scientific research resources, target at the forefront of international science and advanced deployment, and give full play to the advantages and characteristics of the National Science Fund system. It relies on high-level academic leaders, and attracts and unites outstanding scientific and technological talents. Efforts will be made to promote the deep integration of disciplines, support researchers to study and explore in a long term, and strive to break through the frontiers of science, produce a number of internationally leading original achievements, seize the commanding heights of international scientific development, and form a number of highland with academically important international influences.

Table 2-1-19 Funding of Basic Science Center Project in 2019

(Unit: 10,000 yuan)

No.	Title	PI	Host Institution	Direct Funding	Indirect Funding
1	Studies of milky way and local universe based on LAMOST and FAST	Zhao Gang	National Astronomical Observatories	8,000.00	1,042.10
2	Studies on multiscale problems in nonlinear mechanics	He Guowei	Institute of Mechanics, CAS	8,000.00	961.50
3	Transformation chemistry of key components of air	Xi Zhenfeng	Peking University	8,000.00	944.20
4	Bioinspired super wettability from interfatial materials to chemistry	Jiang Lei	Technical Institute of Physics and Chemistry, CAS	8,000.00	892.60
5	Regulation of oogenesis and embryonic development	Meng Anming	Tsinghua University	8,000.00	1,067.85
6	Responses of ecosystems to global changes	Fang Jingyun	Peking University	8,000.00	981.00
7	Basic science center for tibetan plateau earth system	Chen Fahu	Institute of Tibetan Plateau Research, CAS	8,000.00	1,078.50
8	Resource and ecology based synthetic polymeric materials	Chen Xuesi	Changchun Institute of Applied Chemistry, CAS	8,000.00	877.91
9	Phase evolution of multiphase media under hypergravity	Chen Yunmin	Zhejiang University	8,000.00	983.60
10	Intelligent optimization and control mechanism for material conversion-based manufacturing process	Qian Feng	East China University of Science and Technology	8,000.00	947.20
11	Study of the frontier fields of terahertz sciences and technologies	Wu Yirong	Institute of Electronics, CAS	8,000.00	903.52
12	Econometrics and quantitative policy evaluation	Hong Yongsen	Xiamen University	6,000.00	747.00
13	Integrated research in cancer molecular alteration and microenviroment	Zhan Qimin	Peking University	8,000.00	1,055.10
Total				102,000.00	12,482.08

2.1.15 Special Projects

Function and Positioning: The Projects support innovative research that requires timely funding, as well as scientific and technological activities related to the development of the National Science Fund. Special projects are divided into two subcategories: research projects and scientific and technological activities. The research projects are used to fund the timely implementation of research of strategic deployment of the country's economic, social, scientific and technological fields, and the study of key scientific issues involved in major emergencies, and the innovative and cutting-edge research with high potentials that requires timely funding; scientific and technological activities are used to fund strategic and management research, academic exchanges, scientific communication, platform establishment and other activities related to the development of the National Science Fund.

Table 2-1-20 Funding of Special Projects in 2019

(Unit: 10,000 yuan)

No.	Types	Awards	Direct Funding	Indirect Funding
1	Research projects	213	25,969.54	4,444.72
2	Scientific and technological activities	502	15,093.00	0.00
Total		715	41,062.54	44,44.72

2.1.16 Tianyuan Fund for Mathematics

Function and Positioning: The Fund is set up to consolidate the collective wisdom of mathematicians, explore funding methods that meet the characteristics and development laws of mathematics, and promote the building of a powerful mathematical country. The Fund supports scientific and technical personnel to combine the characteristics and needs of mathematics disciplines, develop scientific research, nurture young talents, promote academic exchanges, optimize the research environment, and disseminate mathematics culture, thereby enhancing innovation ability of Chinese mathematics.

Table 2-1-21 Applications and Funding of Tianyuan Fund for Mathematics Projects in 2019

(Unit: 10,000 yuan)

Types	Applications	Approved				Success Rate (%)
		Awards	Direct Funding	Direct Funding Per Project	Indirect Funding	
Tianyuan Fund for Mathematics	203	89	3,500.00	39.33	0.00	43.84

2.1.17 Research Fund for International Young Scientists

Function and Positioning: The Fund supports foreign young scholars to choose their own topics within the funding scope of NSFC, and conduct basic research work in mainland China to promote long-term and stable academic cooperation and exchanges between foreign young scholars and Chinese scholars.

Table 2-1-22 Application and Funding of Research Fund for International Young Scientists Projects (by Scientific Department) in 2019

(Unit: 10,000 yuan)

Scientific Departments	Applications	Approved					Success rate (%)
		Awards	Direct Funding	Percentage of the Total (%)	Average Funding Per Project	Indirect Funding	
Mathematical and Physical Sciences	143	24	652.00	14.49	27.17	105.64	16.78
Chemical Sciences	149	24	660.00	14.67	27.50	111.09	16.11
Life Sciences	213	32	933.00	20.73	29.16	180.15	15.02
Earth Sciences	79	13	350.00	7.78	26.92	63.53	16.46

(continued)

Scientific Departments	Applications	Approved					Success rate (%)
		Awards	Direct Funding	Percentage of the Total (%)	Average Funding Per Project	Indirect Funding	
Engineering and Materials Sciences	173	27	744.70	16.55	27.58	127.16	15.61
Information Sciences	125	21	562.33	12.50	26.78	100.57	16.80
Management Sciences	69	11	297.97	6.62	27.09	54.59	15.94
Health Sciences	68	9	300.00	6.67	33.33	58.80	13.24
Total	1,019	161	4,500.00	100.00	27.95	801.53	15.80

2.1.18 International (Regional) Exchange Program

Function and Positioning: The Program encourages the science fund project holders to carry out extensive international (regional) cooperation and exchange activities during the implementation of the project under the framework of the MoU agreements, and accelerate the steps of the funded project in improving innovation ability, personnel training, and development of disciplines, and improve the quality of the funded research. Such projects can be divided into exchange projects based on mutual visits and academic workshop projects. The exchange project aims to strengthen researchers' understanding of international academic frontiers and research hotspots, establish and deepen the cooperative relationship between domestic and foreign counterparts, strengthen the dissemination of research results of scientific funds, and enhance the international influence of scientific research in China.

Table 2-1-23 Application and Funding of International (Regional) Exchange Program Projects in 2019

(Unit: 10,000 yuan)

Types	Applications	Approved					Success rate (%)
		Awards	Direct Funding	Percentage of the Total (%)	Average Funding Per Project	Indirect Funding	
Exchange Program under Agreements/MOU	1,412	253	6,038.37	80.62	23.87	0.00	17.92
International Conference under Agreements/MOUs	280	247	737.15	9.84	2.98	0.00	88.21
Academic Conference under Agreements/MOUs at home	141	51	714.15	9.54	14.00	0.00	36.17
Total	1,833	551	7,489.67	100.00			

2.2 Selected NSFC Grants

2.2.1 Major Program

Study on the Non-Equilibrium Physical Process in Micro and Nano-Devices

The major research project of"Non-equilibrium physical process in micro and nano-devices" is led by Prof. Wei Suhuai at Beijing Computational Science Research Center (CSRC). It will be launched in 2020 and run for 5 years, with 19.44 million yuan of direct funding. The project is divided into three subprojects: "the theory of non-equilibrium micro and nano- solid state devices", "the characterization of the non-equilibrium carriers and dynamic properties of micro and nano-structure" and "the physical mechanism of micro and nano-optoelectronic devices under the non-equilibrium conditions". This project is jointly carried out by CSRC, Fudan University, Shanghai Institute of Technology Physics (SITP) of CAS and Shanghai Tech University.

Non-equilibrium process is an important and general physical phenomenon in the nature. The non-equilibrium process in micro and nano-solid state devices plays an important role in technologies of the information and energy industry such as nano-electronic devices, photodetectors, photovoltaic cells, thermoelectric devices, etc. With the traditional micro and nano-devices approaching their physical size limit of the equilibrium or quasi-equilibrium region, the development of new device principles based on the non-equilibrium physical process has become an important research direction for breakthroughs in the performance limit of traditional devices and the generation of innovative device technology.

Through systematic and in-depth research on the energy conversion dynamics involved in the non-equilibrium physical process of micro and nano-scale devices from the perspectives of coupling between electron, phonon and photon, the project aims to reveal the formation, evolution and characteristics of the metastable and/or the non-equilibrium states, discover the physical phenomena with significant non-equilibrium characteristics (Figure 2-2-1), and understand the solid state properties under operating conditions. It is hoped that based on an innovative non-equilibrium doping theory and new experimental methods, e.g. the terahertz fluctuation microscopy, the basic rules of the micro and nano-scale non-equilibrium physical process will be revealed, and physical models and theories will be developed to

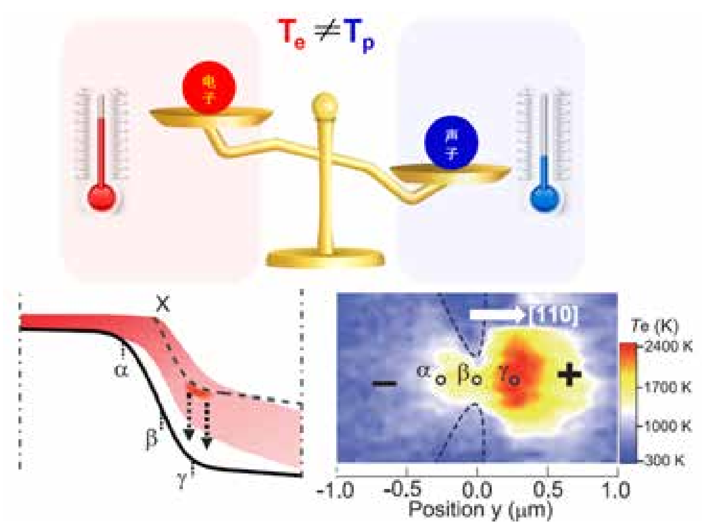


Figure 2-2-1 Hot electron transport and nonlocal energy dissipation of micro and nano-devices with non-equilibrium electrons and phonons

improve the performance of micro and nano-electronic devices, photodetectors, photovoltaic cells, thermoelectric devices, etc.

The expected scientific impact of this project is to reveal the mechanism and laws of electro-optic-phononic interaction in the micro and nano-scale non-equilibrium physical process, and boost the rapid development of "non-equilibrium nanodynamics" as a new physical research discipline. Technologically, the project helps to further improve the thermal management performance of nano electronic devices in the post Moore era, and accelerate the breakthrough of the existing photoelectric and thermoelectric device conversion efficiencies. Through the development of new physical theories and experimental techniques related to the micro and nano scale non-equilibrium dynamics, the team believes this project can play an important role in promoting key areas of national security and economy, such as integrated chips, optoelectronic devices, national defense, aerospace, green-energy.

Artificial Intelligence Methods for Optimization Problems

The major research project of “Artificial intelligence methods for optimization problems” is led by Prof. Yang Xinmin from Chongqing Normal University. The project will start from 2020 and last for 5 years, with 19.68 million yuan of direct funding. The project is divided into 4 subprojects: “Artificial intelligence (AI)- based continuous optimization methods”, “Machine learning methods for multi-objective optimization problems”, “Artificial intelligence of mixed integer programming” and “Artificial intelligence methods for combinatorial optimization and their applications”. The project will be jointly carried out by Chongqing Normal University, Academy of Mathematics and Systems Science of CAS, University of Chinese Academy of Sciences and Xi’an Jiaotong University.

Optimization is an important branch of mathematics. Many scientific problems in natural sciences can be described as optimization problems. Nevertheless, existing optimization theory and methods face lots of challenges and cannot provide adequate solutions to a large number of practical problems. For example, classical optimization methods are usually designed to search for local optimum. The optimization procedure does not sufficiently utilize priori knowledge such as the historical iteration information and the existing optimization experience. And the algorithm design does not take into consideration of the compatibility with concrete problems. Artificial intelligence has provided important inspirations for the development of optimization theory and methods (Figure 2-2-2 and Figure 2-2-3).

The core scientific problems of this project include: how to design adaptive schemes for escaping from local optimum; how to develop deep neural networks for global optimization driven by both data

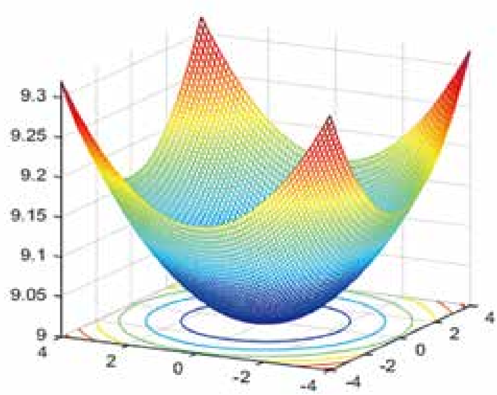


Figure 2-2-2 Convex optimization

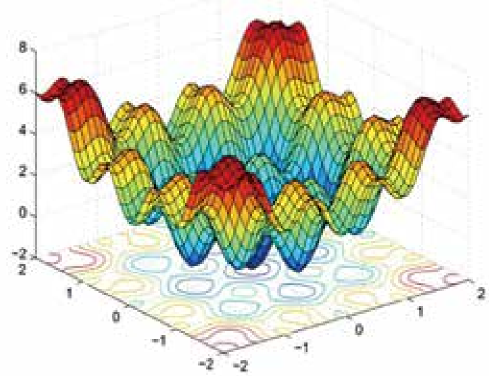


Figure 2-2-3 Nonconvex optimization

and model; how to construct optimizers with self-learning mechanism; how to establish the evaluation and feedback mechanism for adaptive global optimization algorithms aimed at solving non-convex, non-smooth optimization problems with specific structures; how to describe the generic structure of combinatorial optimization problems and then design the corresponding deep reinforcement learning network framework; how to construct the value network and the policy network for deep reinforcement learning methods and the relevant evaluation and feedback mechanism; how to establish the performance evaluation and feedback mechanism to evaluate AI-based branching and cutting modules for solving mixed integer programming problems.

With the aim of overcoming the limitations of traditional optimization theory and methods, this project will carry out research in a global view and develop AI-based methods for optimization problems through exploring new ideas and skills in Artificial intelligence. The team will establish several new theories and methods as well as design a series of high-performance algorithms to solve complex optimization problems from practical fields such as micro-nano photonic devices, traffic signal control, and pattern recognition. It is expected that the project can fundamentally overcome the shortcomings of traditional optimization methods, promote the development of optimization theory and methods, open up a new research paradigm in the optimization field, lead the development of optimization discipline, provide original innovation, and significantly improve the optimization research in China.

Synthesis of High Performance Perfluoroelastomers Resistant to Extreme Environment

The major research project of "Synthesis of high performance perfluoroelastomers resistant to extreme environment" is led by Prof. Qing Fengling of Shanghai Institute of Organic Chemistry of CAS. The project will be launched in 2020 and run for 5 years with 20 million yuan of direct funding. It is divided into five subprojects: "The molecular design and monomers synthesis of perfluoroelastomers", "The polymerization of monomers for synthesis of perfluoroelastomers", "The investigation of the relationship between structure and properties of perfluoroelastomers", "The vulcanization and application of perfluoroelastomer resistant to high temperature" and "The vulcanization and application of perfluoroelastomer resistant to low temperature". Principal investigators of the five subprojects are Prof. Qing Fengling and Prof. Xiao Jichang of Shanghai Institute of Organic Chemistry of CAS, Prof. Sun Shengtong of Donghua University, Prof. Su Zhengtao of AECC Beijing Institute of Aeronautical Materials, and Prof. Wu Fudi of Aerospace Research Institute of Materials and Processing Technology, respectively.

Perfluoroelastomer is one kind of fluorinated polymers used as sealing materials in harsh environment. It has excellent high temperature resistance, chemical resistance, aging resistance and low compression deformation at high temperature. The project team will carry out research on the molecular structure design of perfluoroelastomer, the efficient synthesis and polymerization of fluorine-containing functional monomers, and the relationship between perfluoroelastomer's structure and performance, and develop high performance perfluoroelastomers resistant to extreme environment that meet the urgent needs of the high-tech industries in China.

To accumulate expertise required for the preparation of high performance perfluoroelastomers, organic chemists, polymer chemists and engineers will work together in this project to solve the core scientific and engineering problems of the preparation of perfluoroelastomer. The goal is to successfully produce two types of perfluoroelastomers for the high-tech industries: (1) perfluoroelastomer with high resistance to low temperature and strong oxidants; (2) perfluoroelastomer with high temperature resistance and chemical resistance.

The key scientific problems to be addressed include: (1) the selective formation and cleavage of carbon-fluorine and the controlled formation of fluorinated carbon-carbon bond; (2) the characteristics and rules of the polymerization of fluorine-containing monomers; (3) the unique properties of perfluorolastomers and the relationship between structure and properties of perfluorolastomers; (4) the unique rules of vulcanization of perfluoroelastomers.

With the goal of producing high-performance perfluoroelastomers resistant to extreme environment for the high-tech industries, this project will promote the development of organic fluorine chemistry and fluorine-containing materials in China, and train a number of excellent fluorine chemists. Furthermore, the project will strengthen the collaborative research for the goal-oriented project between academia and industry.

A Fundamental Study of New Electrochemical Interfaces for High Energy/Matter Conversion

The major research project of “A fundamental study of new electrochemical interfaces for high energy/matter conversion” is led by Prof. Zhuang Lin from Wuhan University. The project will be launched in 2020 and run for 5 years, with 19.98 million yuan of direct funding. It is divided into four subprojects: “research on catalytic materials and devices for alkaline H2 oxidation and CO2 reduction”, “electrode/ polyelectrolyte interface structure and electrochemical behavior”, “structure-activity relationship and evolution of membrane-electrode assembly under operating conditions”, and “in situ spectroscopy study of the electrode/ polyelectrolyte interface and electrocatalysis”. The principal investigators of these four subprojects are Prof. Zhuang Lin, Prof. Cheng Jun from Xiamen University, Prof. Chen Liwei from Shanghai Jiao Tong University, and Prof. Liu Zhi from Shanghai University of Science and Technology.

In modern electrochemical technology, the electrochemical interface has undergone great changes. More solid and semi-solid electrolytes are used than the conventional liquid electrolytes. A deep understanding of the microstructure, dynamic evolution and structure-activity relationship of new interfaces will largely re-establish the scientific basis of electrochemical energy and matter transformation, and will directly influence the future development of related technologies.

This project integrates scientists from multiple disciplines such as electrochemistry, theoretical chemistry, spectroscopy and materials chemistry to conduct joint research, mainly focusing on the microscopic characteristics, construction methods and regulation of the "electrode/polyelectrolyte" interface, as well as the alkaline membrane fuel cells and CO_2 electroreduction. It is expected that this innovation research will deliver achievements of significant impact and intellectual property.

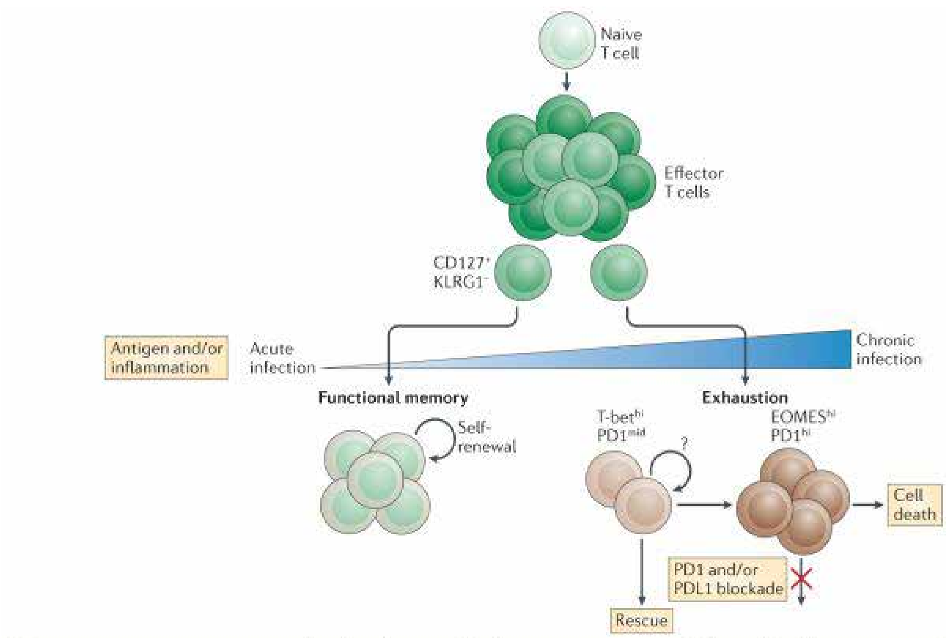
This project will focus on the “electrode/polyelectrolyte” interface, and deeply analyze its microstructure and polarization behavior, as well as the dynamic evolution under electrochemical working conditions. On this basis, they will systematically develop the innovative concept of surface chemical field coupled electrocatalysis to form quantitative theory. They will also study the controllable construction method of the ordered microstructure of the electrode interface to realize the efficient transport of electrons/ions/substances at the electrochemical interface. The project will focus on a number of cutting-edge topics of electrochemical energy/matter conversion, with the expect of achieving iconic results, including breakthroughs in the problem of non-precious metal catalysts for hydrogen electrode of alkaline membrane fuel cells, and great improvement of the efficiency and selectivity of CO_2 electroreduction to ethylene, laying a scientific foundation for a new generation of fuel cells and electrochemical carbon cycle technology.

The core scientific problems to be addressed in this project include: (1) "electrode/polyelectrolyte" interface structure and polarization characteristics; (2) Surface chemical field design and electrocatalytic selective regulation; (3) Dynamic structural evolution and orderly construction of membrane-electrode assembly.

Mechanism Underlying the Regulation of Immune Cells Fate in Tumor Microenvironment

The major research project of “Mechanism underlying the regulation of immune cell fate in tumor microenvironment” is led by Prof. Dong Chen from Tsinghua University. The project will be launched in 2020 and run for 5 years, with 19.85 million yuan of direct funding. The project is divided into 4 subprojects: “molecular characteristics of immune cells in tumor microenvironment”, “molecular characteristics of tumor microenvironment that influence immune reactions and their occurrence mechanism”, “molecular screening of tumor-infiltrating lymphocytes that regulate T cell exhaustion and functional verification”, and “regulation of T cell anti-tumor immune responses by innate immune cells and inflammation”. The project is jointly carried out by Tsinghua University, the Chinese PLA General Hospital, the Army Military Medical University, and Peking University.

Malignant tumor (cancer) is a broad category of diseases that result when normal cells genetically mutated, stimulated by carcinogenic factors, and proliferate in the body with invasive and metastatic potentials. According to the latest statistics, cancer is the first cause of death among Chinese residents, and morbidity and mortality have continued to rise in recent years. Therefore, effective control of the



Feature	Functional memory T cell	Exhausted T cell
Proliferative potential	+++	+/−
Cytokine production	+++	+/−
Memory markers (e.g. CD44, CD62L, CD127 or CXCR3)	+++	+/−
Inhibitory receptors (e.g. PD1, LAG3, CD160 or 2B4)	−	+++
IL-7- and/or IL-15-driven self-renewal	++	−
Antigen dependency	−	+

Figure 2-2-4 Differentiation of exhausted T cells

occurrence and development of cancer has always been a major topic of biomedical research, and also one of the main tasks of building a healthy China. Strengthening basic and translational research is the prerequisite for improving capabilities of cancer prevention and control.

The key problem to be solved by the project is that the tumor microenvironment can induce unique transcriptional and epigenetic changes of cytotoxic T lymphocyte (CTL) in a variety of ways through multiple cells, and intervention of key pathways will restore CTL function and enhance anti-tumor immunity. With the aim of discovering new regulatory molecules for T cell exhaustion, the project team will use molecular biology techniques such as Crispr/Cas9 and 10X Genomics RNA-seq, cell culture techniques such as enzymatic method for isolating tumor-infiltrating lymphocytes and culturing various tumor cell lines in vitro, and various mouse tumor models. They will analyze differential transcript, signal pathway, k-means cluster and gene enrichment on transcriptome sequencing and epigenetic sequencing data. Via the above methods, they will systematically analyze the tumor microenvironment as well as intratumor cells, identify new potential molecules that regulate T cell exhaustion, perform functional validation, and discover new regulatory signaling pathways that provide molecular targets for tumor immunotherapy.

Regulatory Mechanism and Biological Function of Chromatin Plasticity

The major research project of"Regulatory mechanism and biological function of chromatin plasticity"is led by Prof. Li Guohong from Institute of Biophysics of CAS. It will be launched in 2020 and run for 5 years, with 20 million yuan of direct funding. The project is divided into 4 subprojects: "the high-order structural and functional analysis of chromatin at various organization levels", "structural basis and molecular mechanism of chromatin plasticity", "the mechanism and regulatory role of chromatin dynamics in oogenesis and early development", and "driving mechanism of higher order chromatin dynamics and plasticity in tumorigenesis and deterioration of breast cancer". This project is jointly carried out by Institute of Biophysics of CAS, Institute of Biochemistry and Cell Biology of Shanghai Institutes for Biological Sciences of CAS, and Peking University.

The chromatin structure in eukaryotic cells, with high dynamics and plasticity, plays an important role in the activation and silencing of gene transcription, and determines the tissue specificity and cell fate. Abnormal gene expression and improper replication process caused by chromatin plasticity disorders are often accompanied by major diseases, which makes many epigenetic regulators of chromatin dynamics and plasticity ideal druggable targets. Therefore, it is an important question of scientific frontier to study the regulatory mechanism and biological functions of chromatin plasticity, which is not only very important for a better understanding of the process of life and the occurrence and development of various human diseases, but also of strategic significance for public health and the development of pharmaceutical industry.

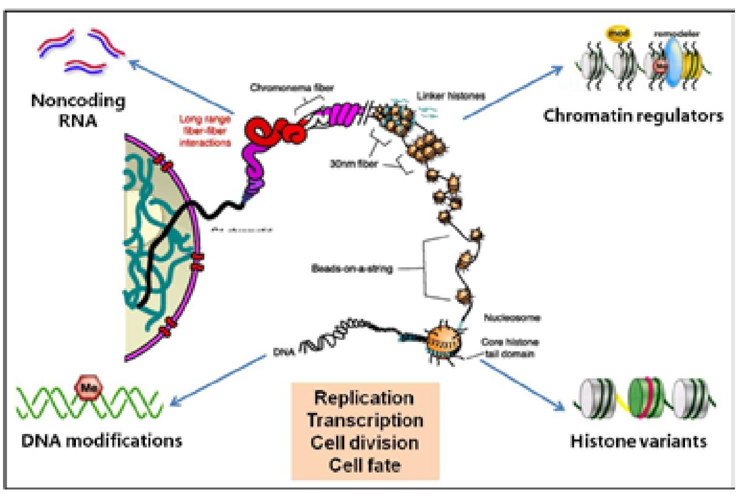


Figure 2-2-5　Different levels of chromatin organization and their epigenetic regulation in the nucleus

This project will study the structural features and biological functions of different levels of chromatin structures in the nucleus,

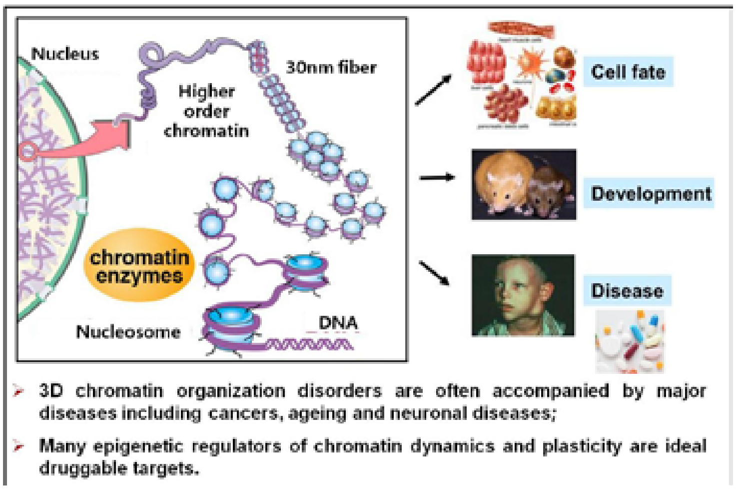


Figure 2-2-6 Biological functions of chromatin plasticity and its regulation in development and diseases

and reveal novel principles and mechanism of chromatin folding in nucleus. It also aims to dissect the structural basis by which nucleosome and higher order chromatin structures are dynamically regulated and to reveal molecular mechanisms governing the epigenetic regulation of chromatin plasticity. In addition, by exploring the impact of excessive Tet3-mediated oxidation on oogenesis, oocyte maturation and embryonic development process, the project will reveal the regulatory mechanism and biological function of chromatin plasticity during gamete and embryo development. Using breast cancer as a model, the project aims to study the dynamic changes of higher order chromatin structures and its epigenetic regulation in the processes of breast cancer occurrence, metastasis, and drug resistance and understand the molecular mechanism by which chromatin plasticity and its regulation affect gene expression network and DNA replication in tumor cells and thereby providing potential molecular targets and theoretical basis for future precise cancer treatment.

The scientific achievements of this project will increase the scientific influence of Chinese scholars and enhance China's leading position in the field of chromatin biology and epigenetics. It will also provide technical support and a theoretical basis for the development of clinical diagnosis and anti-cancer drug targeted on chromatin and epigenetics.

Eco-Hydrological Processes and Their Impacts on Ecosystem Services in Arid and Semi-Arid Areas

The major research project of "Eco-hydrological processes and their impacts on ecosystem services in arid and semi-arid areas" is led by Prof. Fu Bojie from Beijing Normal University. It will be launched in 2020 and run for 5 years, with 19.594 million yuan of direct funding. The project includes five subprojects and will be carried out by five institutions, including Beijing Normal University, Research Center for Eco-Environmental Sciences of CAS, Lanzhou University, Institute of Remote Sensing and Digital Earth of CAS, and Institute of Geographical Sciences and Natural Resources of CAS.

Arid and semi-arid areas are widely distributed in China with diverse and vulnerable ecosystem types. Under the influence of climate change and human activities, ecohydrological processes and ecosystem services are undergoing profound changes, and ecosystem restoration and ecological security are facing severe challenges. However, existing research efforts are not comprehensive enough to include multi-factor, multi-process and multi-scale aspects. It's difficult to reveal the mechanisms and effects of changing ecosystem structures, processes and services in arid and semi-arid areas under the changing environment, which limits the improvement of sustainable ecosystem management in arid and semi-arid areas.

The key scientific problem to be addressed by the project is the impacts and mechanisms of eco-hydrological processes on ecosystem services under changing environment. The project plans to carry out research from five different aspects, by the five subproject respectively, including: (1) climate change in arid and semi-arid areas and its impact on water cycle; (2) land cover change and its eco-hydrological effects in arid and semi-arid areas; (3) mechanisms of interaction between water cycle processes and ecosystem in arid and semi-arid area; (4) changes in structures and functions of ecosystem and their carrying capacity of water and land resource; (5) ecosystem services and ecological security in changing environments.

In order to meet the major national needs of ecosystem restoration and ecological security in arid and semi-arid areas, the project will conduct an integrated multi-factor, multi-process and multi-scale research to reveal the impacts of climate change and land cover change on water cycle and eco-hydrological processes in arid and semi-arid areas. It will reveal the mechanism between interaction of water cycle processes and ecosystem, analyze the mechanism of structural and functional changes of ecosystem and carrying capacity of water and soil resources, illustrate the cascading relationship between ecological hydrological processes, structures and functions of ecosystem, ecosystem services and human wellbeing. It is expected that the project will help to construct regional ecological security pattern, provide a scientific basis for ecological construction and sustainable development in arid and semi-arid areas of China, and promote advance of comprehensive scientific research on earth surface system in China.

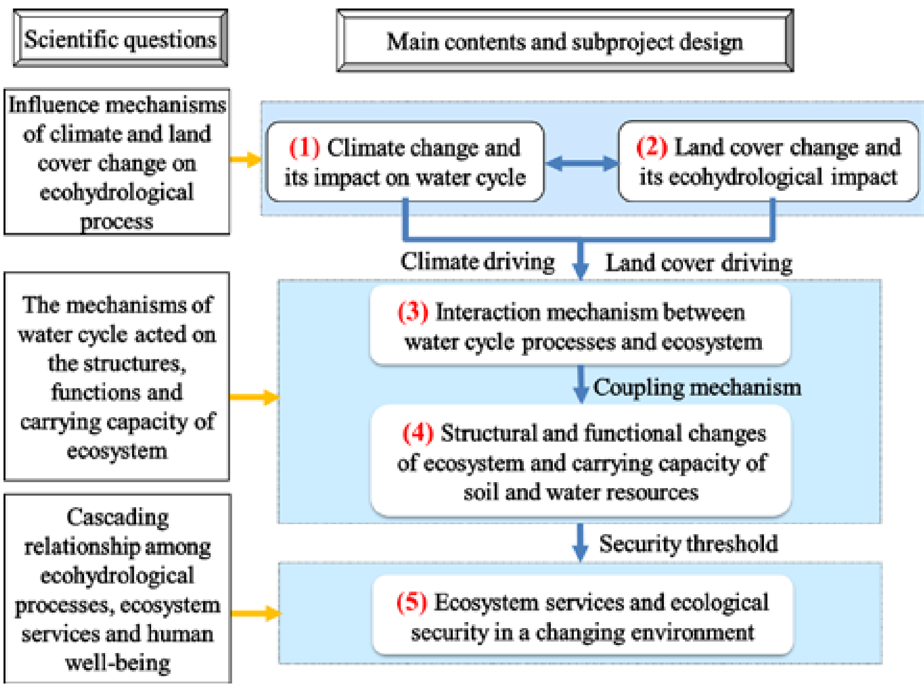


Figure 2-2-7　Scientific questions and work packages

Environment-Geochemical Processes and Health Effects of Industrial Pollutants from Typical Chemical Industrial Parks

The major research project of "Environment-geochemical processes and health effects of pollutants from typical chemical industrial parks" is led by Prof. Tao Shu from Peking University. It will be launched in 2020 and run for 5 years, with 19.87 million yuan of direct funding. The project includes five subprojects and will be carried out by five institutions, including Peking University, Guangdong University of Technology, Nankai University, Shanghai Jiao Tong University and China Academy of Environmental Sciences.

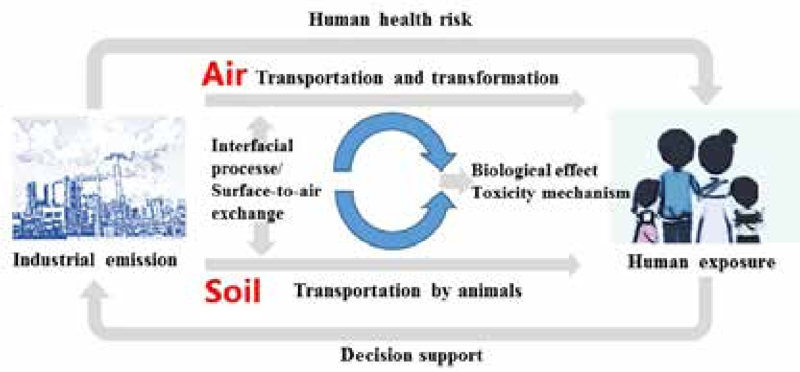


Figure 2-2-8 Research background

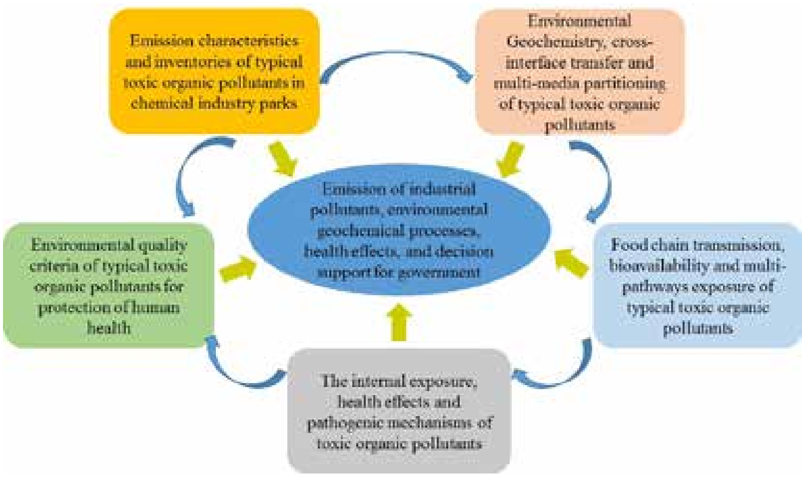


Figure 2-2-9 Key scientific problems and work packages

Industrial emissions, especially emissions from the chemical industry, are one major source of toxic volatile or semi-volatile organic pollutants (VOCs / SVOCs). There are still big gaps in data and knowledge of emissions, transportation, transformation, impacts and controls of toxic VOCs/SVOCs from the chemical industry, which restricts the development of a scientific control system. Under the background of the new trend and strategies of China's economic, social and industrial development, it is an important and urgent task to carry out a whole-process research on the generation, transfer, transformation, biological transfer, health impact and decision making of typical toxic organic pollutants from the chemical industry (Figure 2-2-8) and incorporate the research findings into the making of environmental protection standards and control policies.

The project has five corresponding subprojects, including (Figure 2-2-9): (1) Emission characteristics and inventories of typical toxic organic pollutants in chemical industry parks; (2) Environmental geochemistry, cross-interface transfer and multi-media partitioning of typical toxic organic pollutants; (3) Food chain transmission, bioavailability and multi-pathways exposure of typical toxic organic pollutants; (4) The internal exposure, health effects and pathogenic mechanisms of toxic organic pollutants; (5) Environmental quality criteria of typical toxic organic pollutants for protection of human health.

This project will focus on several VOCs/SVOCs that are believed to be typical and representative for the chemical industry, identify emission characteristics and develop emission inventories; break through the bottleneck of the research on surface-to-air exchange and clarify the source-sink relationship. It will further explore the bioavailability mechanism and analyze the food chain transmission and human exposure levels, find out the specific biomarkers, health effects and mechanism, evaluate potential human health risks, select priority controlled pollutants, and obtain environmental benchmarks of the pollutants. By combining the expertise of environmental geoscience and environmental health, the project will pursue innovative breakthroughs in the major scientific problems in this field, train talents of interdisciplinary innovative research, and contribute to the development of environmental geoscience and environmental health research in China.

Sub-10 nm Van der Waals Heterostructures and Semiconductor Devices Based on Two-Dimensional Materials

The major research project of "Sub-10 nm van der Waals heterostructures and semiconductor devices based on two-dimensional (2D) materials" is led by Prof. Zhang Yue from University of Science and Technology Beijing who is also an academician of CAS. The project will be launched in 2020 and run for 5 years, with 19.9951 million yuan of direct funding. The project consists of four subprojects, including "Controllable growths of sub-10 nm 2D materials and their heterostructures", "Characterizations and theoretical studies on 2D van der Waals heterostructure interfaces", "Electronic and optoelectronic devices of 2D van der Waals heterostructures", and "Van der Waals integrations and multifunction-coupling systems of 2D semiconductor devices". The project is jointly carried out by University of Science and Technology Beijing, Peking University, Tsinghua University, Institute of Physics of CAS and Hunan University.

Semiconductor materials are the foundation of the information industry. The heterojunction of semiconductor materials is the most basic structural unit of a chip. However, the development of chip technology worldwide is facing a big challenge of the sub-10 nm size limit. Therefore, countries around the world have increased investment in materials research and strived to take the lead in breakthroughs in new principles, new effects, and new materials of semiconductor heterostructures, aiming at acquiring the core technology of the next generation of chip manufacturing. 2D materials and their heterostructures are important material systems that have great potentials in overcoming the sub-10 nm size limit of semiconductor industry. Therefore it is of great scientific significance to fully utilize the structural advantages of 2D materials and their heterostructures, innovate the design of van der Waals heterostructures, reveal the basic working mechanism of devices of 2D van der Waals heterostructures, and develop devices of 2D van der Waals heterostructures with low energy consumption and high performance based on new principles.

Based on previous research work, this project focuses on the material system of 2D transition-metal dichalcogenides (TMDs) semiconductor materials, represented by MoS_2, WSe_2, and $MoTe_2$, and establishes a full-chain research plan (Figure 2-2-10) to achieve application breakthroughs of sub-10 nm semiconductor devices with new principles. By developing controllable growth methods, they intend to synthesize 2D TMDs materials and their heterostructures (in-plane and stack heterogeneous structures) with large-area and property-uniform, which provides necessary guarantee for device applications. Through

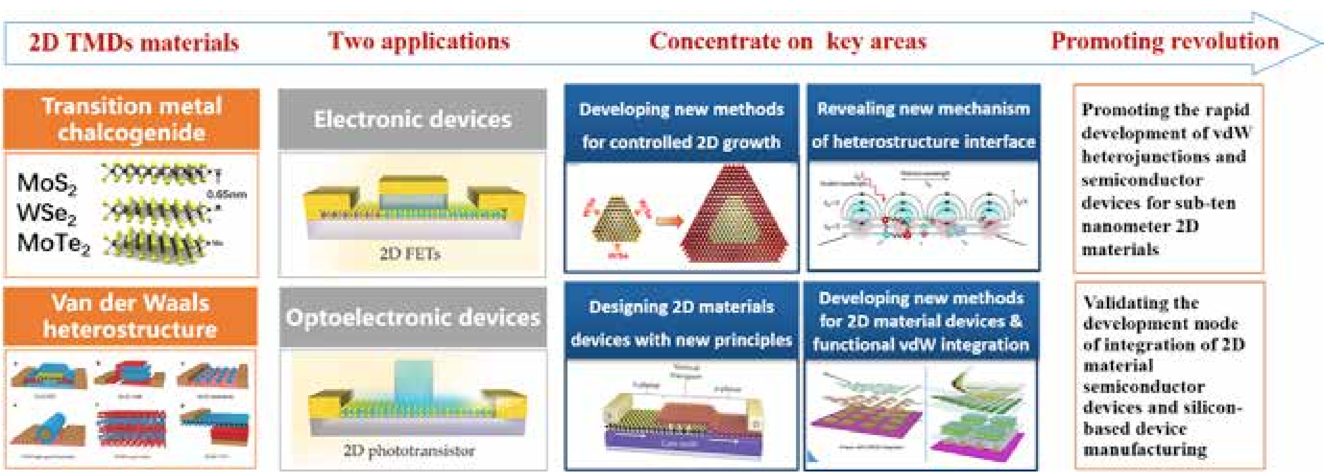


Figure 2-2-10 Research topics

the development of high time-space resolved in-situ characterization techniques for 2D TMDs materials and their heterostructures, the project plans to interpret the interface charge and exciton generation and transport mechanisms of 2D heterostructures and establish a theoretical basis for device applications. By designing and constructing sub-10 nm 2D heterojunction devices with new principles, the project aims to reveal the novel working principles and performance modulation mechanisms of the devices and establish performance optimization strategies for the device applications. By developing large-scale van der Waals integration technologies, the project prepares to solve the problem of interlayer-coupling between multi-layer van der Waals heterostructures and explore large-scale integration techniques for next-generation device applications.

This project will solve the key scientific problems and break through the technical bottlenecks in sub-10 nm 2D van der Waals heterostructures and semiconductor devices, and promote the development of 2D materials and related semiconductor devices in China.

Construction and Operation Hazards and Their Control Measures for Super-Long Subsea Tunnels in Adverse Geological Conditions

The major research project of "Construction and operation hazards and their control measures for super-long subsea tunnels" is led by Prof. Du Yanliang from Shandong University who is also an academician of Chinese Academy of Engineering. It will be launched in 2020 and run for 5 years, with 20 million yuan of direct funding. The project is divided into five subprojects, and will be jointly carried out by Shandong University, Institute of Rock and Soil Mechanics of CAS, Guangzhou University, Southwest Jiaotong University and Beihang University.

The subsea tunnel is one of the strategic needs for building China into a strong country in marine economy and transportation. The construction of subsea tunnels has entered into a dynamic stage in China. A number of world-class super-long subsea tunnels will be built soon. However, due to extremely complicated geological conditions, the wide area covered by seawater, the earthquake-prone seabed environment, and the extremely harsh service environment, the construction and operation of super long-distance subsea tunnels frequently cause a series of major disasters such as water inrush and tunnel collapse. The main scientific and technological gaps include: first, there is a lack of methods to accurately detect sources of geological disasters in the extremely complex geological structures and environment that cause seabed disasters; second, useful design methods of tunnel structures resistant to earthquake are lacked due to limited understanding of the complicated mechanism of subsea earthquake; and third, there is limited knowledge of the interaction between subsea tunnel structure and surrounding rock and the geological disaster evolution mechanism in the construction and operation of subsea tunnels.

The key scientific problems to be addressed include: the detection of sub-meter water inrush channel around the tunnel by using accurate geophysical imaging theory, the multi-scale long-term deformation theory of surrounding rock under coupled hydro-mechanical-chemical conditions, and the transmission mechanism of seismic wave in a strong earthquake environment. The project plans to carry out research in five aspects: fine forward-prospecting and hazard prevention technology for adverse geological bodies in super-long subsea tunnels during the construction period; the mechanisms of progressive failure of subsea tunnels under adverse geological conditions and the safety design method for long-term performance; the seismic damage mechanism and seismic resilience design method of subsea tunnels in unfavorable geological sections; intelligent perception and mechanical property evaluation based on multi-source information for subsea tunnels in unfavorable geological conditions; big data-driven structural disaster prediction and maintenance in hazardous geological regions of subsea tunnels. The project will carry out a series of innovations on the theory and method based on multi-discipline collaborations, using the cutting-edge theories. The test platform for large-scale advanced physical models and the multiple simulation platforms for tunnel vibration will be conducted. The overall research roadmap of the project is shown in Figure 2-2-11.

The ultimate objectives of the project are to create a new method for detecting ocean noise source by transparent imaging, borehole-tunnel radar and borehole-tunnel excitation, to take the lead in the development of detection technology for sub-meter geological structures harming subsea tunnels, to establish a method for analyzing macro and meso-scale mechanical failure process of surrounding rock and structures under coupled hydro-mechanical-chemical conditions, to create a resilient structure design method to prevent subsea tunnel seismicity and close the research gap, and to establish multi-source intelligence information perception and structural performance evaluation methods. It is expected that the project will eventually form a disaster prevention method for multi-hazard identification in characteristics, evolution prediction and processing control, and lead the development of big data-driven disaster warning technology for subsea tunnels.

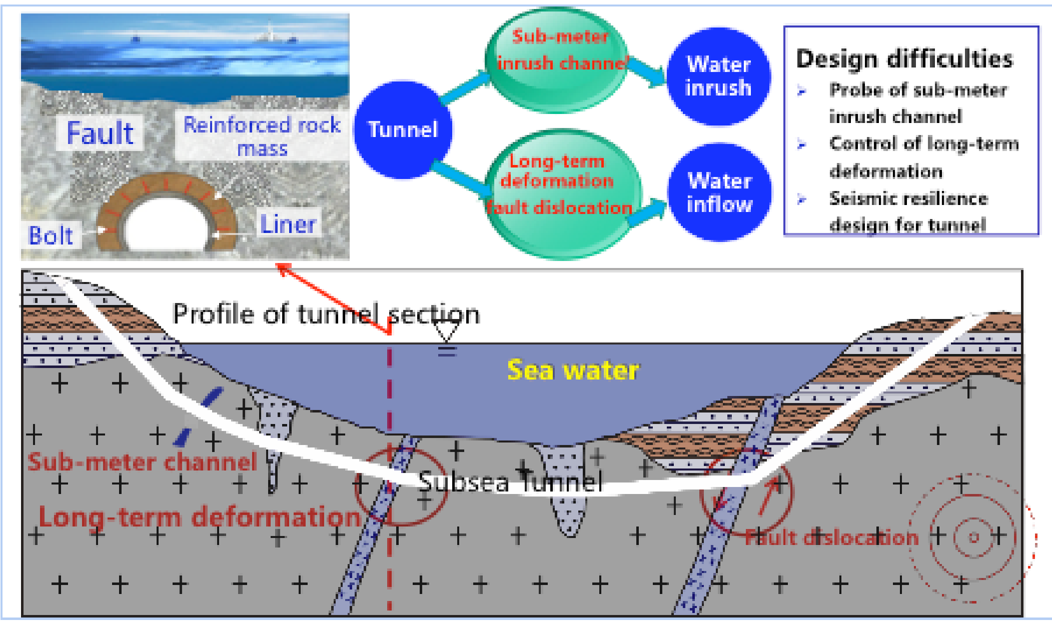


Figure 2-2-11 Construction and operation hazards and their control measures of super-long subsea tunnels

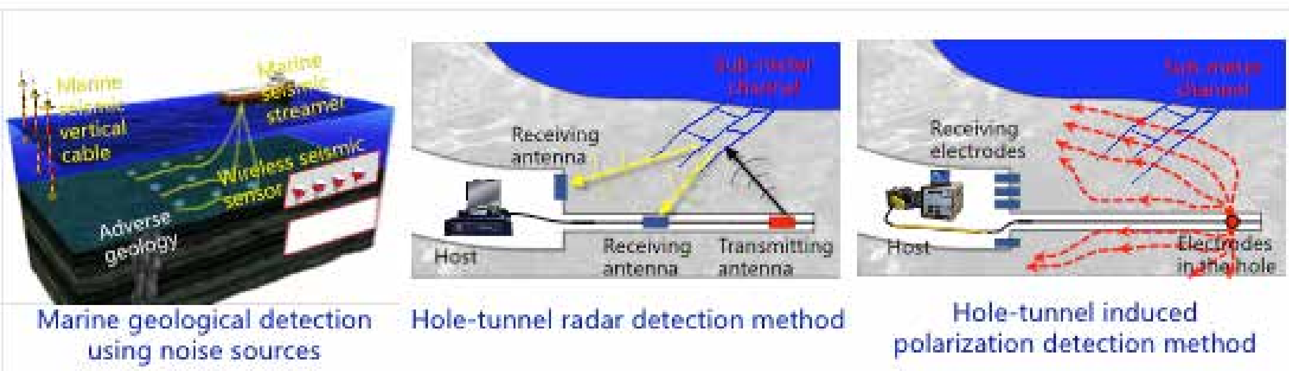


Figure 2-2-12 Probe method for sub-meter channel of water inrush of super-long subsea tunnels in adverse geological conditions

Basic Theory and Key Technologies of Marine Scattered Light Field Imaging

The major research project of “Basic theory and key technologies of marine scattered light field imaging” is led by Prof. Chen Weibiao from Shanghai Institute of Optics and Fine Mechanics (SIOM) of CAS. It will be launched in 2020 and run for 5 years, with 19.60 million yuan of direct funding. The project has four subprojects: (1) the mechanism, characterization and measurement of scattering by marine light scattering, (2) the key theory and technologies of marine scattered light field imaging, (3) the reconstruction theory and evaluation method of marine scattered light imaging, and (4) the developing of prototype system and the experimental demonstration in marine environment. The project will be jointly undertaken by SIOM, the Second Institute of Oceanography of the Ministry of Natural Resources, Sun Yat-sen University, Xi’an Jiaotong University and Tsinghua University.

High resolution optical imaging with long distance in marine environment is a leading-edge technology for ocean science and technology. The greatly limited penetrated distance and blurring of optical imaging in strong scattering marine media is a well-known bottleneck problem. The key scientific problem of the project is to develop a novel optical image theory by using scattered light field instead of screening scattering light as shown in Figure 2-2-13. Combining the methods of computational reconstruction and deep learning, the project is aiming to achieve high quality imaging through a strong marine scattering media not less than 10 attenuation lengths. The project focuses on four core scientific and technological problems: (1) key elements restricting the maximum range with optical imaging using scattering light field, (2) mechanism imaging enhancement method in complex scattered marine environment, (3) optical scattering image reconstruction with ultra-low signal-to-noise ratio, (4) the coupling relationship between target properties and imaging performance in real marine environment. The coupling mechanics between imaging and scattering will be deeply understood by laser radiative transfer model in strongly scattered media. A new measurement method of scattering properties for sea fog and turbid water will be developed, and an ocean scattering characteristics database of typical sea areas in China will be built. The project will study the estimation method of the scattering matrix of marine scattering medium as well as the statistical modeling method of the scattering noisy caused by the scattering lights. The ocean target image modeling method based on sparse representation and deep learning will also be investigated. For

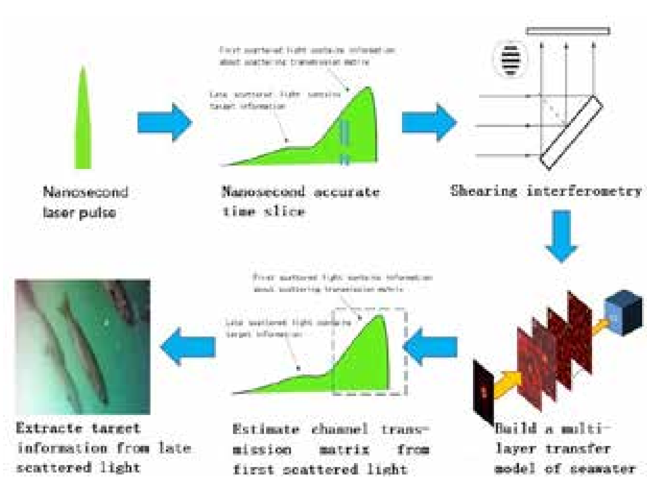


Figure 2-2-13 Principle and method of scattering field optical imaging in marine environment

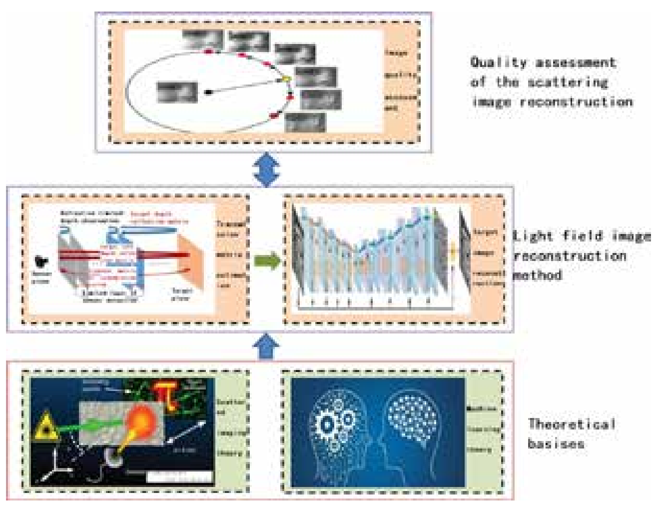


Figure 2-2-14 Reconstruction schematic and method of scattered light field imaging

better image reconstruction performance of ocean target, the new optical scattering image reconstruction theory and method will be proposed as shown in Figure 2-2-14. The key technology and the prototype system of optical scattering imaging will be tackled under a real marine environment. Both optical scattering imaging and the performance evaluation in marine fog and turbid water will be conducted for typical targets.

The research results of this project are expected to achieve breakthroughs on optical scattering imaging and significantly improve the optical imaging performance in marine environment, which is anticipated to be applied in fields of landing, target detection and sea rescue. It will provide both theoretical and technical support for the development of long-distance and large depth optical imaging equipment in target detection underwater.

Research on SAR Microwave Vision Three-Dimensional Imaging Theory and Application Foundation

The major research project of "Research on SAR microwave vision three-dimensional (3D) imaging theory and application foundation" is led by Prof. Ding Chibiao from Institute of Electronics of CAS. It will be launched in 2020 and run for 5 years, with 19.61 million yuan of direct funding. The project is divided into 4 subprojects: "three-dimensional electromagnetic scattering mechanism and the inverse problem for microwave visual information sensing", "3D visual cognition theory and method on SAR images", "theory and method of sar three-dimensional imaging based on microwave vision" and "verification of sar microwave visual three-dimensional imaging" (Figure 2-2-15). It will be jointly carried out by Institute of Electronics of CAS, Fudan University, Institute of Automation of CAS, Peking University and Beijing Institute of Remote Sensing Information.

Synthetic aperture radar (SAR) is one of the most important means of high-resolution earth observation, which has the advantage of fitting to all time and all kinds of weather. It has shown great potentials in military reconnaissance, disaster assessment and other applications. SAR 3D imaging can eliminate severe overlaps in 2D images and improve target recognition and 3D modeling capabilities. It has already become an important trend in the development of SAR. At present, 3D imaging techniques, such as SAR tomography and array SAR, have the disadvantages of long imaging period and high system complexity, which hinder their wide applications. This project proposes a new concept of SAR microwave vision 3D imaging for the first time. It combines the 3D imaging clues from microwave scattering mechanism and image visual semantics with the SAR imaging model to realize three-dimensional reconstruction, and aims to develop the theory and method of SAR microwave vision 3D imaging (Figure 2-2-16) and achieve high efficiency and low-cost SAR 3D imaging. This new technique will contribute to the improvement of SAR technology in China.

The project aims to solve three key scientific problems. The first is the three-dimensional microwave scattering mechanism and its inverse problem. It intends to solve the difficulty of identifying the mechanism of microwave scattering and estimating the three-dimensional parameters from SAR echo data. It is the electromagnetic physics foundation of SAR microwave vision 3D imaging. The second is the theory and method of three-dimensional SAR image visual cognition. It draws lessons from the mechanism of human vision and makes use of the method of computer vision to solve the problem of extraction of semantic 3D features from SAR images.It provides the visual cognitive basis of SAR microwave vision 3D imaging. The last is the theory and method of SAR 3D imaging based on microwave vision. Since the 3D information extracted from microwave scattering mechanism and SAR image semantics is usually qualitative and obscure, it is of great significance to combine the information with the quantitative and accurate SAR imaging model. It will lead to high efficiency and high accuracy 3D imaging.

The results of this project will greatly reduce the complexity of the SAR 3D imaging system, and lay a theoretical and methodological foundation for developing the next generation of SAR 3D system and improving the efficiency of SAR applications in China.

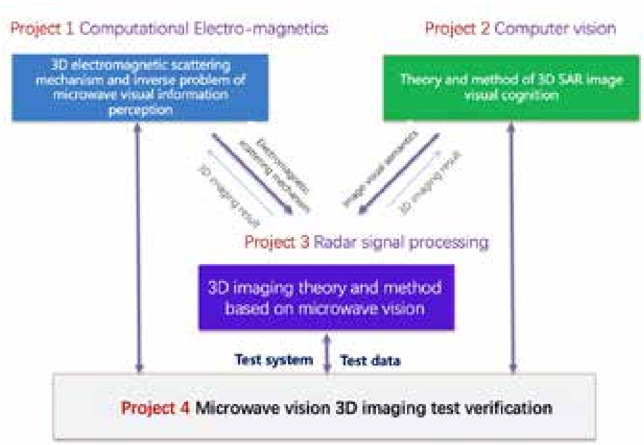


Figure 2-2-15 Work packages

Figure 2-2-16 Diagrammatic sketch of SAR microwave vision 3D imaging

Econometric Modeling and Prediction

The major research project of "Econometric modeling and prediction" is led by Prof. Fan Jianqing from Fudan University. It will be launched in 2020 and run for 5 years, with 14.624 million yuan of direct funding. The project has 5 subprojects: "macroeconomic data modeling and prediction", "high-dimensional unstructured data modeling and prediction", "spatial-temporal data modeling and prediction", "microeconomic big data modeling", and "financial big data modeling under contemporary network ecosystem". Principal investigators of the subprojects are Prof. Wang Tongsan from Institute of Quantitative & Technical Economics, Chinese Academy of Social Sciences, Prof. Fan Jianqing from Fudan University, Prof. Chang Jinyuan from Southwestern University of Finance and Economics, Prof. Li Zhongfei from Sun Yat-sen University and Prof. Gong Pu from Huazhong University of Science and Technology, respectively.

The stylized features of economic big data include heterogeneity, high dimensionality (economic and financial data), unstructuredness (text and image data), spatial-temporality (environmental, meteorological monitoring data and traffic flow data) and high connectivity (financial network data, social media data, Internet of Things data) (Figure 2-2-17). Traditional econometric models can hardly be applied to address these complicated characteristics, which gives rise to new challenges and opportunities to the development of contemporary econometrics.

The project will focus on major issues in Chinese economy, finance and social governance etc. Based on construction, operation and maintenance of big data systems, and oriented to extensive demand for macroeconomic and microeconomic data resources and big data applications in various fields, the project will systematically develop new theories and novel intelligent analytical methods for econometric modeling based on dimensionality reduction techniques, variable selections, spatial econometrics and latent factor learning etc., with in-depth analysis of the diversity and complexity of Chinese big data resources. The key scientific problems to be investigated include: (1) collecting and integrating multi-source data in macroeconomic operations, (2) constructing machine learning methods in predictive studies, (3) constructing high dimensional and unstructured robust factor learning AI models for accurate prediction and effective management of the economy, finance and social governance in China, (4) exploring new theory and methods for large-scale spatial-temporal data modeling and prediction, (5) studying causal effects based on multi-source integration of microeconomic big data, and exploring assessment methods of the implementation of specific policies and individual decision-making effects, and (6) systematically exploring systemic financial risk contagion and evolution mechanisms under complicated network structures.

Methodological roadmap of this project includes: (1) using big data to improve the technical approaches of macroeconomic indices prediction, macrostructures analysis, and policy effectiveness assessment, (2) constructing high dimensional and unstructured robust factor learning and intelligent prediction models from a data mining perspective, (3) proposing dynamic models to depict the formation and evolution mechanisms of social networks, and constructing theoretical framework and fast algorithms for large-scale spatial-temporal data modeling, (4) using machine learning and other data-driven methods to establish an econometric theory of causal analysis based on microeconomic big data, (5) constructing links and relations of multi-source and heterogeneous financial big data and exploring the formation and contagion mechanisms of systemic risk under contemporary network ecosystems (Figure 2-2-18).

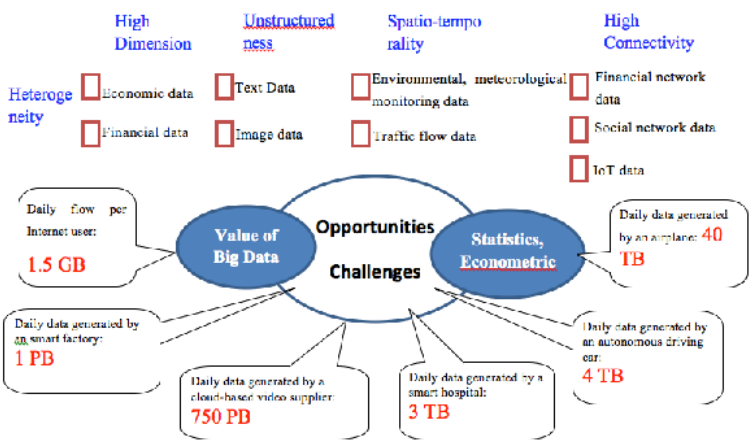


Figure 2-2-17 Basic characteristics of big data in economics

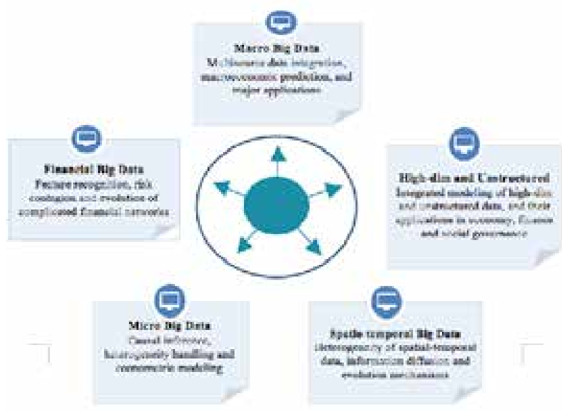


Figure 2-2-18 Big data in economics and its applications

Business Operation and Service Innovation Management Theory and Application

The major research project of "Business operation and service innovation management theory and application" is led by Prof. Chen Xiaohong from Hunan University of Technology and Business who is also an academician of CAS. It will be launched in 2020 and run for 5 years, with 14.638 million yuan of direct funding. It is jointly undertaken by Hunan University of Technology and Business, Tsinghua University, University of Science and Technology of China, Central South University and Shenzhen University.

Aiming at the key requirements and major scientific problems of business operation and service innovation management in the era of digital economy, this project aims to set up a comprehensive theory and application system from five aspects (Figure 2-2-19):

(1) Innovation of operation and service mode of smart supply chain. On the premise of accurate

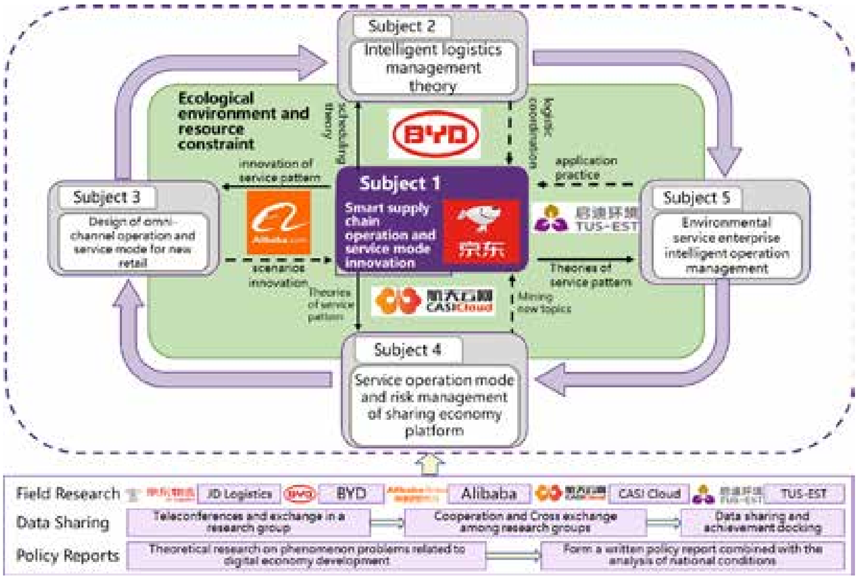


Figure 2-2-19 Key scientific problems

analysis of consumer purchase behavior and enterprise marketing forecast, the project will develop the collaborative scheduling mode, system and decision optimization methods based on big data, as well as methods of the layout strategy optimization, layout optimization value factors and dynamic hybrid warehouse location allocation decision-making method for intelligent warehouse layout.

(2) Intelligent logistics service mode and collaborative design. This project will explore the interaction mechanism of multi-control strategies of intelligent systems and the patio-temporal patterns of the supply and demand of logistics and distribution services, develop intelligent distribution decision-making, logistics financial model and its collaborative structure, and achieve information sharing and decision-making optimization based on blockchain distributed storage technology.

(3) Design of omni-channel operation and service model for new retail. Focusing on consumer experience, the project will reveal consumer omnichannel behavior and the underlying psychological and physiological mechanisms, design omnichannel models, omnichannel inventory and dynamic pricing models and methods, and explore precise and intelligent matching methods for omnichannel operation strategies and their service models.

(4) Mode Optimization of service operation and risk management of sharing economy platform. The project will explore the dynamic analysis mechanism of the control and development of sharing economy platforms, establish a joint optimization model of supply and demand matching and pricing strategy for sharing economy services, and innovate the sharing platform service model and its integrated risk management method.

(5) Intelligent operation decision models and methods for environmental service enterprises. The project will establish models for dynamic site selection of environmental monitoring equipment, intelligent service pricing, and service contract optimization, as well as dynamic intelligent analysis methods and technologies for environmental big data, and innovate environmental service models driven by big data.

The research protocol of this project is shown in Figure 2-2-20. The scientific goal is to drive the breakthrough of core and key technologies in the field of China’s operations and management in the context of deep integration of new technologies such as big data, artificial intelligence, 5G, and blockchain. By systematic and in-depth research on the theory, methods and technologies of enterprise operation management and service innovation, the project will provide systematic and comprehensive scientific support for the integration of China's digital economy with the real economy and even the deepening of supply-side structural reforms.

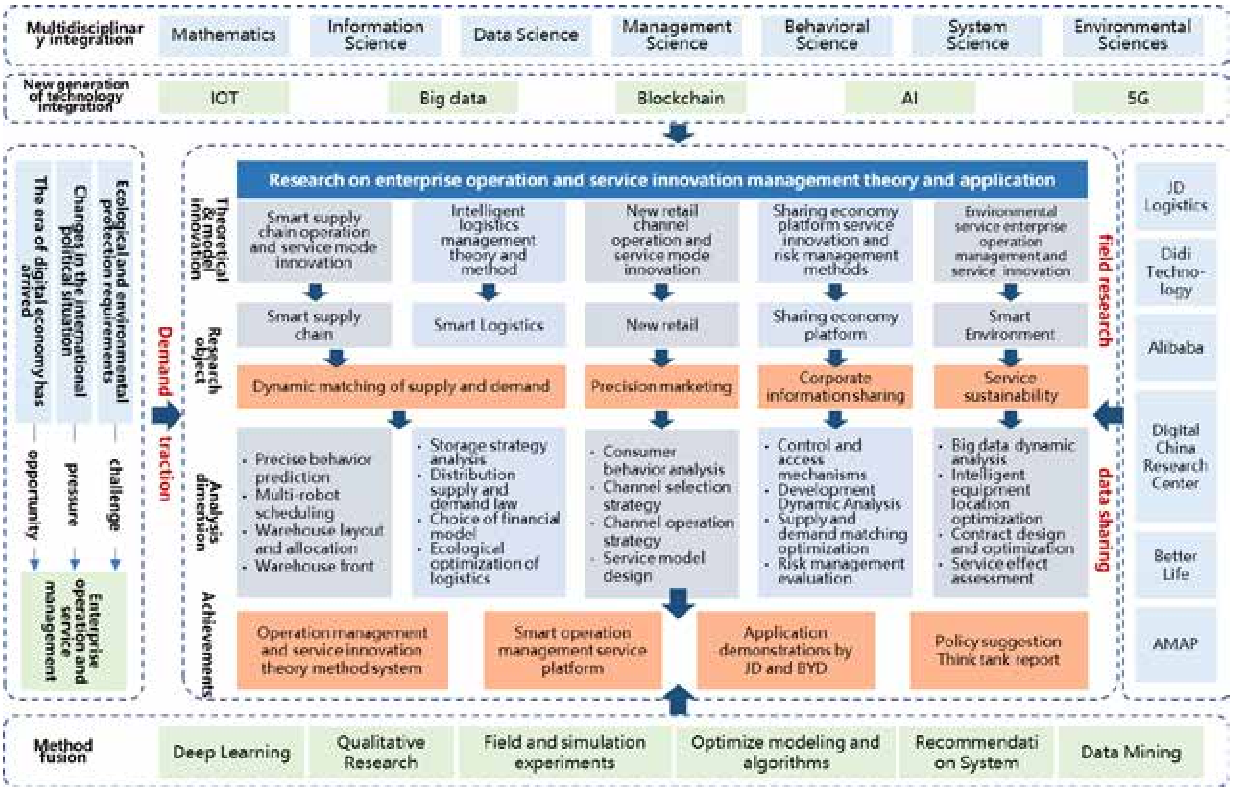


Figure 2-2-20 Overall research protocol

Strategic Factors and Their Underlying Regulatory Mechanism for Modulating Vaccine Efficacy

The major research project of "Strategic factors and their underlying regulatory mechanism for modulation vaccine efficacy" is led by Prof. Xia Ningshao from Xiamen University. It will be launched in 2020 and run for 5 years, with 17.818 million yuan of direct funding. The project includes five subprojects: "structure-directed immunogen design and immune protection mechanism with wide breadth", "adjuvant discovery targeting immune-metabolism and immune negative feedback", "the study of immune mechanism of the lymph node-targeted delivery", "mechanism of how pre-existing immunity influences vaccine-elicited immune response", and "the formation and maintenance of protective humoral immunity". The project is jointly carried out by Xiamen University, Tsinghua University, Fudan University, Institute of Zoology and Institute of Biophysics of CAS.

Vaccination is the most effective way to prevent and control infectious diseases, and it is an important national policy to promote health in countries around the world. In addition to disease prevention, vaccines have also shown potentials in the treatment of chronic diseases like cancer and autoimmune diseases. Although the technical strategies of traditional vaccines have been proven effective, it is difficult to meet the requirements of current research and development of challenging and innovative vaccines, especially in face of the more complex multi-genotype or highly variable pathogens, and weak immunogenicity, or different pre-existing immunity in individual patients. Under the circumstances, higher requirements are imposed on the precise design and application of vaccines. Systematic research on critical factors affecting vaccine effects and their regulatory mechanisms will not only help to promote basic theoretical research on vaccine innovation, but also lead to breakthroughs in key technologies of relevant important vaccine products.

Figure 2-2-21 Major challenges for representative viral vaccines

This project addresses three key common issues in innovative vaccine research: insufficient theoretical basis for immunogen selection and design, lack of novel adjuvants and delivery systems with immune-enhancing effects and good safety, and unclear mechanisms of vaccine immune response. This project will explore the immunogen, adjuvant, delivery system, pre-existing immunity and formation and maintenance of immune memory. The critical factors affecting vaccine effects and their regulation will be studied through multidisciplinary studies such as structural vaccine science, immunology, pharmacy, materials science and chemistry.

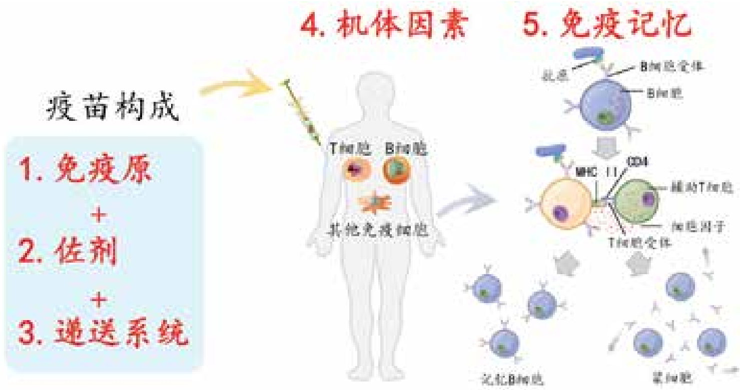


Figure 2-2-22 Key factors affecting the vaccine effect and the starting point of its regulation

It is expected that the project will clarify the theoretical basis of precise design of structure-guided vaccine immunogens, develop new adjuvants that target immune metabolic barriers and negative immune feedback loops, clarify the immune mechanism for targeted delivery of lymph nodes, and reveal impact of pre-existing immunity and mechanism of vaccine immune response, elucidate the formation and maintenance mechanism under the protective humoral immunity, and finally lay the foundation for the containment of related major infectious diseases.

Discovery and Formation Mechanism of Marine Pharmaceutical Molecules

The major research project of "Discovery and formation mechanism of marine pharmaceutical molecules (MPMs) " is led by Prof. Tan Renxiang. It will be launched in 2020 and run for 5 years, with 18 million yuan of direct funding. The project has five subprojects, including (1) characterization of marine stress-induced new MPMs, (2) efficient discovery of trace and novel MPMs, (3) mode of action and target identification of promising MPMs, (4) formation mechanism and abundance regulation of MPMs, and (5) genome mining and heterologous expression for unusual MPMs. The subprojects are led by Prof. Guo Yuewei from Shanghai Institute of Materia Medica of CAS, Prof. Yu Guangli from Ocean University of China, Prof. Hu Gang from Nanjing University of Chinese Medicine, Prof. Tan Renxiang from Nanjing University of Chinese

Medicine & Nanjing University, and Prof. Lin Wenhan from Peking University, respectively.

Ocean covers 71% of the Earth's surface and fosters 80% of the bio-resources we can predict. The special organisms living in the special marine environment could produce special molecules with special functions. Therefore, marine organisms are very likely to produce diverse MPMs with unforeseeable architectures. Global competition in the field has been in full swing and all developed countries invest more and more to enhance their MPM exploration capability. However, the field remains challenged by: (1) the structural complexity that prevents the chemical preparation of MPMs, (2) the scarcity of new MPMs that falls in most cases below the detection limit, and (3) the difficulty of compound re-isolation that leads to a growing waste of human and fiscal resources.

Therefore, as illustrated in Figure 2-2-23, the project is particularly committed to: (1) identifying new bioactive molecules produced in response to marine environmental stresses; (2) establishing an efficient platform capable of discovering functional molecules in (extremely) low abundance; (3) addressing the mechanism of MPMs with promising bioactivities (e.g., anti-tumor, anti-infection, anti-neurodegeneration, and immune regulation); (4) deciphering and subsequently modulating the MPM biosynthetic steps including oligomerization and rearrangement steps that affect the structural diversity and functional potency/span; and (5) deeply mining and heterologously producing MPMs biosynthesized by poorly expressed or unexpressed genes.

It can be anticipated that the project may achieve a substantial improvement of the field and enhance China's international leading position in the discovery, druggability assessment, and formation mechanisms of MPMs with unique or unprecedented architectures.

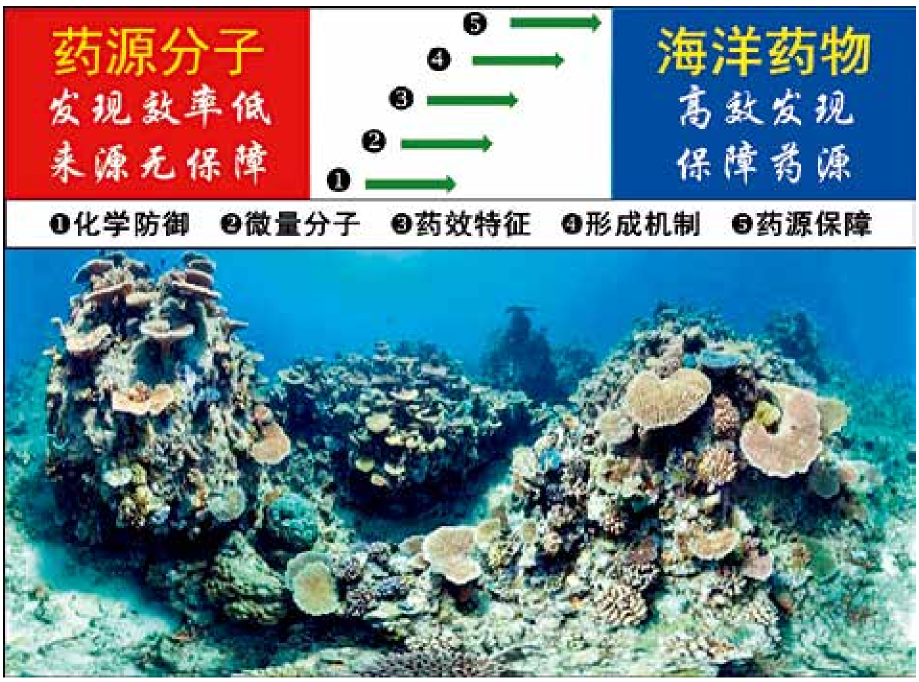


Figure 2-2-23 Focusing on the bottlenecks of patent medicine through innovation along the whole value chain

2.2.2 Major Research Plan

Cluster Architectures, Functionalities and Hierarchical Evolution

The major research plan of "Cluster architectures,functionalities and hierarchical evolution" was launched in 2019 and will run for 8 years, with 200 million yuan of direct funding.

Based on the current development trend of material science and national strategic needs, the major research plan aims at making full use of the characteristics of clusters as a mesoscopic dimension material with precise molecular structure (Figure 2-2-24), giving full play of the advantages of clusters as an ideal model for correlating microstructure and macroscopic properties of materials, and solving key scientific issues of cluster materials by carrying out a comprehensive and interdisciplinary study.

The leading scientist of the steering committee of this major research plan is Prof. Zheng Lansun from Xiamen University who is also an academician of CAS. The key scientific problems to be addressed include: the structure-function relationship of clusters, the evolution rule of material structure and properties in changing cluster size, the stabilization mechanism of clusters, the mechanism of the host-guest interaction in hierarchical clusters, the precise construction and large-scale preparation of function-oriented clusters. The major research plan is organized and implemented on the basis of the following three key scientific issues:

(1) The mechanism underlying the stability of clusters, including the discovery of novel clusters with special structures and unique properties; formation and stabilization mechanism of clusters. The study of this topic will establish the directional, efficient and large-scale preparation methods of clusters, develop new methods for characterization and property study of clusters, reveal various chemical bonds and weak interactions in clusters and the mechanisms underlying the nucleation, growth and evolution of clusters.

(2) The regularity of electronic structure of clusters, including the evolution of cluster structure as the cluster size changes, the "magic number" of clusters, and the structure-function relationship of clusters. Research on this topic will establish a cluster structure database, develop the electronic structure and stability theory of clusters, reveal the systematic regularity of cluster structure and properties, develop new computational methods and software of cluster system, and conduct experimental studies on electronic structure of clusters.

(3) The modulation principle of functions of hierarchical clusters, including the relationship between the function of hierarchical clusters and the intra-cluster aggregation state, the interaction between clusters, and the coupling between clusters and the environment. Through interdisciplinary research, it is expected that the researchers will reveal the influence mechanism of cluster structure and environment on the performance, design and synthetize function-oriented multi-level clusters, and fabricate the cluster-based functional materials and devices.

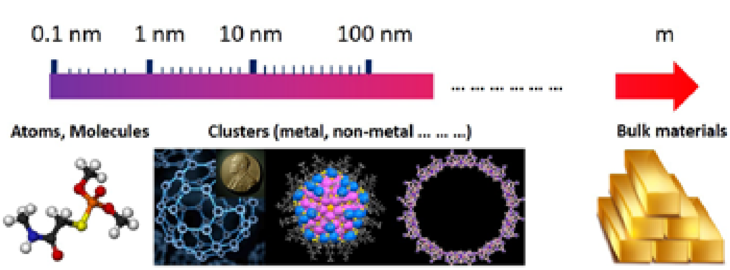


Figure 2-2-24 Distribution of cluster sizes

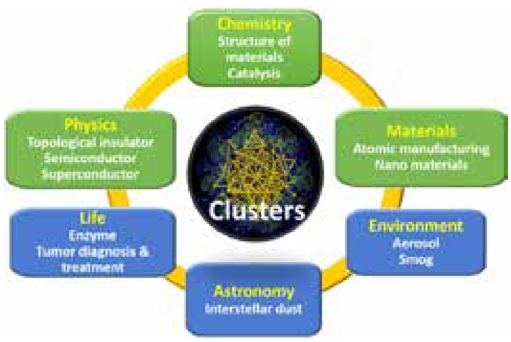


Figure 2-2-25 Intersections of cluster science and other disciplines

Through the interdisciplinary study of chemistry, physics, biology, material, environment science, and astronomy (Figure 2-2-25), the major research plan aims to achieve the following goals: developing new reactions, new methods, new concepts and new strategies for multi-level structural construction of novel clusters; developing new technologies to characterize the clusters with high precision and resolution; revealing the structural inherence and evolution regularity of clusters with special properties at atomic scale; advancing the understanding of the relationship between cluster structure and function; fabricating functional cluster materials and devices; and solving key scientific issues underlying cluster-based revolutionary technology and promoting the development of the related disciplines.

Extreme Enrichment and Ore-Forming Dynamics of Strategic and Critical Metals

The major research plan of "Extreme enrichment and ore-forming dynamics of strategic and critical metals" was launched in 2019 and will run for 8 years, with 200 million yuan of direct funding.

Based on major national needs, this major research plan aims at the strategic and scientific values of critical mineral resources. It identifies the key scientific problems of the mineralization of key metals and will achieve a breakthrough of ore deposit geology and promote the development of earth sciences.

The leading scientist of the steering committee of this major research plan is Academician Chen Jun from Nanjing University. The key scientific problem to be addressed is the extreme enrichment and driving mechanism of ultra-low abundance metal elements, which includes three key issues:

(1) The relationship between the earth's multi-system interaction and the enrichment of critical metal elements. The abundance of critical metal elements (as shown in Figure 2-2-26) is extremely low in the Earth's crust. Critical metal deposit is a special geological body with ultra-high enrichment of metal elements. Existing research has not been paying sufficient attention to the geochemical behavior of critical metal elements. The geochemical behavior and enrichment process of critical metal elements in the the Earth's multi-system interaction is a problem that requires to be settled urgently.

(2) The metallogenic mechainsm and regularity of critical metal elements. The formation of ore deposits is the result of complicated geological-physical-chemical processes. The key to the further understanding of the metallogenic mechanism and regularity of critical metal elements is to clarify the characteristics and distribution regularity of the critical metal deposits, and the geological-physical-chemical processes that control the formation of key ore deposits.

(3) Occurrence and strengthening separation mechanism of critical metal elements .Critical metal elements are always associated with the main elements in certain deposits and are worthy of mining and utilization. However, to utilize the associated elements, it is necessary to reveal their paragenesis characteristics and identify the main controlling factors in the first place. Research on the strengthening separation and regulatory mechanism is essential to the efficient and clean utilization of complex mineral resources.

The overall scientific objectives of this plan are: (1) revealing the conditions of extreme enrichment of critical metal elements, establishing the theory of extreme enrichment mineralization, and achieving a breakthrough in metallogenic theory; (2) revealing the mineralization regularity of critical metals, recognizing new critical deposit type, and achieving a breakthrough in breakthrough in ore prospecting; (3) identifying the microscale occurrence of critical metals, conquering the theoretical bottleneck of strengthening separation, and achieving a breakthrough in separation theory.

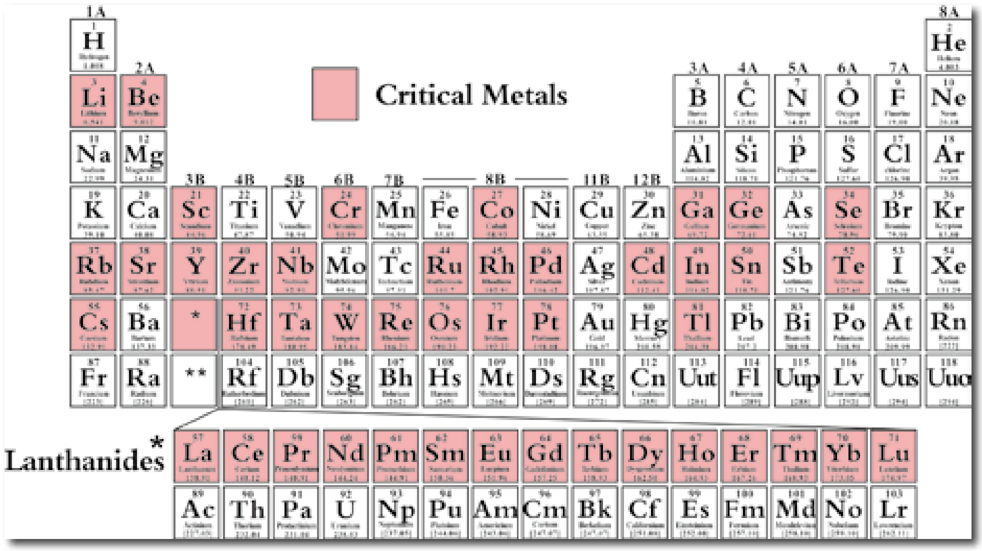


Figure 2-2-26 Types of critical metals

Element	Crustal Abundance	Ore Industrial Grade	Mineralization Enrichment Multiple	Smelting Enrichment Multiple
Beryllium (Be)	1.9 ppm	0.1% BeO	156	2,700
Iron (Fe)	5.05%	30% Total iron	6	3

Figure 2-2-27 Extreme enrichment of critical metal (Be) and normal enrichment of bulk metal (Fe)

Basic Research on High-Performance Materials Based on Ordered Structures with Functional Units

The major research plan of “Basic research on high-performance materials based on ordered structures with functional units” was launched in 2019 and will run for 8 years, with 200 million yuan of direct funding.

Ordered Structures with Functional Units (OSFU) is a major breakthrough in the research paradigm of material sciences (Figure 2-2-28). It is expected that OSFI can realize a large number of transformative and disruptive high-performance materials, and resolve the contradiction between the rapid development of high-end technology and the limitations of existing materials. This major research plan focuses on the requirements of information, structure, energy, and extreme conditions for materials and aims at the key scientific/technical issues. The goal is to reveal the underlying mechanisms and establish the corresponding theories. The implementation of the plan will greatly promote the development of the national economy and enhance the China's core competitiveness.

The leading scientist of the steering committee of this major research plan is Prof. Zhang Qingjie from Wuhan University of Technology who is also an academician of CAS. The plan is to address the following 4 key scientific issues:

(1) The influence of the intrinsic characteristics of functional units on material performance and its manipulating mechanism, including the relationship between the physical properties, shape size of functional primitives and macro-physical properties; the critical size effects and quantum confinement

effects of functional primitives; the interface coupling effects between functional primitives; the mechanism of new effects.

(2) The optimization and enhancement effects of ordered-structures on material properties, including the enhancement effects of ordered-structures symmetry on energy absorption, conversion, propagation and output; the regularity of the order changes of the ordered-structures on the optimization and enhancement of the material properties; theoretical and experimental support to the design and implementation of the OSFU.

(3) Synergistic correlation effect of OSFU, including theories and experimental rules of the interaction and synergy between functional-units and ordered-structures; principles and design methods of OSFU materials that meet the performance requirements; high-performance OSFU materials that break through the limitations of existing materials.

(4) Preparation and characterization technology of high-performance OSFU materials, including the preparation technology and equipment, preparation of OSFU materials by both "top-down" and "bottom-up" techniques.

The overall scientific objective of this major research plan is: aiming at the frontiers of material sciences, to construct high-performance new materials through "Ordered Structures with Functional Units" to meet the demand for materials in information, structure, energy and extreme conditions and improve China's innovation capabilities in material sciences.

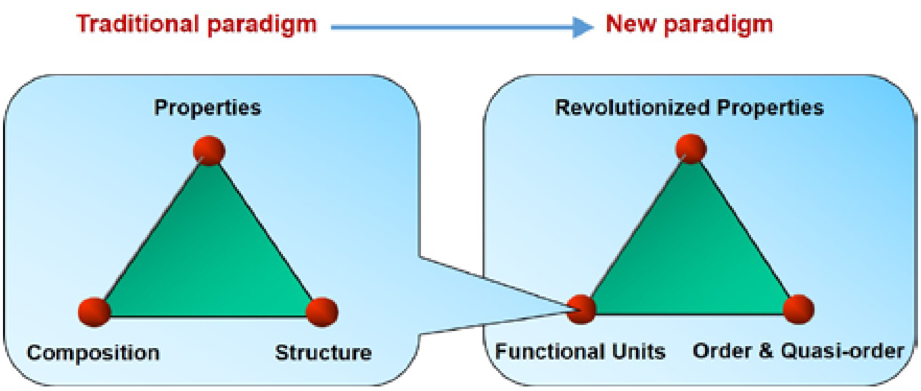


Figure 2-2-28 Comparison of the research paradigm of ordered structures with functional units with traditional material research paradigm

Fundamental Research on Beyond-Moore Novel Devices

The major research plan of "Fundamental research on beyond-moore novel devices" was launched in 2019 and will run for 8 years, with 200 million yuan of direct funding.

High efficiency computing has become an urgent demand in processing the surge of data growth brought by the rapid development of information technologies including big data, cloud computing and artificial intelligence. However, higher efficiency computing itself is a critical fundamental challenge at the current stage due to the limits posed by classic device basics and architecture from conventional scaling defined by the Moore's Law. On the one hand, the power consumption for a single operation of data processing cannot continue to be reduced as the device scaling keeps reducing. The resulted "Power Wall" problem limits the improvement of computing efficiency. On the other hand, the classic von Neumann architecture also limits further improvement in high efficiency computing due to the constrains in data access and data exchange efficiency between the separated memory and computing units, i.e., the "Memory Wall" (Figure 2-2-30). Focusing on higher efficiency computing, this major research plan aims to develop new devices and architecture to break the fundamental limits of energy efficiency for the beyond-Moore era, and promote China's research capabilities in IC technology to meet the strategic demand for the independent development of the IC industry.

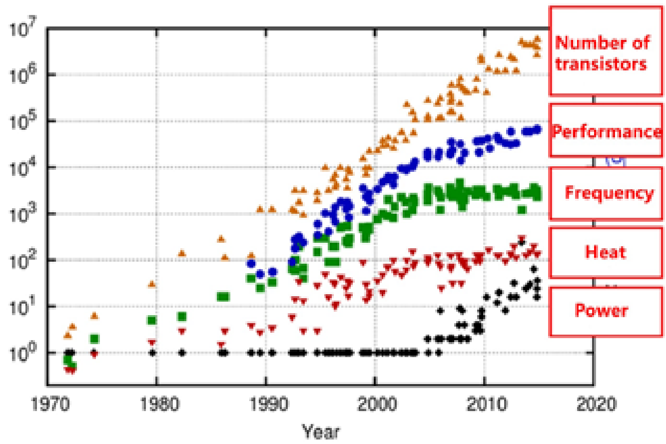


Figure 2-2-29　Power wall

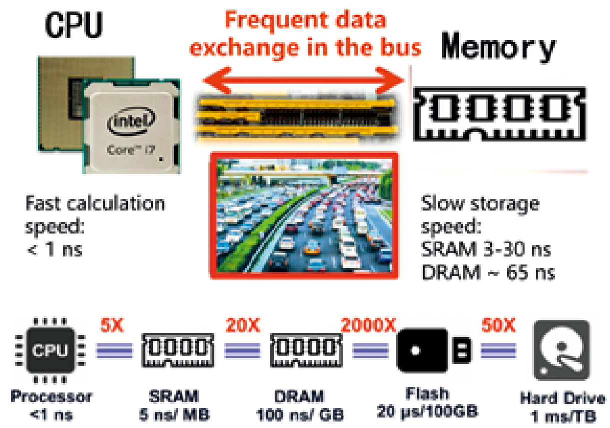


Figure 2-2-30　Memory wall

The leading scientist of the steering committee of this major research plan is Prof. Huang Ru from Peking University, who is also an academician of CAS. The key scientific problems to be addressed include:

(1) The power efficiency limit and new mechanisms of CMOS devices, including but not limited to: the power efficiency limit of a single operation of data processing by CMOS devices, and new mechanisms to break the limit which can lead to the ultra-low power operation of data computation, storage and exchange.

(2) New mechanisms of devices that can break the speed limit of silicon-based technology, including but not limited to: exploring novel channel materials with long mean-free-path and high density of states, and device physics of quasi-ballistic transport which can lead to high performance devices surpassing the carrier speed limit in silicon technology.

(3) New mechanisms that breaks the energy efficiency limit of classic von Neumann architecture, including but not limited to: new theories and methods for the integration of memory and computing, and novel computing architecture based on new paradigms of information coding that breaks the energy-efficiency bottleneck of the classic von Neumann architecture.

The overall scientific objectives of this major research plan is to achieve breakthroughs in novel mechanisms for ultra-low power information operation and quasi-ballistic carrier transportation; novel channel materials with high carrier mobility and high density of states; new algorithms of high-density integration and high energy-efficiency non-von Neumann computing architecture. Based on interdisciplinary research, the major research plan will remarkably increase the IC computing efficiency, build up a research team with global influence and improve china's innovative research capability in IC technology.

2.2.3 Science Fund for Creative Research Groups

Space Astronomy

The research group, led by Prof. Chang Jin from the Laboratory of Dark Matter and Space Astronomy, Purple Mountain Observatory of CAS, was awarded as the Creative Research Groups by NSFC in 2019. The research group consists of six members, including Prof. Gan Weiqun , Prof. Wei Daming, Prof. Fan Yizhong, Prof. Guo Jianhua and Prof. Feng Li as well. All are from the Key Laboratory of Dark Matter and Space Astronomy.

To solve some key issues in the dark matter physics, high energy astrophysics (including gravitational wave astronomy) and solar physics, this research group has been keen on developing the detection techniques and then carrying out space missions. Together with some publicly available data, this research group has made significant progresses on the direct measurements of the high energy cosmic ray electrons and protons, the identification of the optical counterparts of the neutron star merger events, and the solar material ejection. These results have been published in some high impact journals such as *Nature*, *Nature Astronomy*, *Nature Physics*, *Nature Communications*, *Physical Review Letters*, *Astrophysical Journal Supplementary*, and *Astrophysical Journal Letters*.

In the next five years, this research group expects to make the following achievements: (1) making breakthrough on dark matter indirection detection and/or cosmic ray measurements with the high quality data of the DAMPE satellite; (2) launching the first Chinese solar satellite ASO-S and making significant progresses on the solar physics studies; (3) achieving important results on high energy astrophysics and gravitational wave astronomy with the publically available data; (4) developing new techniques for high energy particle detection and proposing the second generation of the dark matter particle explorer (DAMPE).

Figure 2-2-31 Group members

Mechanics of Soft Materials and Flexible Structures

The research group, led by Prof. Feng Xiqiao at the Department of Engineering Mechanics of Tsinghua University, has awarded by NSFC for the Creative Research Groups in 2019. This group is affiliated with the State Key Discipline of Mechanics at Tsinghua University and the Ministry of Education Key Laboratory on Applied Mechanics. The key members in the group are Prof. Zheng Quanshui, Prof. Liu Bin, Prof. Chen Changqing, Prof. Feng Xue and Associate Prof. Li Bo.

The research thrusts of the group are problem-oriented, with an over-arching goal to conquer the critical challenges faced by the society and the nation to advance on science, technology, health, and economy. Such an ambitious research goal is substantiated and driven by our members' passion for innovation, equipped by their broad knowledge and deep insights on the frontiers of mechanics, along with rich experiences on collaborative researches that merge mechanics with biology, medicine, materials science, aerospace engineering, etc. By seamlessly integrating original works on both theoretical and experimental mechanics, the group has made significant progresses and achieved global impact on a number of research fields, including biomimetics, micro/nano-mechanics, smart materials and structures, space engineering, soft matter, medical engineering, etc. The group has also been endeavoring on translating lab-validated technologies to industry-scale products. Several applications in aerospace engineering, defense, as well as chemical engineering, have so far been highly valued by the market and the society.

To meet the tremendous needs to advance national health and state safety, the group will continue leveraging a multidisciplinary approach in its research and pushing the frontiers of solid mechanics further into an uncharted territory. Specially, a great deal of efforts will be steered to towards investigating the mechanics of soft materials, soft biological tissues, and flexible structures and devices, along with developments of novel theories and numerical methods to guide the design and manufacturing process. This project expects to advance: (1) the multi-physics, multi-scale mechanics of soft materials and biological tissues; (2) integrative design of flexible structures for medical applications; (3) mechanics of the interface in biological tissues and flexible structures. This will also expand the body of solid mechanics via incorporating non-linearity, mechano-chemo-biological coupling, multi-scale behaviors, and material-structure-function integration design into existing subjects. The outcome of this project is expected to enrich and extend the theoretical frameworks and the application fields of solid mechanics, and provide theoretical foundations for innovations on the design and fabrication of soft robotics, flexible devices and structures, as well as the diagnosis and treatments of diseases such as cancer.

Figure 2-2-32 Group members

Nonlinear Optical Crystal Materials

The research group led by Prof. Guo Guocong at State Key Laboratory of Structural Chemistry, Fujian Institute of Research on the Structure of Matter of CAS was awarded as the Creative Research Groups by NSFC in 2019. The key members in the group are Prof. Hong Maochun, Prof. Ye Ning, Prof. Mao Jianggao, Prof. Luo Junhua and Prof. Deng Shuiquan.

The creative group has intensively investigated in the fields from fundamental researches to applications including new nonlinear optical (NLO) theory, material structure design, crystal growth techniques and new crystal devices. Some great achievements have been made. For example, atom response theory and laser induced damage threshold (LIDT) measurement method using high energy focused single pulse were proposed. In exploring new deep-UV NLO materials, the problem of layer growth habit of KBBF was resolved by the strategy of strengthening interlayer interactions and new material systems of phosphates and fluoborates were obtained. In exploring new mid- and far-IR NLO materials, some structure design strategies were proposed to circumvent the incompatibility between large NLO efficiency and high LIDT. Some crystals with high IR NLO performances were obtained, such as BGS with highest LIDT. During the exploration of new UV/near-IR NLO materials, new material systems containing conjugate triangular CO_3^{2-} and NO_3^- groups and triangular pyramidal IO_3 and SeO_3 groups with lone pair electrons were obtained.

With the support of the creative research group funding, the research group will follow the international industry and developing trend of NLO crystals and laser equipment on the basis of leading role of our country in the NLO research. Specifically, the research group will focus on some crystals that are extremely important for national economy and defense with the guidance of atom response theory, and will achieve the goal of revealing the relationships between NLO efficiency and materials structures, obtaining some new original deep-UV and mid/far-IR high performance NLO crystals, and developing 2-4 kinds of new crystal devices to meet the requirements of our country. The research group will also train next generation of high-level researchers in the fields of new theory, new materials, new devices and new applications to lead international NLO researches.

Figure 2-2-33 Group members

Special Separation Membrane

The research group funded by NSFC is led by Prof. Xing Weihong from Nanjing Tech University. The group members include Prof. Wang Yong, Lu Xiaohua , Jin Wanqin, Fan Yiqun and Bao Ningzhong.

In the past two decades, this group was organically established based on three 973 Programs, seven Major or Key Programs of NFSC. The researches of the group members are focused on the transport mechanisms in the membrane preparation and applications. The theoretical framework of the design and preparation of inorganic membrane was established, and the novel concepts such as homoporous membranes and mass-transfer confined membranes were also proposed. The engineering research on design and preparation of inorganic membranes such as ceramic membrane and zeolite membranes has converted empirical methods into quantitative controlling strategies, which supports the rapid development of inorganic membrane industry. The integrated research based on membranes has developed the technologies of membrane reactor and membrane-based zero discharge of pulp tail water. The membrane reactor technology was firstly industrialized in main processes of petrochemical industry. The world's first project of zero discharge of pulp tail water was built in complete sets. This group has won five national science and technology awards. Over 1,250 papers have been published with more than 10,000 citations and over 240 Chinese patents have been licensed.

The group will focus on special separation membranes to study the mass-transfer confined mechanism and the microstructure preparation, develop the membrane with confined mass transfer characteristics, create new membrane-based process to support high-quality green industry. The original basic research will be conducted to lead the development of materials-oriented chemical engineering. The collaborative innovation research platform will be built to enhance the competitiveness of membrane industry and be cultivated to form the group with international academic influence.

Figure 2-2-34　Group members

Perception and Responses of Abiotic Stress in Plants

The research group led by Prof. Guo Yan in the State Key Laboratory of Plant Physiology and Biochemistry, College of Biological Sciences, China Agricultural University, was awarded by NSFC in 2019. This group consists of four core teams in this key lab, whose investigations are in the fields of plant abiotic stress response and nutrition uptake, and the key members include Prof. Gong Zhizhong, Yang Shuhua, and Wang Yi.

Abiotic stress, including drought, salt, cold, and nutrient limitation, is a major environmental factor that adversely affect plant growth and development, as well as crop productivity and quality. The group has been devoted together for a long time to addressing the fundamental biological questions in plant abiotic stress field. Besides that, many important components in abiotic stress signal transduction were identified, and the original and great contribution to the understanding of plant response to abiotic stress were made. These findings have been published in high-impact journals during the last 5 years, such as *Molecular Cell, Developmental Cell*, *Nature Communications*, *Proceedings of the National Academy of Sciences of the United States of America*, *EMBO Journal*, *Plant Cell* and *Molecular Plant*.

This group will focus on studying how abiotic stress signals are perceived by plants, how these signals are transduced in the cells, how plants respond to abiotic stress, and how plants balance stress tolerance and plant growth/development. The goal of this project is to unravel the molecular and biochemistry mechanisms underlying the regulation of plant responses to abiotic stress and identify new determinants that can be used to improve crop stress tolerance.

Figure 2-2-35 Group members

Brain Development

The research group led by Prof. Xu Zhiheng, was awarded as the Creative Research Group on brain development by NSFC in 2019. The group consists of six interrelated whereas independent research teams. All of them are from the Institute of Genetics and Developmental Biology of CAS. The brain is the most complicated organ in the human body. Developmental anomalies may lead to various neuropsychiatric disorders including mental retardation, microencephaly, autism spectrum disorder, and schizophrenia. The group aims to make major contributions to the biomedical researches focusing on fundamental scientific issues for brain development. The six key members in the group are top scientists in their respective fields, including five recipients of the "Hundred Talents Program" of CAS, one awardee of the "Thousand Young Talents Program" of the Organization Department of the Central Commitee of CPC, three awardees of the "National Science Fund for Distinguished Young Scholars" and one of the "Excellent Young Scientists Fund". Through collaborations, members of the group have made significant progress in the molecular and cellular mechanisms of brain development as well as the pathogenic mechanisms of brain development-related diseases, which are well recognized by the international science community. In the past 5 years, the group published over 80 original research articles, including 20 in *Science, Cell* and their publishing group journals. The research group aims to further explore fundamental issues in the field of brain development including mechanisms underlying neural stem cell proliferation and differentiation, neuronal migration, axonal and dendrite development, synaptic development and plasticity, as well as the pathogenic mechanisms of brain developmental disorders.

Figure 2-2-36 Group members

Changes in Atmospheric Composition and Their Impacts on Climate and Environment

Atmospheric composition has been significantly changed due to anthropogenic emissions of gases and aerosols since the industrial revolution. The changes in atmospheric composition and their impacts on climate and environment are of great interests to the international community. Led by Prof. Zhang Qiang at Tsinghua University, a research group focusing on the changes in atmospheric composition and their impacts on climate and environment has been gradually formed from extensive collaborative research activities, with the development of earth system science at Tsinghua University during the same period. The group was awarded as the Creative Research Groups by NSFC in 2019. The key members in the group include Prof. Luo Yong, Prof. Guan Dabo, Prof. Lin Yanluan, and Prof. Liu Zhu.

The research group has intensively investigated the impacts of anthropogenic emissions on climate and environment from the following aspects: (1) new approaches for anthropogenic emissions accounting were developed and the Multi-resolution Emission Inventory for China (MEIC) was constructed. The emission database has been widely used by the community. With the emission data, key driving forces of anthropogenic emissions in China has been identified. (2) New methods for evaluating the relationship between economic activities and air pollution were developed, and the health impact embodied in global trade was quantified. (3) Several important mechanisms on the impact of climate change on precipitation were explained. (4) Mitigation pathways of greenhouse gases and air pollutants by using a combination framework of big data and numerical simulation were explored.

In response to the urgent requirements on low-carbon development and air quality improvement, the research group will study the co-governance of air pollution and climate change based on the previous work described above. The group will first develop a high-resolution global emission database for greenhouse gases and air pollutants. With the newly developed database, the group will investigate how anthropogenic activities impact the emissions, and seek the ways for mitigation pathways with ultimate benefits.

With the focus on the anthropogenic impacts on climate and environment, the group will face to the urgent needs from the country and develop a world-class research platform which extends from natural sciences to interdisciplinary research on both natural and social sciences. Based on the database developed in-house, the group will aim to discover new scientific knowledge with innovative methods, and shape global impact on the field of co-governance of air pollution and climate change.

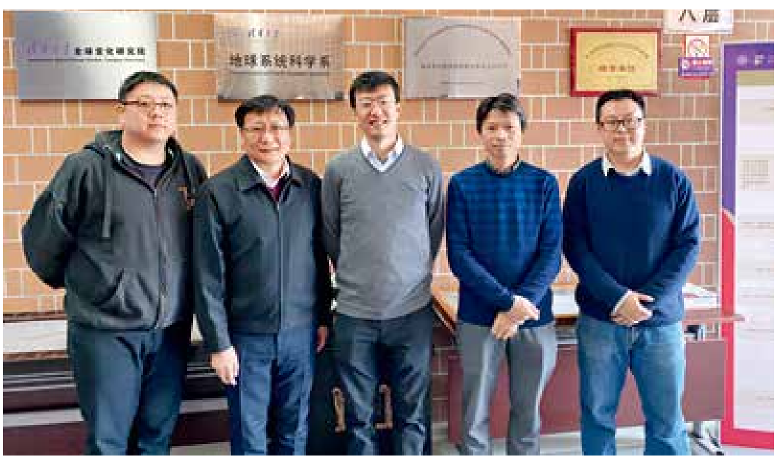


Figure 2-2-37 Group members

Deep-Sea and Subsurface Biosphere

The research on deep-sea and subsurface organisms attracts tremendous attention recently from both biologists and geologists around the world, and is soon becoming the research hotspot and focus. The basic scientific questions include the carbon cycling processes mediated by the "deep" organisms, their origin and evolution as well as the great potential to promote new technological innovation and unexpected recourses from deep-sea and subsurface biosphere. After 18 years of unremitting efforts, Prof. Xiao Xiang has gradually established an extraordinary research team in Shanghai Jiao Tong University, focusing on the core scientific issues of "microbial diversity and elemental cycling in deep-sea and subsurface biosphere under high pressure environments". The team was awarded as Creative Research Group by NSFC in 2019. The key members of the group include Prof. Xiao Xiang, Prof. Wang Fengping, Prof. Zhang Yu, Prof. Xu Heng and Prof. Zhang Ruifeng.

The research group focuses on the deep-sea and subsurface biosphere in high pressure environments and builds the domestic deep-sea high pressure simulation cultivation and analysis platform for microorganisms, including the design and construction of the only one long-term gas-liquid mixed high pressure continuous flow culture system, single cell ultra-high-resolution imaging platform and trace element analysis platform. The group members also established the International Center for Deep Life Investigation (ICDLI), which provided a communication stage and research gate for international scientists working in this field.

On the basis of the above scientific platform, a series of obligatepiezophilic, piezophilic and piezo-tolerant bacteria and archaea were isolated and cultured. Multiple genetic manipulating systems for microorganisms under high pressure were constructed. The team also named two new deep-branchingphyla in the domain Archaea, which were widely cited by international peers. The team leader Prof. Xiao Xiang also proposed a hypothesis that antioxidation is the basis of adaptation in high pressure and other harsh environments. This hypothesis has been confirmed not only in microorganisms but also in other deep-sea organisms such as deep sea snailfish and gammarid, and all these works have been published on high-impact journals like *Nature Microbiology*, *Proceedings of the National Academy of Sciences of the United States of America* and ISME.

The research group is now dedicated to exploring the life boundary under ultra-high pressure conditions, and trying to reveal how microorganisms participate in the elemental cycling processes in deep-sea and subsurface environments. These researches are on the way to answer the important scientific questions such as the origin of early life, ancient productivity and biological role of extreme climate change.

Figure 2-2-38 Group members

High Voltage and Insulation Technology

The research group, led by Prof. He Jinliang from the State Key Laboratory of Power Systems, Department of Electrical Engineering, Tsinghua University, was awarded as Creative Research Group by NSFC in 2019. The key members of the research group include Prof. Zeng Rong, Prof. Liang Xidong, Prof. Dang Zhimin, Prof. Zhang Bo and Associate Prof. Li Qi.

The separation of energy bases and large load centers requires long-distance, large-capacity power transmission to achieve optimal allocation of energy resources across the country. Facing the needs of national key projects and international frontiers, the research group was engaged in key basic research on power transmission technology at the interdisciplinary level in the direction of high voltage and insulation technology. Systematic innovations have been made by the research group in the aspects of outdoor insulation discharge and lightning flashover characteristics of power systems, electromagnetic transients and their protection technologies, outdoor insulation technologies, electromagnetic environmental technologies and DC cable power transmission technologies. The research group has solved a number of major key fundamental problems in the long-distance UHV transmission lines with complex geographical and climatic environments, and made important contributions to achieving “environment-friendly, resource-saving, safe and reliable” power transmission.

The safe and reliable electric power transmission is crucial for high-performance electric equipment. One of the key aspects to the development of future power grid and the energy internet is to drive the development through the equipment innovation. The reative research group will carry out the basic research on key materials in the field of power and energy systems for the future and focus on the core scientific issues, such as principles of self-healing and self-diagnosis associated with the physical process of material aging, the multi-performance regulation mechanism of composite dielectric materials based on the understanding of nanoscale interfaces, and the micro-sensing theory based on multi-field response characteristics of materials, and eventually make breakthrough in intelligent insulation materials for power equipment, super-hydrophobic external insulation materials, high-temperature large-capacity capacitor materials, and built-in sensors in power equipment. Based on the breakthroughs in basic materials, the group will drive the leapfrog development of power energy system equipment and create an innovative path that subverts the traditional high-voltage equipment manufacturing technology.

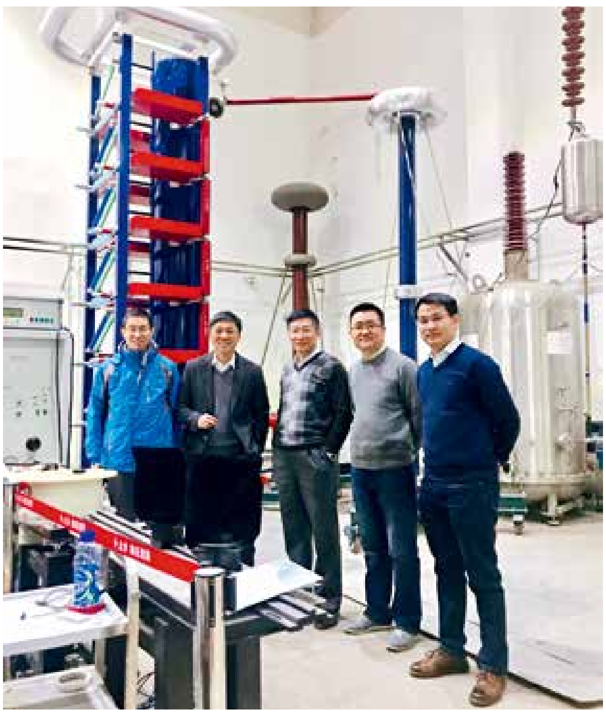


Figure 2-2-39 Group members

Manufacture and Monitoring of Aircraft Monolithic Structures

The research group led by Prof. Yuan Shenfang from Nanjing University of Aeronautics and Astronautics has been awarded as the Creative Research Group by NSFC in 2019. Based on the Mechanical Manufacture and Automation State Key Discipline and the State Key Laboratory of Mechanics and Control of Mechanical Structures, the key members in the group include Prof. Zhu Di (academician of CAS), Prof. Xu Jiuhua, Prof. Qiu Jinhao, Prof. Li Yingguang, and Prof. Wang Lifeng.

Focusing on the development of high performance, high reliability and economic efficiency aircraft monolithic structures, the main researches were on the mechanisms and methods for high-precision manufacturing of monolithic structures under multi-constraints in the field of aerospace. Meanwhile, a new field in smart health monitoring for monolithic structures to guide the design, manufacture and maintenance was established. The innovation achievements have been made in three aspects, including special energy field manufacture for monolithic structures with complex surfaces under multi-constraint, efficient manufacture methods for large thin wall monolithic structures under multi-constraint and light weight smart monitoring for complex monolithic structures with large size. In recent years, the group has gained 6 national grade awards, 3 national teaching achievement awards, 7 provincial and ministerial first grade prizes. Within the recent five years, 590 SCI papers and 4 monographs/translations have been published, and 220 licensed national invention patents are issued. Important achievements have been applied to more than 20 aerospace aircrafts, aircraft engines and missiles, such as Y-20, J-20 and C919.

The key and cutting-edge indicators of the challenging next generation aircrafts make it more important for the aircraft structures to be monolithic. More hard-to-process materials, more complex structural characteristics, higher manufacture precision and higher requirement of reliability bring enormous challenges to the manufacture and maintenance of the monolithic structures. Aims at breaking through the sharp contradictions among the structural efficiency, manufacturing difficulty, high reliability assurance, the group will continue the innovative researches on the manufacture and monitoring methods, improving the smart level of the manufacture and monitoring, including multi-energy field smart manufacture, individualized adaptive machining and multi-parameter smart monitoring.

Figure 2-2-40 Group members

Machine Learning for Open Dynamic Environments

The research group in National Key Laboratory for Novel Software Technology at Nanjing University, led by Prof. Zhou Zhihua, was awarded as Creative Research Group by NSFC in 2019. It is an earlier national research team with an international impact in the field of machine learning and is mainly focused on a series of international cutting-edge research. The group members all focus on machine learning research, where the topics cover a wide range of theories, methods, technologies and applications. This research group is one of the most comprehensive and well-known teams in the Asia-Pacific region. The key members of the group include Prof. Jiang Yuan, Prof. Wu Jianxin, Prof. Li Ming, Prof. Yu Yang, and Prof. Wang Limin.

The research group has carried out long-term and in-depth researches in the field of machine learning, which is at the core of artificial intelligence. Some of the research results have been highly appraised and widely cited by international leading experts, with the topics including ensemble learning, weakly supervised learning, multi-label learning, evolutionary learning, etc. In recent years, the research group has devoted itself to break through the unreal hypothetical constraints in classical machine learning research, and has achieved a number of international-leading original research results in the topics including machine learning with limited label data, learning framework for ambiguous objects, multi-view and multi-modal learning, resource-constrained deep learning, multi-objective learning and zeroth-order optimization, etc. In the past five years, there were more than 1,120 citations from papers in CCF-A class journals and conferences, and more than 960 ACM/IEEE Trans. citations. The referrers include more than 40 winners of Turing Awards, Gödel Awards, and other important international academic awards, and more than 60 academicians from the developed countries. A number of algorithms invented by the research group have become baselines in the field, and are included in a variety of internationally renowned machine learning tools/software libraries. Several technologies developed by the research group have been successfully applied in large-scale businesses such as e-commerce, electric power systems, manufacturing, and Baidu/Alibaba/Tencent companies. The research group also served important and great demands of the nation.

Figure 2-2-41 Group members

Energy Efficient Semiconductor Materials and Information Devices

The research group is led by the Prof. Xu Jun from Microelectronics and Solid-state Electronics of Nanjing University and has been awarded the Creative Research Group by NSFC in 2019. This innovation-collaborative and cross-disciplinary team includes Prof. Shi Yi, Yan Feng, Lu Hai, Wan Qing and Miao Feng. Most of them were funded by NSFC for Distinguished Young Scholars.

Energy consumption of the semiconductor devices has become a burning issue. Centering on the core scientific issues and key technologies of energy efficient electronics, this group has studied semiconductor microelectronics and optoelectronic devices as well as systems to meet the significant demands. They have broken through the technology barrier to fabricate the wide band-gap materials and heterostructures, developed high-efficiency light emitting diodes (LEDs) and solar-blind single photon ultraviolet detector, owned the key technologies for industrialization and realized their applications in national defense. Moreover, they also developed a few types of high-performance semiconductor micro-nano devices, pixel sensors for vertical charge transfer, as well as ultra-high-resolution nanometer imaging chips. In the past 5 years, 18 papers have been published in family journals of Nature and Science. 17 papers have been selected as ESI highly cited papers. In addition, 36 national invention patents and 12 international patents have been authorized. Furthermore, the group has won the second prize of National Nature Science Award as well as the second prize of National Science and Technology Award.

The group plans to develop new fabrication processes for emerging materials and devices, create new proof-of-concept devices to finally realize microelectronics and optoelectronic devices with low-power-consumption and high-efficiency. The focus is on the highly energy-efficient LEDs, UV detector and power electronic devices. With the advanced nanotechnology, the group will explore new physical mechanisms and proof-of-concept devices, as well as nanoelectronics and integrated systems with ultra-low power consumption and high performance. These will lay a scientific foundation for the development of new energy-efficient electronic and optoelectronic devices.

Figure 2-2-42 Group members

Platform-Based Supply Chain Operations Management

The research group led by Prof. Yu Yugang from the School of Management of the University of Science and Technology of China (USTC) was awarded as Creative Research Group by NSFC in 2019. The key members of the group include Prof. Lu Ye, Prof. Liu Hefu, Prof. Wei Jiuchang, Prof. Wu Jie, and Prof. Yang Feng. This research group is mainly focusing on the major strategic needs of China for accelerating the innovation of supply chains and subsequent applications.

With the support of USTC, the group has achieved numerous high-quality research achievements on supply chain design, implementation, maintenance, and improvement. The principal investigator and the key members have conducted more than ten national general and key projects and won multiple major ministerial, provincial, or associational academic awards. The awards include the first prize of Natural Science Award of Outstanding Achievement Award for Scientific Research in Universities of the Ministry of Education and the first prize of Science and TechnologyAward of Anhui Province. Five national invention patents and software copyrights have been authorized. More than 500 papers have been published in SCI/SSCI journals, including 23 papers in UTD24 listed journals. Some of these papers were listed as Top 1% Highly Cited Papers in ESI. Furthermore, their research results have been widely approved and implemented in a number of leading companies and institutions.

The group is aiming at achieving theoretical innovations and upgrades of management techniques at the industrial level by leveraging technology-driven and data-driven approaches, from the following four main aspects of the platform-based supply chain management: (1) system design and coordination mechanism; (2) information system and behavior mechanism; (3) risk analysis and governance; and (4) data mining and decision optimization. The specific scientific objectives of the group include: (1) designing competition and coordination mechanisms for platform-based supply chains, and constructing supply chain ecosystems; (2) revealing the mechanisms of information system configuration, information behavior, and digital service innovation of the platform-based supply chain; (3) exploring the risk diffusion network of the platform-based supply chain, and putting forward risk communication and control strategies; and (4) developing innovative data-mining and data-processing techniques in order to achieve platform-based supply chain performance diagnosis and continuous improvement. As the starting point for the group is to serve the practice in China, the group members aim to obtain world cutting-edge research achievements so as to upgrade the global competitive edges for Chinese enterprises.

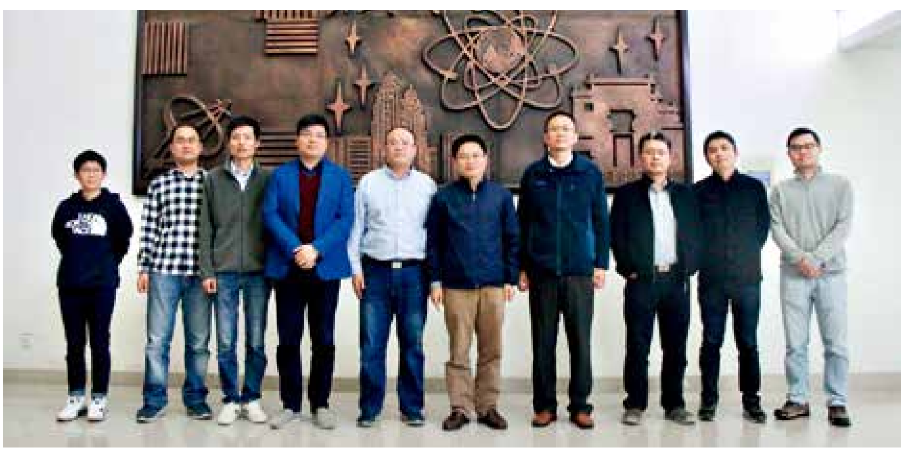


Figure 2-2-43 Group members

Information Resource Management

The research group, led by Prof. Li Gang from the Center for Studies of Information Resources of Wuhan University, was awarded as Creative Research Group by NSFC in 2019. The group consultant is Prof. Ma Feicheng, and the key members include Prof. Chen Chuanfu, Lu Wei, Wang Xiaoguang, Sun Yongqiang and An Lu.

Based on the Center for Studies of Information Resources of Wuhan University, the Key Research Base of Humanities and Social Sciences of the Ministry of Education, the School of Information Management of Wuhan University, and the national "double first-class" discipline of "Library, Information and Data Science", the research group has made a number of important international achievements in the fields of information resource organization and retrieval, information analysis and mining, information resource sharing and service. The research group has won First Prize of Science and Technology Progress Award of Ministry of Education twice, First Prize of Social Science Outstanding Achievement Award of Ministry of Education twice, and First Prize of National Teaching Achievement Award. In recent years, the group members have published 90 related books, 204 papers indexed by the Science Citation Index or Social Science Citation Index, and cooperated with enterprises to complete multiple industrialization projects.

The research group intends to meet the strategic information needs for the nation and society, economic innovation development and security management, aim at the theoretical and practical frontier proposition of modern transformation and innovation development of information services, based on the information resource management practice in several industry fields, and carry out innovative research in the fields of information association and integration in the big data environment, computation-driven information analysis and knowledge discovery, innovative application and development of information services, and digital space and data resource construction to provide information support for national innovation development and security strategic decision-making in the new era.

The scientific objectives of the research group are: (1) building the information fusion framework and model in the big data environment to achieve multi-modal information feature fusion, decision-making level fusion and knowledge discovery, (2) revealing the pattern of information adoption, disclosure and search based on open innovation platform, and (3) establishing a big data resource governance and collaborative management mechanism for public needs. The expected achievements are original achievements in the fields of information organization and retrieval, information analysis and knowledge discovery, information service innovation and so forth to provide the theories and technologies of information resource management for the strategic researches and application development of national big data, and to provide decision-making basis and reference for social governance, public security and industrial development.

Figure 2-2-44 Group members

Viruses, Viral Infection and Immunity

The research group, awarded by NSFC in 2019, is led by Prof. Gao Guangxia, a virologist focusing on the molecular mechanisms underlying virus-host interactions of HIV-1 and some RNA viruses. The five key members in the group are from the CAS Key Laboratorg of Infection and Immunity affiliated with the Institute of Biophysics of CAS. Besides Prof. Gao Guangxia, Prof. Deng Hongyu is also a virologist, focusing on the mechanisms for the replication and virus-host interactions of herpesviruses. Prof. Zhang Liguo's research focuses on the immune responses in viral infections. Prof. Gao Pu is a structure biologist interested in the molecules involved in virus-host interactions. Prof. Xiangxi Wang is also a structure biologist, with his interest more in how viral proteins interact to carry out viral replication.

The members of this group have made multiple achievements in the field of virus replication and virus-host interactions. In the studies of virus replication, which emphasize more on the structures and functions of viral proteins, the group has systematically elucidated the mechanisms underlying the dynamic processes of genome replication and assembly, the regulation of gene expression, and the viral particle assembly and release of herpesviruses. In the studies of virus-host interactions, the group has elucidated multiple mechanisms for host recognition of viruses, identified a number of host antiviral factors and analyzed their acting mechanisms in depth, and demonstrated that type I interferons have dual functions in HIV-1 infection of immune system humanized mice. These results have been published in high-profile journals including *Cell, Science, Nature, Cell Host & Microbe, Nature Microbiology and Nature Structural* and *Molecular Biology*.

The aim of this group in the next 5 years is to further understand how viruses establish effective infections. The group will focus on the mechanisms underlying the replication and virus-host interactions of herpesviruses and retroviruses, and pay special attention to the common features among as well as differences between these two different types of viruses, using comprehensive analysis methods of virology, immunology and structure biology. It is expected these studies will lead to better understanding of the pathogenesis of these viruses and eventually better therapeutics for the diseases caused by these viruses.

Figure 2-2-45 Group members

Mechanism and Intervention of Aging

The research group led by Prof. Liu Guanghui at the Institute of Zoology of CAS has recently been awarded by NSFC. This highly interdisciplinary team is composed of five laboratories with their own expertise from the Institute of Zoology of CAS. The other key members in the group are Prof. Tang Tieshan, Prof. Wang Qiang, Prof. Qu Jing and Prof. Song Moshi.

This group not only plans to better understand the mechanism and intervention of aging and regeneration, but also aims at the development of a number of innovations in aging biology and regenerative medicine in China by exploring new regulatory mechanisms of aging and regeneration, developing original core technologies to delay aging, and providing new intervention strategies for aging-related diseases. Based on multi-omics and a variety of biological research approaches with various animal and cell models, this Creative Research Group has already systematically carried out these studies. New mechanisms of aging, stem cell exhaustion, regeneration disorder and organ degeneration have been elucidated. A series of small-molecule drugs that interfere with aging have been discovered, and new therapeutic targets for stem cell- and gene-based therapies against aging-related diseases have been identified. A number of investigations with international impact have been conducted in the fields of aging mechanism, stem cell, gene editing and aging-related diseases. Plenty of papers were published in high-profile scientific journals such as *Nature, Science, and Cell along* with a series of authorized invention patents.

This group intends to further conduct in-depth studies in the aging of critical tissues and organs, aging biomarkers, tissue-specific evaluation index for aging, new interventions promoting regeneration and delaying aging, reparative and regenerative strategies for aged tissues and organs, as well as treatment for aging-related diseases. Within a highly collaborative environment, this Creative Research Group is expected to make theoretical breakthroughs, technological innovations and translational application of intervention strategies in the fields of aging biology and regenerative medicine.

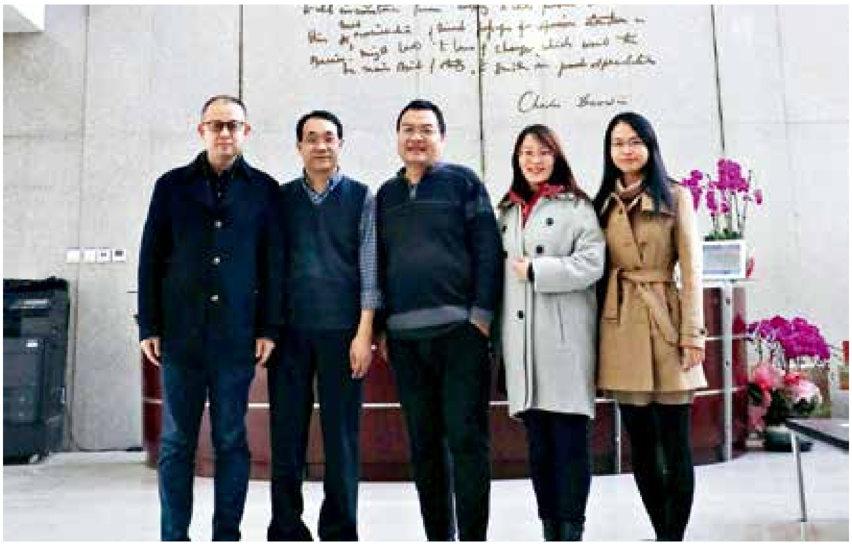


Figure 2-2-46 Group members

2.2.4 Special Fund for Research on National Major Research Instruments (by Recommendation)

Cooling-Storage-Ring External-Target Experiment

The project of "Cooling-storage-sing external-target experiment" (CEE) is led by Prof. Xu Nu from the Institute of Modern Physics (IMP) of CAS. The direct funding of the project is 74.5241 million yuan, which is shared by IMP, University of Science and Technology of China, Tsinghua University, Fudan University and Central China Normal University.

Quantum Chromodynamics (QCD) is a modern fundamental theory describing the strong interactions in the nature. Despite of the great success of this theory, we are yet confronting many questions in QCD. For instance, the quark-gluon-plasma (QPG) has been shown as a novel form of matter at extremely high temperature and/or extremely high density; however, it is unknown when and under what conditions the phase transition occurs between QGP and hadronic matter. In another word, we have not gained entire knowledge on the phase structure of QCD matter. Figure 2-2-47 presents schematic QCD phase diagram with rich phase structure. One of the most important goals of the high-energy nuclear collisions is to reveal the QCD phase structure.

In China, the HIRFL-CSR of Lanzhou has been constructed as a major scientific facility for nuclear physics. A new one, the High Intensity heavy-ion Accelerator Facility (HIAF) is also under construction. Both facilities will provide almost a unique opportunity to the study of the QCD phase diagram in the region of low temperature (relatively) and high baryon density, if equipped with an advanced detector. The proposed spectrometer, as a Cooling-storage-ring External-target Experiment (CEE), will be the first large-scale nuclear experiment running in GeV/u region in China. CEE aims to measure the charged particles in nearly full spatial coverage in the center of mass system, which hence provides an experimental tool to study the dense stellar objects, the nuclear reaction dynamics, spin- and isospin-dependent nuclear force and nuclear equation of state, as well as the QCD phase structure at low temperature and high baryon density.

Figure 2-2-48 presents the conceptual design of CEE. It contains a large-acceptance superconducting magnet dipole, the tracking detectors, the zero-degree calorimeter (ZDC), a beam monitor and the electronics and data acquisition system (DAQ). Inside the large dipole, a time projection chamber (TPC) is installed with multi-gap resistive plate counters (MRPC) covering on both sides as inner time of flight (iTOF) wall to provide PID and momentum measurement of the charged particles in midrapidity. On the

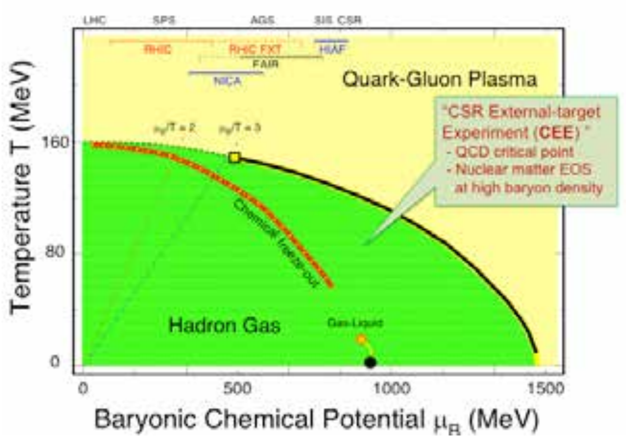
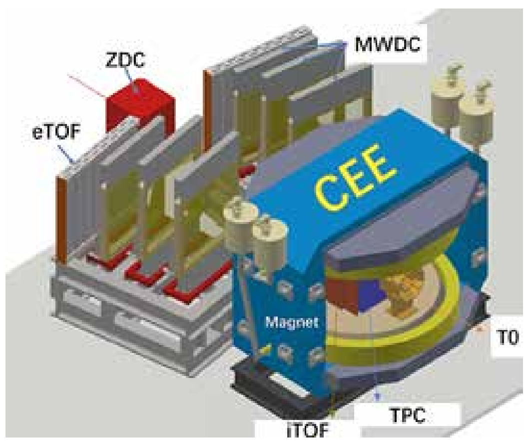


Figure 2-2-47 Schematic QCD phase diagram in the thermodynamic parameter space spanned by the temperature T and baryonic-chemical potential μ_B



Figrue 2-2-48 Conceptual design of CEE (Beam monitor is not seen)

downstream side of the dipole, two arms of multi-wire drift chamber (MWDC) arrays followed respectively by an end Time-of-Flight (eTOF) wall are installed to do particle identifications at the forward rapidity. Downstream to the beam line, the ZDC records the total kinetic energy of the projectile-like fragments to provide the information of collision centrality. The spectrometer adopts high-integration, high-speed and high precision read-out electronics and DAQ to reach cutting-the-edge performance at some specifications.

With the opportunities brought by CEE, important and original works can be expected from the research on the QCD diagram at low-temperature and high baryon density region, including the phase-boundary, the existence of the QCD critical point and the equation of state for the nuclear matter.

An Ultrahigh Spatio-Temporal Resolution System for Ion Chemistry

The project of "An uitrahigh spatio-temporal resolution system for ion chemistry" is led by Prof. Wu Kai of Peking University with a direct funding of 73.5268 million yuan. It gathers a team of outstanding scientists in physical chemistry, inorganic chemistry, condensed matter physics and theory and computations with the expertise in state-of-the-art technologies in ion beam, molecular beam, low temperature, and ultrahigh spatio-temporal resolution imaging and spectroscopy as well. The aim of the whole project is to design and build an ion chemistry system that enables experimental measurements and explorations of ion solvation as well as microstructures, migration dynamics and electronic properties of solvated ions at the atomic and molecular levels.

Ion chemistry has been widely applied in chemistry, physics, materials science and energy, including areas of major national strategic needs such as spent nuclear fuel treatment, separation of isotopic nuclear elements, separation and purification of rare earth elements, ion battery and its waste recycling. Solvated ions possess complicated structures and dynamics, leading to their amorphous existence in aggregates. Conventional molecular structural analysis techniques are unable to reveal the molecular structures of the solvated ions in amorphous state. Despite its high temporal resolution, ultrafast laser spectroscopy lacks of the high sensitivity required to detect single ions. Precise description, analysis and prediction of the thermodynamic and dynamic behaviors of the solvated ions must be based on the full understanding of the structures and properties of single ions in different media and at various interfaces. Therefore, the de novo investigation of ion chemistry requires state-of-the-art technologies, namely, a ubiquitous preparation technology of single ions to remove the effects of counter ions and solvents; a soft-landing technology that can place the ions at any specific spots of the ion migration media; the precise preparation of the solvent layers suitable for of the ion motion at the atomic and macular scales; and ultra-high spatio-temporal resolution direct observation of the ion solvation, charge transfer and energy transport.

To break the bottlenecks of ion chemistry study, it is necessary to design and construct an ultra-high spatio-temporal resolution ion chemistry system. Successful implementation of the project will open up a new direction and greatly advance research on ion chemistry in China, which is of tremendous significance for the fundamental research of chemistry and development of related key technologies in China.

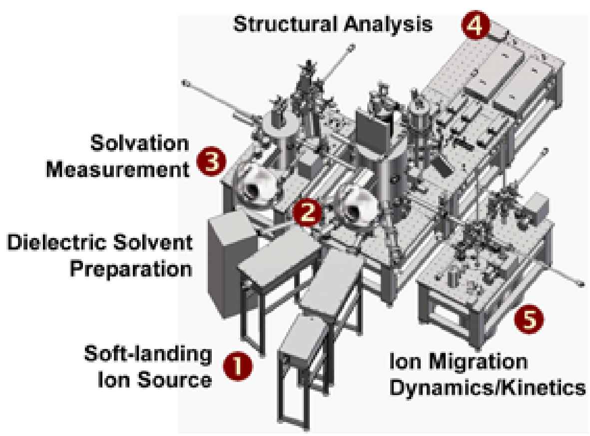


Figure 2-2-49　Functional modules

In-Situ Characterization System for Oxide Defect Evolution in Semiconductor Devices

The project of "In-situ characterization system for oxide defect evolution in semiconductor devices" is led by Prof. Huang Ru of Peking University with a direct funding of 51.8499 million yuan, in collaboration with Institute of Semiconductors of CAS.

Electronic defects in gate oxide strongly affect the performance and reliability of modern semiconductor devices, and thus is the technology bottleneck in advanced IC manufacturing. Different from stacking faults and dislocations which are major issues of the material science, electronic defects inside semiconductor devices cannot be observed directly, and can be detected only via electrical tests. As technology scaling down, this defect problem, especially the impact from single oxide trap, is increasing rapidly. Therefore a scientific instrument that can precisely detect and analyze defects is urgently needed. However, existing commercial instruments for characterizing oxide defects can only obtain the average or the macroscopic electrical properties of defects, but are not capable of obtaining the single defect position or analyzing the defect types. Based on a new principle proposed by the project team, the project aims to characterize the oxide defects by the random telegraph noise (RTN) in semiconductor devices. It is expected that the new characterization system for oxide defect has the capability of analyzing the oxide position, type, and evolution, and can provide non-destructive electrical measurement, on-line monitoring and single defect analysis.

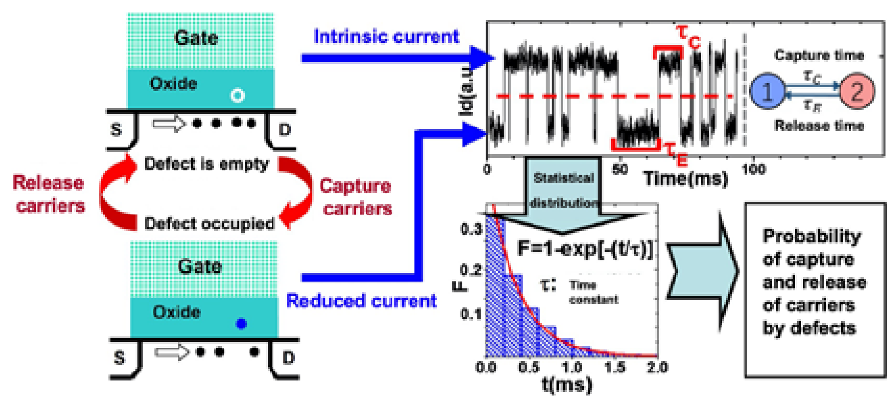


Figure 2-2-50 Principle of random telegraph noise

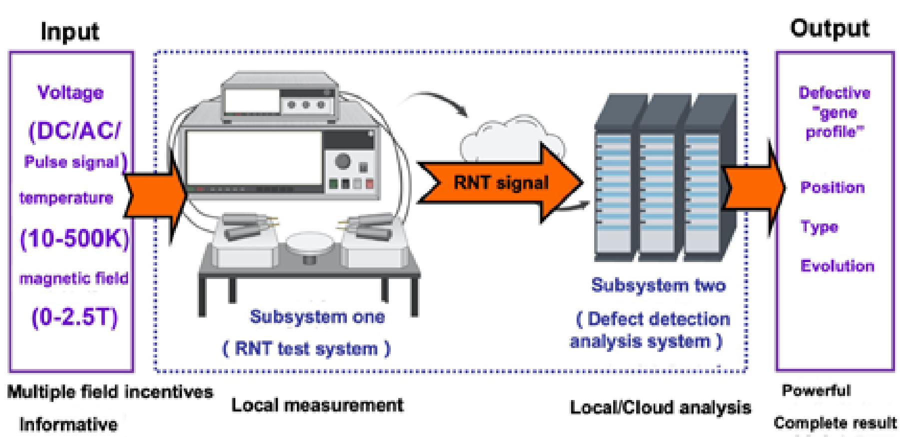


Figure 2-2-51 System composition of the proposed instrument

The system is designed to combine the RTN measurements and the full-quantum defect/device simulation: first to infer the interaction between defect and carrier from the RTN measurement data; then by full quantum model analysis to extract the defect features; and finally to obtain the "Genebook" of oxide defects (including the information of position, type and evolution). This system consists of two co-working sub-systems, i.e. the RTN measurement system and the defect monitoring analysis system. The RTN measurement system has four units: the noise amplifier unit, the anti-alias filter, the dynamic signal sampler and the noise-testing controller. The defect monitoring analysis system has two units: the RTN signal extractor, and the defect and device analyzer.

Based on the above-mentioned new principle, this project will produce the first prototype of the oxide defect characterization system, which has the capability to analyze defects' position, type and evolution. Meanwhile, the system will be applied at several kinds of semiconductor devices to reveal the "Genebook" of oxide defects in practice, and to obtain a defect database for the development of advanced IC technology and defect-based new-principle devices. On this basis, the system will broaden the research frontier of microelectronics, and push forward the industrial development of advanced IC technology.

2.2.5 Basic Science Center Program

Studies of the Milky Way and Local Universe Based on LAMOST and FAST

The Basic Science Center Program of “Studies of the Milky Way and local universe based on LAMOST and FAST”, is led by Prof. Gang Zhao. The project with a direct funding of 80 million RMB is hosted by National Astronomical Observatory of Chinese Academy of Sciences (NAOC). The key members include Prof. Liu Jifeng, Prof. Li Di, Prof. Gao Liang, and Prof. Han Jinlin, who are internationally famous scientists.

A comprehensive understanding of the structure and formation history of the Milky Way is crucial to interpret the formation and evolution of galaxies, which is a key to reveal the formation and evolution history of the universe and the mystery of dark matter. The composition, structure and evolution of Milky Way and local universe can be characterized from multiple dimensions through different tracers such as stars, pulsars, neutron stars, black holes, interstellar media and so on. Advances in study of the Milky Way and local universe relies on the development of large sky surveys. The national large-scale scientific facilities, LAMOST and FAST, are constructed and operated by NAOC. These two world-leading telescopes provide China a unique advantage in the study of the Milky Way and local universe. LAMOST has the highest spectral acquisition in the world. It has published ten million stellar spectra. LAMOST-II is the first time-domain spectroscopic survey in the world. FAST is the largest single-caliber radio telescope with the highest sensitivity in the world, and can observe pulsars, neutral hydrogen, and molecular lines.

Figure 2-2-52 Research background

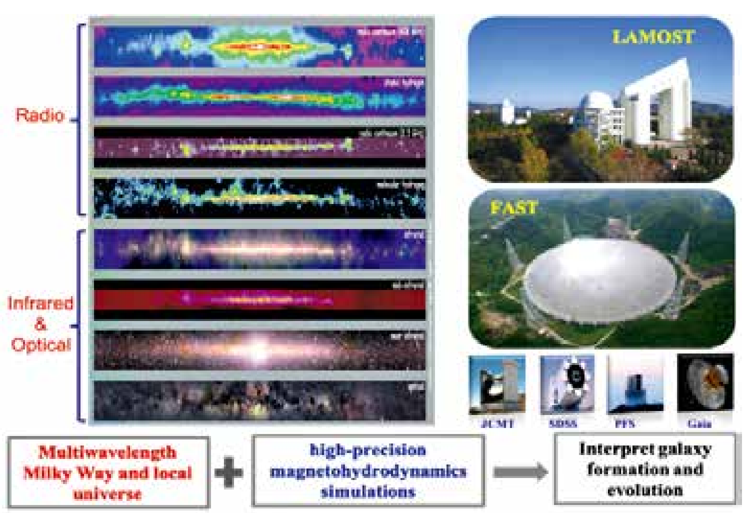


Figure2-2-53 Research fields

The project embodies the best research teams of the Milky Way and local universe in NAOC, which enables strive for major scientific progress, including accurately measuring the mass distribution of the Galaxy; discovering a new set of halo streams to provide a reasonable explanation for "missing satellites"; discovering more extremely metal-poor stars in the outer halo of the Galaxy and adjacent dwarf galaxies to test the early nuclear synthesis and enrichment model; acquiring large medium-resolution time-domain spectroscopic sample of stars in the Milky Way to characterize the physical properties and evolution of stars, and to understand the relationship between star systems, clusters, interstellar media and galaxies, to explore the material exchange process of the binary system, to reveal the black hole formation process;

completing the complete northern sky neutral hydrogen sky map, and constructing the most sensitive data set of the local cosmic baryon material to provide constraints on the "missing baryon" problem; doubling the detection range of the large-scale magnetic field of the Galaxy, and connecting the current large-scale and small-scale disconnected magnetic energy spectrum to provide accurate and even the only observation basis for the origin and evolution of the Galactic magnetic field; developing an internationally unique cosmological magnetohydrodynamics simulation software; and promoting the understanding of the formation and evolution of the Milky Way and local universe.

Through the implementation of this project, it is expected that the academic leaders will be cultivated, a world-leading research team will be built, and the academic highland and international research center of the Milky Way and local universe will be formed.

Multi-Scale Problem Research of Nonlinear Mechanics

The Basic Science Center Program of "Multi-scale problem research of nonlinear mechanics", with a direct funding of 80 million yuan from NSFC, is led by the Academician He Guowei at the Institute of Mechanics of CAS. Peking University and Tsinghua University are the collaborative institutes of the center. The key members in the center include Academician Chen Shiyi, Prof. Sun Chao, Prof. Tang Shaoqiang, Prof. Wei Yujie, and other young and middle-aged, international well-known scientists in the field of nonlinear mechanics.

The two key scientific problems in nonlinear mechanics are complex turbulence and material damage, which are typical multi-scale coupling problems. In the meantime, the most challenging problems in developing high-speed carrying equipment, i.e. turbulence noise and material strength, are also typical multi-scale strong coupling problems. The key scientific problems addressed in this project include:

(1) Establishing the dynamic coupling space-time theory and method for turbulence noise, applying them to simulate the turbulence noise of full-scale high-speed carrying equipment and providing new principles and design tools for the control of turbulence noise.

(2) Developing the theory and model for the interaction between dispersed phases (such as particles, bubbles and droplets) and turbulence in two-phase turbulent flows, studying the bubbles’ drag reduction mechanism, and establishing the control method of using dispersed phases to control the transport in two-phase flows at very high Reynolds number.

(3) Establishing the correlation theory and the constitutive model between macroscopic behavior and microscopic structure in solid plastic flows, developing the formation of mesoscale structure and nonlinear evolutionary dynamics, and proposing algorithms that can efficiently and accurately depict the coupling of material’s local microscopic structure (such as cracks) and its macroscopic/integral behavior.

Through the close collaboration and leveraging the advantage of the cross-discipline nature of the center, the project team will strive to make significant progress on the two key scientific problems of complex turbulence and solid damage, including: (1) developing the space-time correlation model for turbulence from the propagation and distortion process of turbulence eddies, and proposing the identification method and control principle for the source of turbulence noise; (2) studying the interaction between turbulence and particles and bubbles, carrying out fully resolved direct numerical simulation and experimental research, developing the coupling method for the dispersed and continuous phases, and proposing new mechanisms for reducing turbulent drag using bubbles; (3) developing multi-scale models and methods for solid damage, revealing the formation and evolution law for mesoscopic structures, and thus being able to predict the internal correlation between multi-level structure and macroscopic mechanical performance.

Through the development of the Basic Science Center, the group will develop a new knowledge system of multi-scale mechanics, unite and train a high-level research team in the field of multi-scale mechanics, build an international well-known research center in nonlinear mechanics, develop a new generation of numerical simulation software and propose new principles and technologies facing the problems of drag and noise reduction and solid damage of high-speed carrying equipment.

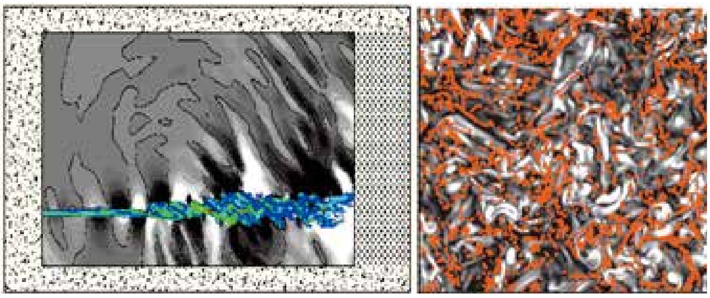


Figure 2-2-54 Research background: Flow-induced noise and particle aggregation in turbulence

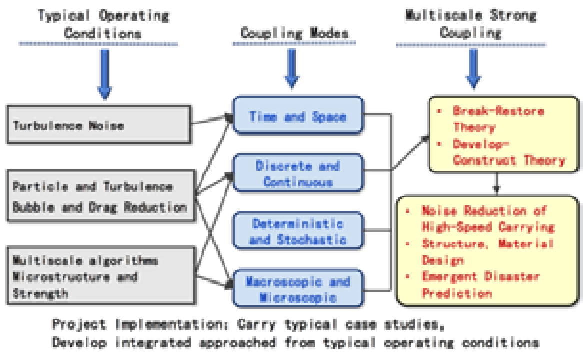


Figure 2-2-55 Implementation approach

Bioinspired Superwettable Interfacial Materials and Interfacial Chemistry

The Basic Science Center Program of "Bioinspired superwettable interfacial materials and interfacial chemistry" (BSIMIC) is led by CAS academician Jiang Lei, funded by NSFC with a direct funding of 80 million yuan and supported by Technical Institute of Physics and Chemistry of CAS, Institute of Chemistry of CAS, and Soochow University. The key members include Prof. Wen Liping, Prof. Wang Yilin, Prof. Jin Jian, and Prof. Feng Xinjian, who are all young or middle-aged scientists with great international influence and keep active in the frontier of bioinspired superwettability research field.

Scientists from our country lead and guide the development of the bioinspired superwettability research. They have got a series of original achievements both in basic and applicated research fields. Since Prof. Jiang Lei's team found that micro/nano structure could finely tune the superwettable behavior at the interface in 2001, the research of superwettable materials and chemistry enters a new era. In the past twenty years, under the guidance of Binary Cooperative Complementary Theory, Jiang's team has founded the superwettability material system driven by multiple innovation integration, built the interfacial material system containing 64 different wetting states of solid/water/oil/gas, and kept focusing on the innovation of basic science to meet the demands from our country. In February 2016, *Journal of the American Chemical Society* published a highlight with the title of "Wettability: A Centuries-Old Science Inspires Modern-Day Materials" and highly evaluated the works by Jiang's team. However, in this blooming field of wetting, there still exists not only the challenge from basic theory, but also the bottleneck of the application techniques.

The basic science center of BSIMIC will focus on the key scientific problem and launch the project under the guide of bionic concept. The research topics include designing the bioinspired superwettable interfacial materials, exploring the superwettability law of liquid drop on interface, revealing the rule of how multiscale structure and chemical composite affect the materials' wettability both in static and dynamic conditions, building the general theoretical model for wetting interface, establishing the design philosophy for bioinspired superwettable interface, developing interface modification technique with high efficiency and precision, and finally realizing sorts of applications, such as, fabrication of organic photoelectric materials, bioinspired energy conversion, new pesticide preparation, emulsion separation, biological chips with high performance. The establishment of BSIMIC center will surely strengthen our country's leading position in the superwettable material field and could bring key techniques for different industries.

The project would motivate the members to show their special features and build an innovation research team by close cooperation and new operating mechanism. Within the frame of the project, the team could continually do the top-level research, output the milestone results, and promote the development of international bioinspired superwettable interfacial materials and interfacial chemistry.

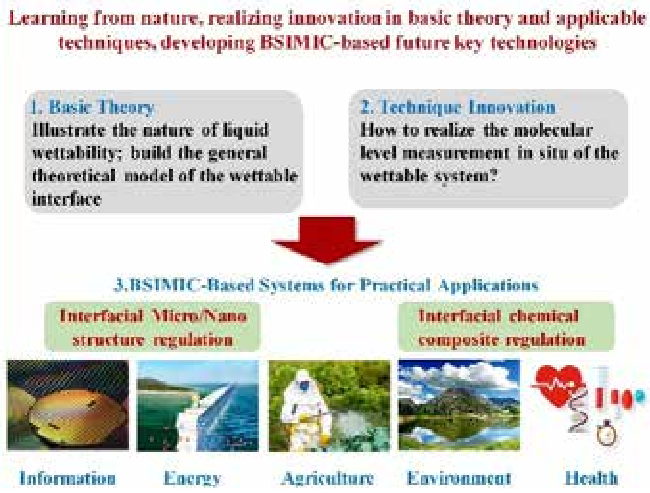


Figure 2-2-56 Research overview

Transformation Chemistry of Key Components of Air

The Basic Science Center Program of "Transformation chemistry of dey components of air", with a direct funding of 80 million yuan, synergizing the research expertise of distinguished scientists and their research teams from Peking University (Prof. Xi Zhenfeng, Director), Fudan University (Prof. Ma Shengming and Prof. Shi Zhangjie) and Dalian Institute of Chemical Physics, CAS (Prof. Chen Ping and Prof. Deng Dehui), targets at the forefront scientific challenges of transformation chemistry of N_2 and O_2, aiming at two goals: (1) the discovery and establishment of key knowledge that are of milestones to the synthetic chemistry in the conversion of N_2 and O_2 directly, selectively and efficiently towards chemicals that are vital to life and society; and (2) the development of proprietary new strategies, methods and technologies that will revolutionize the related chemical industry (see Figure 2-2-57).

Nitrogen (N2, 78.1 vol. %) and oxygen (O_2, 20.9 vol. %) are the key components of air and of vital importance to all life. They are inexhaustible nitrogen and oxygen sources for constructing the world, i.e., most of known compounds with a variety of functions contain nitrogen and oxygen elements. The transformation and functionalization of N_2 and O_2 via elegant natural nitrogen/oxygen cycles are, however, no longer able to sustain the rapid growth of human society. Fundamental and technological breakthroughs are imperative and have been extensively and intensively pursued over a century by determined scientists and researchers.

Specifically, the topics of importance and interests in this project are as follows: (1) Revolutionary strategies and paths for the catalytic transformation and functionalization of dinitrogen directly and efficiently to important nitrogenous organic compounds so as to bypass the traditional NH3-mediated synthetic routes. (2) Selective, effective and green oxygenation and oxidation using dioxygen or air as oxidant, achieving full-chain conversion from alkanes to alcohols, aldehydes, acids and esters, innovating the oxidation technologies in chemical industry. (3) Coupling

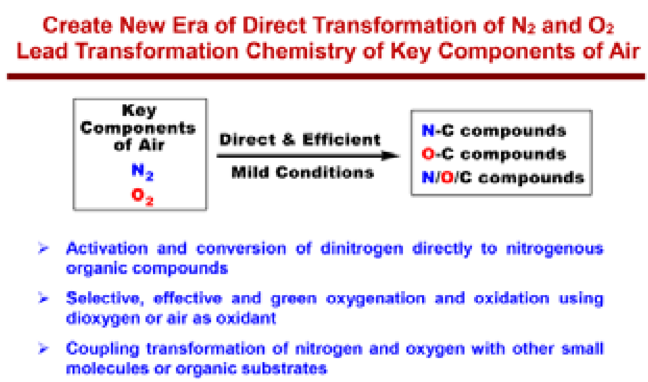


Figure 2-2-57 Reserach overview

transformation of nitrogen and oxygen with other organic substrates to valuable products via photo-, electro- and/or thermal-driven catalytic processes.

Through teamwork and outreach, the project will strive for breakthroughs and make a significant impact on the transformation chemistry of dinitrogen and dioxygen.

Responses of Ecosystems to Global Change

The Basic Research Center Program of "Responses of ecosystems to global change" is led by Prof. Fang Jingyun from Peking University, with a funding of 80 million yuan. The supporting institution is Peking University, with two collaborative institutions including Institute of Geographic Sciences and Natural Resources Research and Institute of Botany of CAS. The key members in the center include Prof. Yu Guirui, Prof. Niu Shuli, Prof. Yang Yuanhe and Prof. Wang Shaopeng, who are young or middle-aged scientists with international influence in the frontier research fields of carbon cycle, global change, and food-web of ecosystems.

The response of ecosystem to global change is not only the focus and forefront of the ecological researches, but also the scientific basis for national strategic decisions on the challenge of climate change (Figure 2-2-58). An accurate prediction of ecosystem response and adaptation to climate change depends on a deep understanding of terrestrial carbon sink and source intensity as well as its spatial pattern, their regulatory mechanisms, and continuous optimization of existing earth system models. The project is based on this internationally cutting-edge area of ecosystems in response to global change, concentrating on the ecosystem carbon cycle and its response mechanisms, comprehensively studying the ecosystem structure and functions in response to climate change and human activities.

This project aims at solving the following key scientific issues: (1) how to quantify the integrated components of terrestrial carbon sink and source behaviors and their spatiotemporal patterns in China; (2) how food-web and biotic factors regulate key processes of ecosystem carbon and nitrogen cycles; and (3) how to effectively simulate and predict the responses of ecosystem structure and functions to global change (Figure 2-2-59).

This project will take full advantage of deep integration of disciplines and intend to achieve major breakthroughs in the research areas of carbon cycle and global change. The tasks planned to be accomplished in this ambitious project include: (1) improving the scaling methods from plot- to region-level, developing the methodology for assessing carbon sink and source for the integrated components of the ecosystem, and forming new advantageous directions of carbon sink and source researches; (2) developing a new food-web theory incorporating food chain, element stoichiometry and functional traits, and revealing the key processes and regulatory mechanisms of “whole chain” in the ecosystem carbon and nitrogen cycles; (3) investigating the mechanisms underlying the impacts of global change on productivity, and carbon and nitrogen cycles of typical Chinese terrestrial ecosystems, and forming new growing points and commanding heights in this research area; and (4) developing a new generation of carbon and nitrogen cycle simulations, based on the new theory and data.

Through the implementation of this project, it is expected a group of international highly-distinguished leaders in ecology and create a world-leading research team will be cultivated. It is also aimed at building a forefront and academic highland of ecological science and international research center of “ecosystem and global change”.

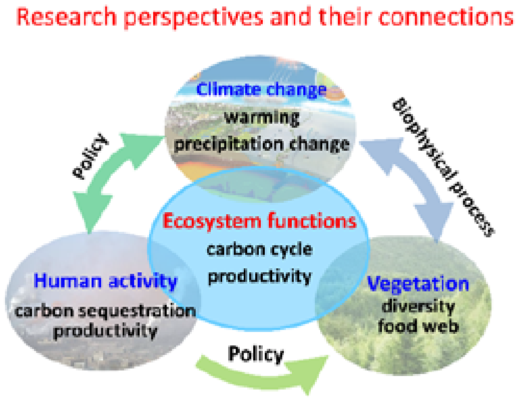


Figure 2-2-58 Research background

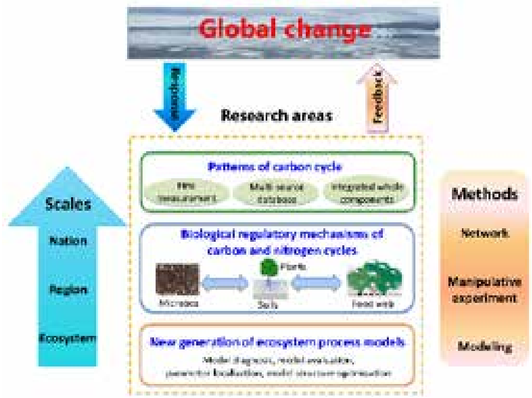


Figure 2-2-59 Research content

Regulation of Oogenesis and Embryonic Development

The Basic Research Center Program of "Regulation of oogenesis and embryonic development" is led by Prof. Meng Anming from Tsinghua University. The other participating institutions include Institute of Zoology of CAS, and Shandong University. The key members in the project include Prof. Chen Yeguang, Prof. Chen Zijiang, Prof. Chen Dahua, and Prof. Xie Wei. The approved project funding is 80 million yuan, and the project implementing period is from January 2020 to December 2024.

Human beings' propagation and population quality rely on reproductive health, which are largely influenced by infertility and birth defects in China. The egg is a specialized type of cell and non-substitutable for reproduction. Oogenesis and embryonic development are precisely regulated. Their dysregulation may lead to infertility, birth defects, and even adult diseases. Hence, studies on regulation of oogenesis and embryonic development are scientifically and clinically desired. This center will focus on the following important scientific questions: (1) how the oogenesis, oocyte maturation and quality are regulated; (2) how the embryonic development is genetically and epigenetically regulated; (3) how the abnormal regulation of oogenesis and embryogenesis causes infertility and whether infertility can be effectively prevented.

To address the above questions, model animals and clinical samples will be used, through combination of basic and clinical research, to investigate (1) regulation of reproductive stem cell fates, interaction between reproductive cells and somatic cells, and regulatory network of transcription and translation during follicle growth and maturation; (2) developmental roles of maternal factors and spatiotemporal regulation of cell fates during early embryonic development; (3) molecular mechanisms underlying infertility caused by abnormal follicle development, oocyte maturation and embryogenesis.

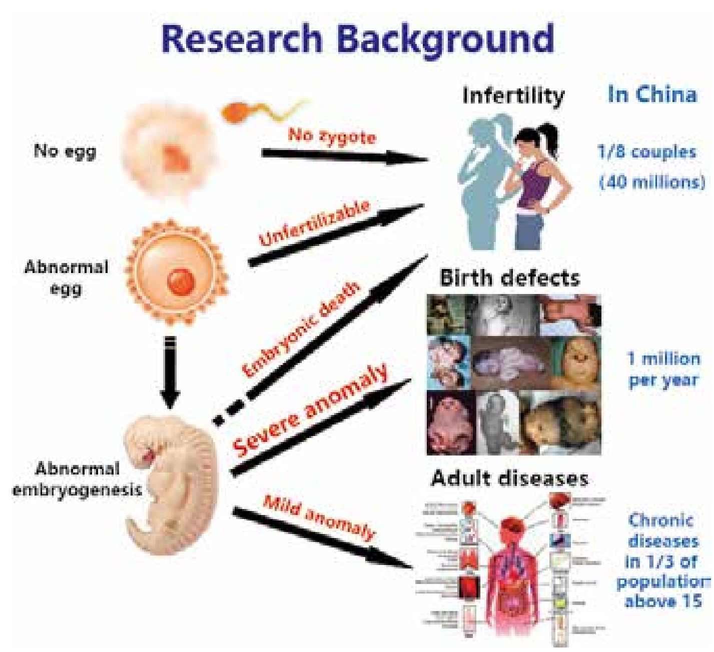


Figure 2-2-60 Research background

The project is expected to make important scientific findings and obtain new knowledge in several aspects. (1) Identifying new ovarian somatic cell types that play critical roles in follicle development; revealing important roles of ovarian somatic cell in regulating oocyte growth and maturation; and disclosing new mechanisms of oocyte-regulated somatic cell behaviors. (2) Identifying a series of asymmetrically distributed maternal factors and elucidating their roles in regulating embryonic development; and establishing important rules regulating spatiotemporal cell differentiation. (3) Revealing critical mechanisms underlying clinical infertility due to abnormal oogenesis and embryogenesis with identification of effective targets for preventive interference; and based on observation and analysis of a large birth cohort, determining major factors affecting the whole life health and establishing new strategies for prevention and therapy of related diseases. This project would become an important base for scientific innovation in the area of reproduction and development as well as fostering young scientists of great potential and contributing to the improvement of population quality and health in China.

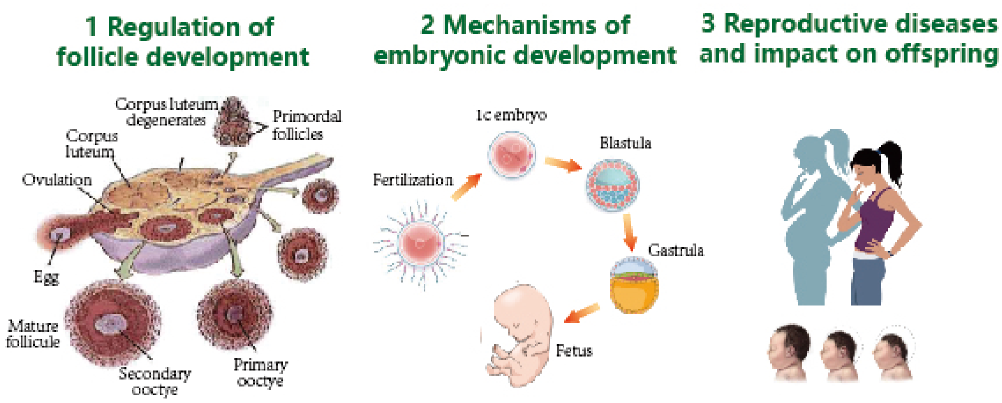


Figure 2-2-61 Research background

Tibetan Plateau Earth System

The Basic Science Center Program of "Tibetan plateau earth system" (CTPES), which is based at the Institute of Tibetan Plateau Research of CAS, along with two other participant institutions, the Institute of Atmospheric Physics of CAS and Peking University, is a project funded by NSFC. The direct funding for this project is 80 million yuan. This project is led by Prof. Chen Fahu (CAS academician). The key members include Prof. Ding Lin (CAS academician), Prof. Zhou Tianjun, Prof. Xu Baiqing and Prof. Piao Shilong. This outstanding research team with a well mixture of young and middle-aged scientists has been organically formed during the development of CAS Center for Excellence in Tibetan Plateau Earth Science, and is highly esteemed in the Tibetan Plateau research.

The Tibetan Plateau (TP) is the region with the strongest and long-lasting plate collision on the Earth, and has been long considered the best place for verifying the theory of plate tectonics, a key scientific breakthrough in geology over the 20th century. The uplift of TP has fundamentally changed the environment of both its own region and that of tele-connected areas. And strong interactions of TP’s multiple spheres (lithosphere, atmosphere, cryosphere, hydrosphere, biosphere and anthroposphere) provide an extraordinary testing bed for Earth system science (ESS), likely leading to new breakthroughs in geoscience of the 21st century. In addition, the TP is renowned as "the Roof of the World", "the Asian Water Tower" and "the Third Pole", and plays a pivotal role as China's ecological security barrier, reserve of strategic resources and preserve of national cultural heritage. The implementation of this project will not only satisfy the needs of ESS development, but also serve the strategic needs of national sustainable development.

Aiming at achieving innovative researches and important breakthroughs in ESS of the 21st century, CTPES focuses on mechanisms of the multi-sphere coupled responses and their influences under the continuous uplifting of the TP and global change (Figure 2-2-62). Three major research directions of this project are outlined here: (a) Continental collision-subduction and plateau uplifting, (b) the coupled effects of westerly-monsoon synergy on cryosphere and water cycle, and (c) alpine ecology and human adaptation. Multidisciplinary methods that break boundaries of time, spheres, space and disciplines, and the development of the TP Earth system model will be the major research approach of this project, which will enable us to reconstruct the paleo-altitude and the chain responses in climate-biology-land surface processes at key historic nodes during the uplift of the TP (Figure 2-2-63). Such multidisciplinary and systematic approach can help to reveal fundamental processes and mechanisms governing the interactions among contemporary Earth's surface layers, and clarify the history and mechanism of human adaptation to this alpine environment.

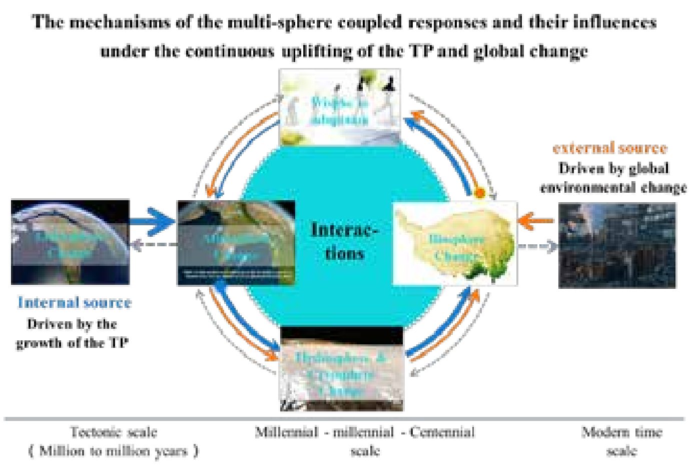


Figure 2-2-62 Schematic diagram of core scientific issues

The CTPES is expected to establish a paradigm of scientific researches on the Tibetan Plateau Earth system science and make Chinese-characterized contributions to theories and applications of ESS. CTPES will bring up a number of strategic S&T talents, leaders and innovation teams and build an international frontier for ESS research, which will also support the regional sustainable development and ecological civilization over the TP and serve the strategic need of the Belt and Road Initiative.

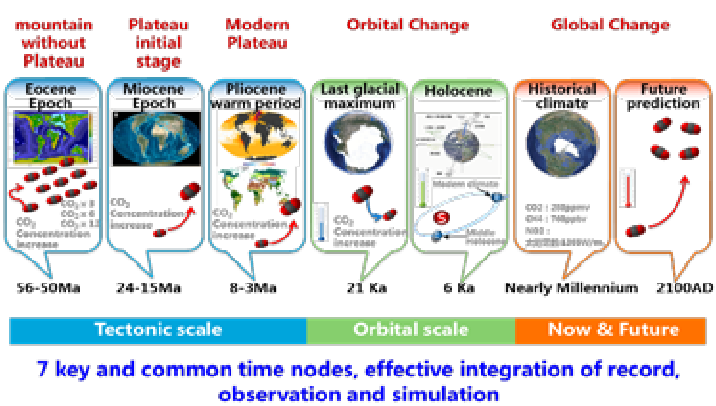


Figure 2-2-63 Multidisciplinary and systematic approach

Resource and Ecology Based Synthetic Polymeric Materials

The Basic Research Center Program of "Resource and ecology based synthetic polymeric materials" is led by Prof. Chen Xuesi, academician of CAS, with a direct funding of 80 million yuan. The supporting institution of this project is Changchun Institute of Applied Chemistry of CAS. The key members in this project are from Beijing University of Chemical Technology and Wuhan University. Other key members are Prof. Yang Wantai, academician of CAS, Prof. Wang Xianhong, Prof. Zhang Liqun and Prof. Cheng Sixue. All these members are working in the fields of polymer chemistry and materials science with international influence.

Synthetic polymers, whose usage has exceeded 500 million tons worldwide per year, is a vast scale material that guarantees national economic development and security. Whereas now it is also facing the formidable challenges of unsustainable development and environmental crisis. Due to the less fossil fuels and worse environmental deterioration, the research center focuses its researches on the sustainable synthesis of ecopolymers based on previous research outcomes, with integrated talents focusing on the newest polymer material progress. The sustainable development of synthetic polymer requires consideration from the origin of resource and ecology system. Considering the resource, the materials need to be bio-based, from waste industrial fossil olefins and CO_2. Considering the ecology, to resolve the plastic pollution, biodegradability is required for bio-based materials. Based on waste fossil resources and biomass resources, long-term researches have been carried out on 5 featured and meritorious fields including polymeric recycle of waste industrial fossil olefins, CO_2-based polymer materials, amino acid-based functional polymer materials, poly(lactic acid)-based polymer materials as well as bio-based elastomers. The goal of this basic research center project is to resolve the key scientific problems of (1) the preparation of bio-based monomer with high efficiency and low cost; (2) the design of catalysts with high activity and selectivity for resource and ecology based polymers; (3) the exploration of polymerization approaches for the resource and ecology based polymers; (4) the modulation of structure and performance of resource and ecology based polymers and (5) the method for the performance evaluation of resource and ecology based polymers.

New outcomes are currently aimed for the next 5 to 10 years including polymer material structure designs, efficient and precise synthetic methodologies and performance control of polymer materials. It is also planned to realize pioneering academic contributions of global impact and more than 5 original Chinese synthetic eco-material brands with leading megaton capacity, for the ultimate contributions to domestic and global sustainable development.

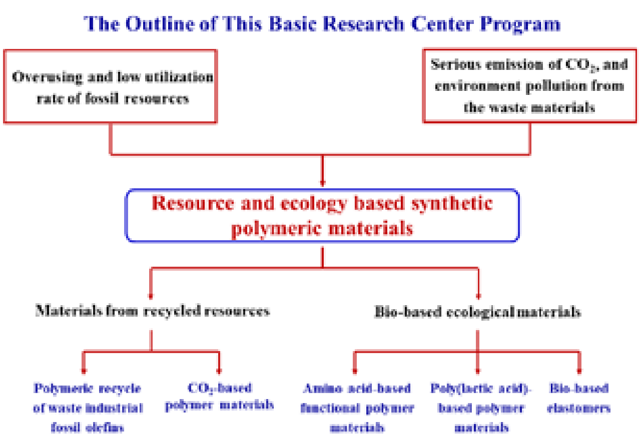


Figure 2-2-64 Outline of the program

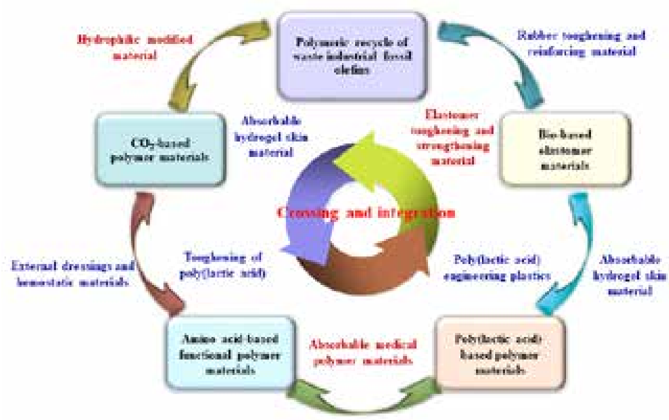


Figure 2-2-65 Crossing and integration of program research

Multiphase Evolutions in Hypergravity

The Basic Science Center Program of “Multiphase evolutions in hypergravity” is led by Prof. Chen Yunmin (academician of CAS). This project is funded by NSFC with a direct funding of 80 million yuan. It is based at Zhejiang University and cooperates with Wuhan University and Beijing University of Technology. The members in this project also include other young or middle-aged scientists, such as Prof. Yang Shufeng (academician of CAS), Prof. Han Xiaodong, Prof. Zhou Chuangbing, and Prof. Zhan Liangtong. All the members in this project are at the forefront of scientific research with the international reputation in the fields of hypergravity experimental science, geotechnical mechanics, tectonic geology, and material science.

Multiphase evolutions, which include phase transformation, phase mass transport, and state transformation, of multiphase media, such as, soils, rocks, and alloys, are controlled by gravitational fields, which are closely related to human life and dominant in most engineering disasters, deep-underground and deep-sea resource exploitation and storage, the contamination to underground soils, and the performance of alloys. The primary key scientific problem of this program is the hypergravity effect and the mechanism of multiphase evolution, based on National Large Research Infrastructure-Centrifugal Hypergravity and Interdisciplinary Experiment Facility (CHIEF). This study will be conducted with an innovative experimental approach, which is the coupled hypergravity experiments with dynamic excitation, high pressure, high temperature, and other physical fields. In this program, various disciplines, including geotechnical engineering, tectonic geology, environmental engineering, and material science, will be integrated. A new academic frontier for the multiphase evolution in hypergravity will be developed, revealing the mechanism of multiphase evolution from the micro to macro scale. In particular, a third-generation soil mechanics with the focus of solid-phase loss, phase mass transport, state transformation, and its coupling effect will be proposed and established. Besides, a new theory of rock mechanics will be established to account for the tectonic deformation, structural surface evolution, water/gas/solute transport, and the coupling effects. After theoretical and experimental studies, this program will provide a series of revolutionary approaches for the construction and long-term service of major engineering, including the thousand-year performance of contaminant barrier systems, long-term service of high-speed traffic subgrade, high and steep slope engineering, deep-sea energy exploration, geological disposal of nuclear waste, deep energy storage, etc. Additionally, the underlying theory for the hypergravity solidification of the melted alloy will be established, while a novel assessment approach of material failure will be proposed. These achievements in material engineering can lead to the technological revolution in the preparation and evaluation of high-performance materials in China. A research team with an international reputation will be gradually gathered and developed through this basic science center program, which will lead the global studies on the multiphase evolution and hypergravity experimental science.

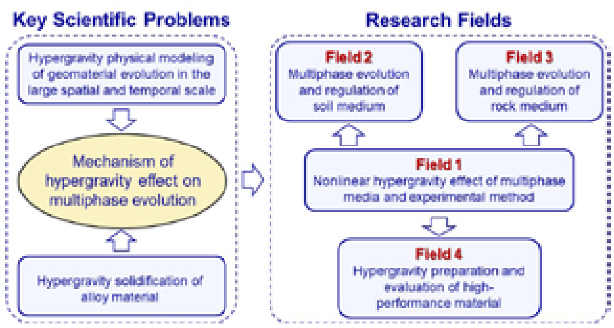


Figure 2-2-66 Research idea and fields

Figure 2-2-67 Hypergravity experimental platform

Study of the Frontier Fields of Terahertz Sciences and Technologies

The Basic Science Center Program of "Study of the frontier fields of terahertz sciences and technologies" is led by Prof. Wu Yirong (academician of CAS). The total direct funding for this program is 80 million yuan. The project is based at Institute of Electronics of CAS, and cooperated with the groups from University of Electronic Science and Technology of China, and University of Shanghai for Science and Technology. The key members of this project include Prof. Gu Min (academician of CAS), Prof. Wei Yanyu, Prof. Fang Guangyou and Prof. Zhu Yiming, who are experts in the fields of the terahertz nanophotonics, terahertz vacuum electronics, and terahertz imaging, respectively. They have important international influence in the corresponding research areas.

The terahertz wave in the transitional region of electronics and photonics is the last part of the electromagnetic spectrum that needs to be studied. It has many unique properties different from optical and microwave. The development of terahertz basic science research will bring revolutionary changes in the use of electromagnetic waves. However, the existence of serious scientific and technical bottlenecks, which heavily limit the extension of traditional electronic and optical methods to the terahertz band, prevent the development of terahertz sources with high power and detectors with high sensitivity.

This project focuses on the fundamental scientific problems about the development of key devices in terahertz band. In addition, the researches on the interaction between terahertz waves and novel materials and structures with quantum electromagnetic responses will be investigated for the applications in high power sources and high sensitivity detectors. The key scientific problem of the project to be concerned are as follows:

(1) How to use theoretical and numerical methods to establish the physical model for the interaction of "photon-electron-quasi-particles" multi-physics in the terahertz band.

(2) How to systematically study and effectively control the quasi-particle-element excitation, to develop novel theoretical and technical methods for high power signal generation and high sensitivity signal detection.

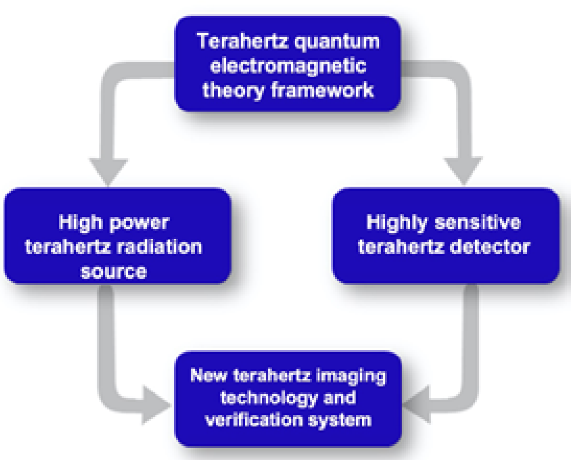


Figure 2-2-68 Research scheme

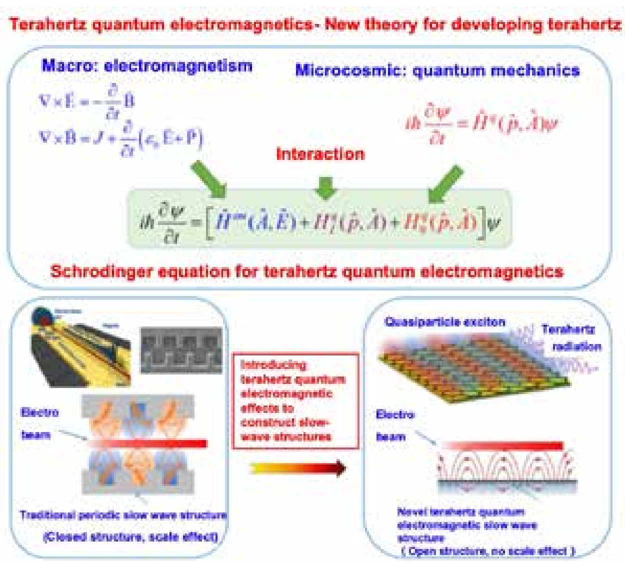


Figure2-2-69 Key scientific problems

(3) How to design open slow wave structures based on quantum electromagnetic effects, and develop corresponding techniques for the device fabrication and integration.

Focusing on the frontier scientific problems about the terahertz devices and application technologies, the terahertz quantum electromagnetic theories are expected to be developed in this program, with the unique quasi-particle-element excitation and control methods systematically studied in terahertz band. On this basis, a series of novel terahertz quantum electromagnetic devices are expected to be developed to break through the bottlenecks of current terahertz devices. And unprecedent terahertz imaging technologies can be studied based on the high quality terahertz sources and detectors developed in this projects, with proof-of-state systems integrated, a complete chain of innovations from basic researches, device technology to application demonstration systems can be build, in a basic science center that leads the development of international terahertz.

Intelligent Optimization and Control Mechanism for Material Conversion-Based Manufacturing Process

The Basic Science Center Program of "Intelligent optimization and control mechanism for material conversion-based manufacturing process" is led by Prof. Qian Feng (academician of Chinese Academy of Engineering). This project is based at East China University of Science and Technology (ECUST). The collaborative research institutions include Central South University and Northeastern University. The direct funding is 80 million yuan. The four key members in this project are Prof. Gui Weihua (academician of Chinese Academy of Engineering), Prof. Ding Jinliang, Prof. Du Wenli and Prof. Zhong Weimin.

The material conversion-based manufacturing industries, such as petrochemical, iron and steel, non-ferrous metals, are the pillar industries of China's national economy. In the context of accelerating global industrial transformation, China's material conversion-based manufacturing industry is facing more prominent problems in resource utilization, agile production as well as safety and environment risks. Therefore, it is urgent to develop optimization and control methodologies for multiple time and space scales, and extend the applications of "Intelligent +". Intelligent, autonomous and controllable will be the frontier research directions in optimization and control of material conversion-based manufacturing process.

This project will focus on the cognition and decision-making of the regulation mechanism in material conversion-based manufacturing process, which includes three frontier scientific problems: the characterization and cognition of the material conversion process, multi-objective autonomous cooperative regulation and control mechanism of the manufacturing process, and cross-layer human-cyber-physical intelligent decision-making of the manufacturing system. The researches will include:

(1) How to characterize the structure-activity relationship between micro-scale material conversion mechanism and macro-scale system operation characteristics, then achieve causal interpretation of massive data/patterns based on the material

Figure 2-2-70 Research backgroud

conversion mechanism?

(2) How to describe the dynamic coupling characteristics of multi-temporal-spatial scale material conversion, then realize the active cooperation of multiple control systems under multiple objectives such as safety, environmental protection, quality and efficiency?

(3) How to enhance the decision-making robustness of the manufacturing process in an open environment through the human-cyber-physical integration, then promote the integration of planning, scheduling and optimization operations of large scale manufacturing system?

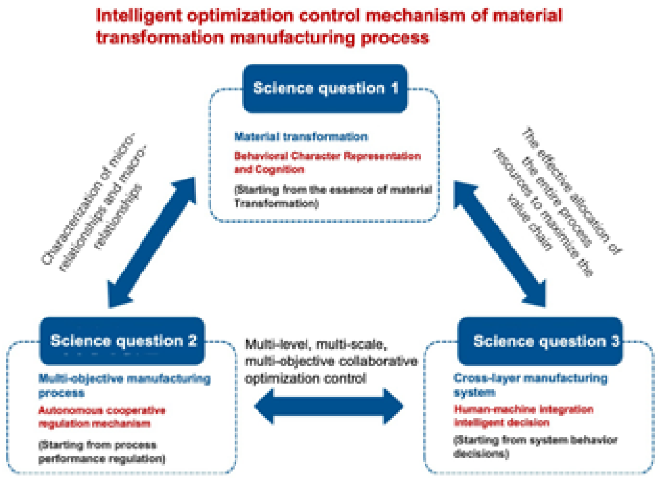


Figure 2-2-71 Key scientific problems

Through the close cooperation and collaborative research in the forthcoming five years, the group will make major breakthroughs in the above scientific problems by developing adaptive & self-learning intelligent representation and autonomous control methods for industrial process, interpretable resource/energy planning and scheduling optimization methods, and dynamic and intelligent risk assessment and decision-making-aided methods which are deeply coupled with the environment. The group will publish 100 publications with high impact in international leading journals in the fields of artificial intelligence, automatic control, chemical engineering, process systems engineering and metallurgical engineering, apply for 40 invention patents and computer software copyrights, make breakthroughs in a series of core technologies and industrial software on optimization and control, have applications in major projects such as ten-million-ton crude oil refinery, million-ton ethylene and aromatic hydrocarbon, and 400 KA or above aluminum electrolysis, which facilitate the intelligent transformation and high-quality development of China's process manufacturing industry.

Econometrics and Quantitative Policy Evaluation

Led by Prof. Hong Yongmiao, the Basic Science Center Program of "Econometrics and quantitative policy evaluation" is funded by NSFC. The direct funding is 60 million yuan. This project is based on Wang Yanan Institute for Studies in Economics at Xiamen University as well as Academy of Mathematics and Systems Science of CAS. Other key members include Prof. Wang Shouyang, Prof. Fang Ying, Prof. Yang Cuihong and Prof. Zhou Yinggang. The group also consists of many world class scholars and active young researchers in Mainland China and from oversea.

Quantitative modeling has been regarded as a fundamental tool in many research areas such as economics, management sciences, and policy studies. Econometrics plays a crucial role in promoting economics as a scientific discipline and thus becomes one of economics fields with the most Nobel Prize winners. In the era of big data, econometrics is very likely to have another wave of major innovative breakthroughs. Moreover, China is fully capable of being a global front-runner in the emerging cross-discipline field.

This project will focus mainly on cutting-edge researches on: (1) Econometric modeling and machine learning application for complex data like interval data, high dimensional data, nonlinear and heterogeneous panel data, and non-stationary data; (2) The evolution, forecasting and warning of complex systems, containing time-varying macroeconomic system modeling, development and implementation of robust prediction and monitoring, econometric theories and methods on frequency domain; (3) Economic security and financial risk management in an open economy, including the modeling, early warning and prevention, and causality identification for economic security and financial risk networks; (4) Quantitative policy evaluation and design for the national development strategies, including improvement and extension of quantitative evaluation methods, the design and evaluation of policies on industrial restructure and trade, fiscal budget, public finance and taxation, regional coordination, targeted poverty alleviation, etc.

The project is expected to produce internationally influential academic research outcomes, train a group of leading young and middle-aged scholars with international reputation, and receive a few important international academic awards. Moreover, the center intends to become one of the best research centers in econometrics and related fields and influential think tank for macroeconomic policy-making in China and the world. Finally, by hosting world-class visiting scholars regularly, the center is expected to become one of the most influential international academic exchange centers.

Integrated Research on Cancer Molecular Alteration and Microenvironment

The Basic Science Center Program of "Integrated research on cancer molecular alteration and microenvironment" is led by Prof. Zhan Qimin, an academician of the Chinese Academy of Engineering. This project supports a scientific breakthrough group composed of five cancer research teams. The other key members include Academician Wang Hongyang, Academician Lin Dongxin, Prof. Zhang Zemin and Prof. Wu Chen. The team members come from world-leading institutes and clinical medical centers, including National Cancer Center, National Cancer Clinical Research Center, National Center for Liver Cancer and State Key Laboratory of Molecular Oncology, affiliated to Peking University, the Eastern Hepatobiliary Surgery Hospital of the Naval Military Medical University, and the Cancer Hospital of the Chinese Academy of Medical Sciences. The above members form a collaborative group combining basic and clinical translational researches, as well as the cutting-edge technological innovations.

Cancer is a major public health threat in China, measured by both incidences and mortality. Cancers arise as a result of somatic variations occurred in the genomes of cancer cells. In addition to cancer cells, tumors exhibit further dimensions of complexity due to the significant presence of stromal cells and immune cells, together forming the major component of the tumor microenvironment, which shape various cancer properties including how they respond to different therapies. It is thus of paramount importance to reveal the composition and interplay between clonal evolution of cancer cells and adaption of tumor microenvironment. The core scientific question we raised in this project is how the mutual regulation between cancer molecular alterations and microenvironment drives the cancer development and progression.

We will advance our understanding of cancer by performing integrated studies on the intrinsic causes (genetic variation of cancer cells) and extrinsic factors (tumor microenvironment) of cancer initiation and development, by focusing on high-incidence digestive tract cancers in China (esophageal cancer, gastric cancer, colorectal cancer and liver cancer). We plan to tackle four fundamental directions: the cancer genome evolution, the single cell atlas of tumor tissues, the molecular regulation of tumor malignant phenotypes, and the advancement of novel technologies for cancer research. We aim to identify 5-10 therapeutic targets or diagnostic biomarkers in perspective of tumor-driven genetic variation and tumor immune factors. Through deep collaboration, we will establish an impeccable cancer research team in China, which is positioned to lead basic cancer research in multiple specific fields worldwide, as well as to be the most strong and unique team to leave a lasting footprint in controlling cancer as a major health threat to China.

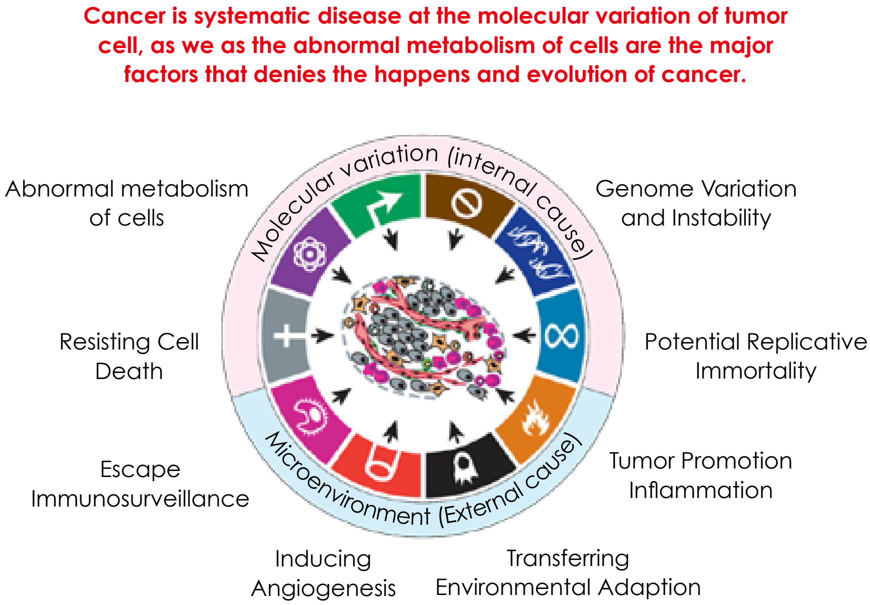


Figure 2-2-72 Research background

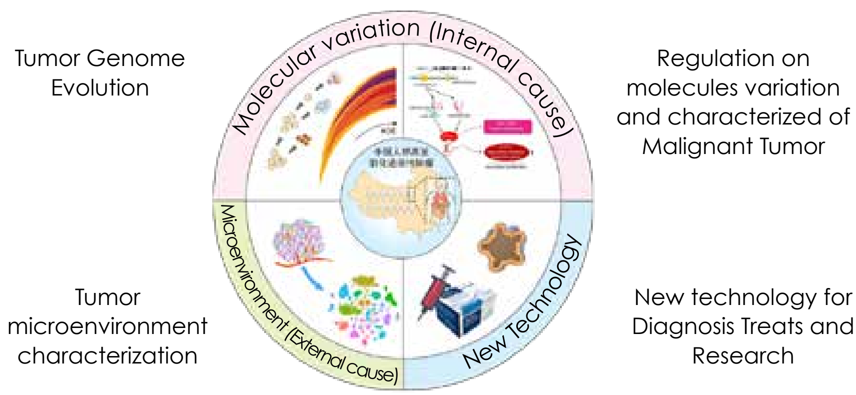


Figure 2-2-73 Research content

Part 3

Selected Research Achievements

NSFC

2019 ANNUAL REPORT

3.1 Achievements of Major Research Plans

Fuel Breeding and Transmutation of Advanced Nuclear Fission Energy

The Major Research Plan of "Fuel breeding and transmutation of advanced nuclear fission energy" has supported 88 research projects with a total funding amount of 190 million yuan, which include 64 Cultivation Projects, 17 Key Projects, 4 Integrated Projects and 3 Strategic Research Projects. The corresponding total budget for each category is 51.2 million yuan, 80.3 million yuan, 48 million yuan and 10.5 million yuan, respectively. Thirty-one research units participated in this major research plan. Academician Zhan Wenlong and Academician Chai Zhifang from CAS served as the chair and vice-chair of the steering committee, respectively. More than 600 investigators from well-known institutes and universities participated in this major research plan, including some overseas scholars.

Through multidisciplinary studies, this major research plan conducted innovative research on the major direction of nuclear fuel breeding and transmutation, and explored or developed new mechanisms, new methods, new technologies, and new materials for future advanced nuclear fission energy systems, which benefits the establishment of nuclear energy industry system with innovative capabilities, independent intellectual property rights and provides scientific basis, technology accumulation and talent support for the development of the Third Generation of nuclear power in China, making China rank among the first level community in the Fourth Generation of nuclear power research.

The successful implementation of this major research plan has solved several major scientific issues in the process of breeding and transmutation of advanced nuclear fission fuels. It has achieved a series of important progresses with significant international impacts in the general concept of advanced nuclear energy system and four sub-fields such as accelerators, reactors, nuclear materials and fuel cycles:

(1) Conducted research on high-power superconducting linear accelerator integration and stable operation, realizing the high-power stable operation of the ADS superconducting linear accelerator front-end demonstration prototype with more than 2 mA continuous proton beam flow and more than 100 hours, the beam availability is 89%. The result is the highest beam power and the longest running time achieved by the continuous continuous beam current linear accelerator in the world, and is at the international leading level.

(2) Originally proposed the principle of particle flow target and completed the development and experiment of the first prototype of the particle flow spallation target in the world, and developed the world's first particle-flow-based ADS target reactor system-level integrated design with independent intellectual property rights. The software platform has established a dedicated database for ADS system design.

(3) Realized the design and synthesis route of advanced nuclear fuel, clarified the irradiation damage mechanism of advanced nuclear structural materials (such as MAX phase and SiC), set up the structure-effectiveness relationship of microstructure, component and property of structural materials in nuclear environment.

(4) The advanced solvent extraction based process for the efficient separation of actinides over lanthanides with dithiophosphinic acid ligands was developed, and the verification bench test with mCi level of radioactivity was carried out. The removal rate of Am-241 in the lanthanides was greater than 99.998%. The removal rate of lanthanides in Am-241 is 99.2%. These key parameters are internationally advanced compared to that of other similar separation processes. In addition, a new concept based on active Al cathode was developed to achieve highly efficient separation of actinides over lanthanides by molten salt electrolysis.

There are 1,449 scientific papers produced from this major research plan, including 1,247 papers published in SCI journals and 926 papers in EI journals. In addition, investigators in this major research plan contributed 190 domestic patents and 2 international patents. They also won the Second Prize of the National Natural Science Award 1 time, Second Prize of the State Technological Invention Award 2 times, First Prize of provincial or ministerial rank award 6 times, Second Prize of provincial or ministerial rank award 5 times. The PIs made 80 invited talks at major international academic conferences. With the support of this major research plan, China has emerged a group of outstanding scientists with international impact in the field of nuclear energy. During the implementation of this major research plan, 2 PIs became academicians of CAS, 6 won the National Science Fund for Distinguished Young Scholars, 6 won the Excellent Youth Scientist Fund, one becames national leading talent in science and technology innovation under the "Ten Thousand Talents Plan". A total of 122 doctoral students, 27 postgraduate students and 12 postdoctoral associates were trained.

Figure 3-1-1 China ADS Front-end Demo Linac (CAFe)

Controllable Preparation and Structural Design of the Function-Directed Crystalline Materials

The Major Research Plan of "Controllable preparation and structural design of the function-directed crystalline materials" has layout 158 projects including Cultivation Projects, Key Support Projects, Integration Projects and Strategic Research Projects, with a total funding of 188 million yuan. Among them, there are 124 Cultivation Projects with a funding of 80.2466 million yuan, 29 Key Support Projects (72.1 million yuan), three Integration Projects (31 million yuan) and two Strategic Research Projects (4.5 million yuan). There are 57 institutions participating in the Major Research Plan. Prof. Maochun Hong, a prestigious academician of CAS from Fujian Institute of Material Structure (FJIRSM), is served as the head of the guidance expert group. The research team concentrates more than 700 talents and expertise, most of whom are distinguished scientists from domestic research institutes and universities.

In the program, multi-disciplinary research methods are employed to reveal the intrinsic relationships between the optical, electrical, magnetic and composite properties of crystalline materials and their spatial or electronic structures, unveil the determining functional blocks of the macroscopic functions of crystalline materials and integration modes of these functional blocks in space, and provide theoretical basis for the design and preparation of function-oriented crystalline materials, which finally improves innovation ability of the basic research of chemistry and materials and provides scientific support for solving important problems for our society.

Through the implementation of the program, a theory of functional block is developed, the research methods of controllable synthesis and assembly of crystalline materials, detection and characterization of functional blocks, simulation and prediction of material properties are established, a batch of crystalline materials with international influence and leading role in relevant technologies and industries are obtained, and a series of world leading achievements with significant international influence are accomplished.

(1) Molecule-based materials research has occupied an international high spot. A series of high-performance molecular crystals of single molecule magnets, single ion magnets, single chain magnets, low-temperature magnetic refrigeration are first designed and synthesized. Ferroelectric domains are observed and the phenomenon of orderly coexistence of ferromagnetic and ferroelectric are discovered for the first time. Furthermore, the theory that symmetry breaking can produce ferroelectric magneto-electric coupling materials is put forward.

(2) The research of nonlinear optical (NLO) materials are in the international lead: new nonlinear optical crystal theory has been developed; the mechanism of dipole interaction enhancement of asymmetric elements has been proved by experiments; new theory of grain boundary engineering and polycrystalline microstructure has been put forward; crystal transparent ceramic laser materials have made significant breakthroughs, which makes China the second country to realize multi-chip superposition of ten thousand watt laser output after the United States.

(3) Significant breakthroughs have also been made in the research of energy conversion materials: a series of new antimony-based thermo-electric materials and Fe-based superconductors with excellent properties and performance have been found, which have made a significant impact in the world.

The above achievements have been published as 4,016 papers in international authoritative journals, including 7 papers in *Science*, 3 in *Nature*, 37 in *Science* Series, 31 in *Nature* Series, 146 in *Journal of the American Chemical Society*, 110 in *Angewandte Chemie* and 53 in *Advanced Materials*. 308 international and domestic patents have been authorized. A number of important awards have been received, including ten National Natural Science Awards (Second-Class Prize), and two National Technology Invention Awards (Second-Class Prize). One of the research results was selected into China's top 10 scientific and technological progresses.

With the support of the project, a group of excellent scientists with international standards have emerged in the field of crystalline materials in China. During the implementation of the program, 8 members of the expert steering committee or project undertakers were elected as the academicians of CAS. Among the project undertakers, 14 won the National Science Fund for Distinguished Young Scholars from NSFC, 5 won Excellent Young Scientist Fund, and 9 were academic leaders of Creative Research Groups.

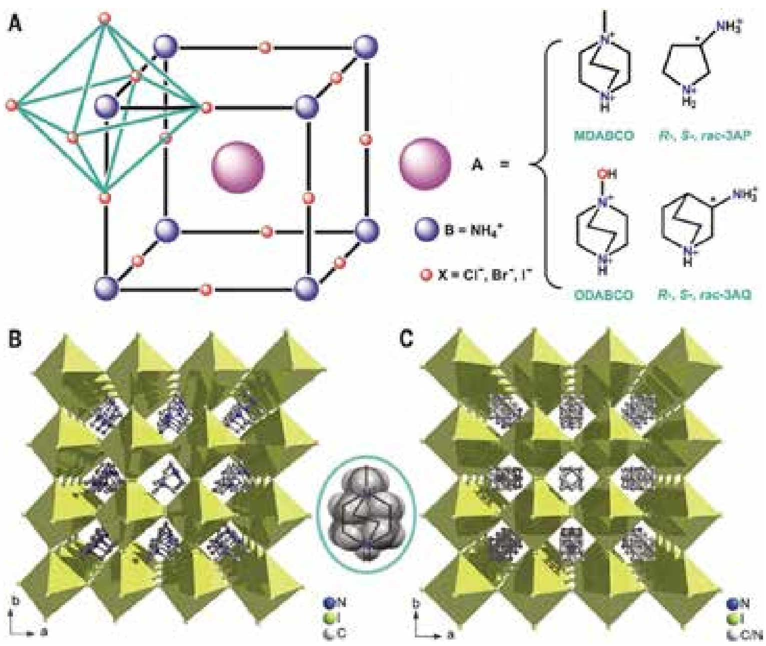


Figure 3-1-2 World's first metal-free perovskite ferroelectric

Controllable Self-Assembly Systems and Their Functionalization

The Major Research Plan of "Controllable self-assembly systems and their functionalization" has been framed with 137 programs, including fostering program, key program, integrated program and strategy research program, with a funding of 200 million yuan. Among them, 103 Fostering Program were supported with 73.6 million yuan; 19 Key Program were supported with 56.4 million yuan; 10 Integrated Program were supported with 63.693 million yuan; and 5 Strategy Research Programs were supported with 6.307 million yuan. The Major Research Plan was led by Prof. Zhang Xi from Jilin University as the leader of the steering committee. The key applicants/researchers were mainly from different famous scientific research institutes and universities.

The Major Research Plan has fully taken the advantages of multidisciplinary researches. To further improve the knowledge of self-assembly, the Major Research Plan has discovered new driven force of the self-assembly, established new self-assembly strategies with Chinese labels, and realized functional self-assemble systems at different levels. These achievements have improved the innovative capabilities and fast development of chemistry, materials and clinic investigations in China, which also provided scientific support to life health and advanced material researches.

The implementation of the Major Research Plan has achieved a lot of breakthroughs with extraordinary international influences in many fields, including the design of novel assembly elements, new driving forces and assembly strategies, multi-functional assembly systems, theory in self-assembly and the self-assembly of biomolecules. Under the support and guidance of the major research plan, our scientific researches of self-assembly has made excellent progresses, which strengthen and complete the field of self-assembly in China, greatly promoting the development of the controllable self-assembly:

(1) Novel driving forces including anion-ϖ interaction and Se-N bonds have been developed and revealed, and new self-assembled elements have also been constructed, realizing the specific regulation of supramolecular self-assembly process.

(2) The novel concept of Cat-assembly has been proposed, and controlled supramolecular polymerization has been developed with major breakthroughs in novel strategies and materials.

(3) The Major Research Plan has revealed the discipline of multi-levels self-assembly, made important breakthroughs in functional self-assembly materials, and achieved a lot highest international performance records.

(4) The assembly of biological molecules such as peptides, proteins and DNA, as well as drug molecules have been developed, which improves the understanding of the mechanism in bio-macromolecules assembly, and developing functional drug delivery and bio-self-assembly materials.

The results supported by the Plan have published more than 2,300 papers on many famous international journals, including 2 on *Nature*, 1 on *Science*, 4 on *Nature Chemistry*, 5 on *Nature Series*, 51 on *Science Advances*, 175 on *Journal of the American Chemical Society,* 155 on *Angewandte chemie*, 135 on *Advanced Materials*. Especially one result was selected as one of the top ten progresses of Chinese science in 2018, which was also selected as one of the top seven technological advances around the world in 2018 by the journal The Scientist. 163 international and Chinese patents were applied, and many important awards were achieved, including 3 Second prize of National Natural Science Award.

With the support of the Major Research Plan, many outstanding Chinese scientists have achieved outstanding results on controllable self-assembly, which has influenced the whole world. During the implementation of the Plan, five experts were elected as academicians of CAS. Among the program researchers, 26 people were awarded by National Science Fund for Distinguished Young Scholars, 12 people were selected as Changjiang Scholars Distinguished Professors, 28 people received the Ten-thousand Talents

Program, 13 people received the Excellent young talents program, 33 people won the Excellent Young Scientists Fund and 7 people became academic leaders of Science Fund for Creative Research Groups.

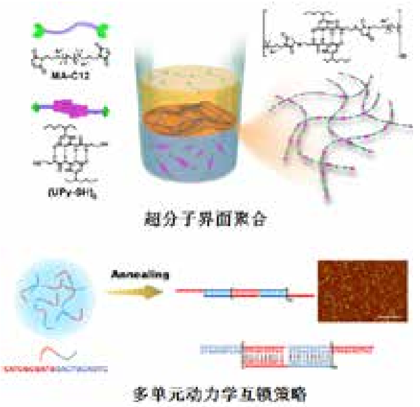


Figure 3-1-3 New assembly method: supramolecular interfacial polymerization and multi-unit dynamic interlocking strategy

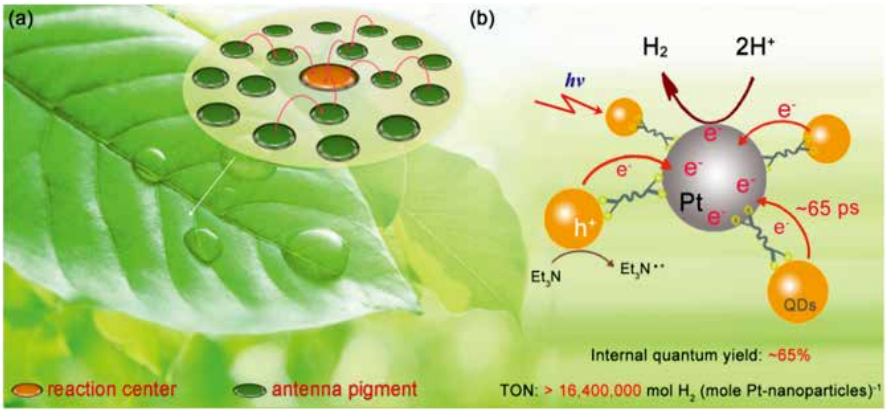


Figure 3-1-4 The structure of the reaction center of natural photosynthesis system (a), the structure of supramolecular nano-assembly and photocatalytic hydrogen production process (b)

Integrated Research on the Eco-Hydrological Processes in the Heihe River Basin

The Major Research Plan of “Integrated research on the eco-hydrological processes in the Heihe River Basin” (referred to the Heihe Plan thereafter) has arranged a total of 86 sub-projects with a total funding of 190 million yuan, including 42 Fostering Projects with a funding of 24.9 million yuan, 29 Key Projects with a funding of 78.84 million yuan, 8 Integrated Projects with a funding of 71.18 million yuan, and 7 Strategic Projects with a total funding of 15.08 million yuan. The Heihe Plan was led by Academician Cheng Guodong from the Cold and Arid Regions Environmental and Engineering Research Institute of CAS, and has more than 70 participating institutions with approximately 350 backbone members mainly coming from domestic research institutes, universities and colleges, and including a few from overseas.

Based on the establishment of a comprehensive eco-hydrological research platform that integrates observation, experiment, and data simulation at basin scale, the Heihe Plan applied multi-disciplinary research methods to (1) reveal the interactions of the eco-hydrological processes at multiple scales including the individual plant, community, ecosystem, landscape and watershed, to (2) unveil the mechanism of the eco-hydrological responses to climate change and human activities in the inland river basins, to (3) develop the scaling methodologies of different eco-hydrological processes, and to (4) develop an integrated model of coupling watershed ecology, hydrology and social economy. The researches of the Heihe Plan have improved the understanding and the predictive abilities of the formation and transformation mechanisms of water resources in inland river basins, and have significantly promoted the research level of the watershed eco-hydrology in China.

The Heihe Plan has achieved a series of breakthroughs with important international influences in several aspects, including the integrated watershed observation, the plant water use efficiency and its adaptative mechanism to water stress in an arid environment, the integrated modeling of watershed surface-groundwater, ecology, hydrology and socio-economy, as well as the response characteristics of eco-hydrological processes to climatic change and human activities, etc.

(1) The Heihe Plan implemented the large-scale remote sensing experiment of watershed eco-hydrology, i.e., Heihe Watershed Allied Telemetry Experimental Research (HiWATER), and established the "Integrated Observation Network for Heihe Basin Surface" (Figure), which makes the Heihe River Basin to be an experimental watershed for large-scale international projects such as GEWEX, G-WADI and ISMN, etc.

(2) The Heihe Plan revealed the coupling control mechanism of the multi-media water cycles in the Heihe River Basin, which advances the understanding of the hydrological cycle in inland river basins.

(3) The Heihe Plan developed a precise evaluation and forecasting system for water resources in the Heihe River Basin, which improves the utilization and management of water resources in inland river basins.

(4) The Heihe Plan enabled the paradigm shift of the integrated research of watershed ecology, hydrology and economy, which deepens the overall understanding of the human-nature interactions of the terrestrial surface systems.

A total of 1,432 SCI papers about the above-mentioned results were published in international journals, including 18 ESI high-cited papers. Meanwhile, 17 monographs were published, and 115 international and domestic patent/software copyrights were applied and granted. The researches of the Heihe Plan won several important awards, including 1 second-class prize of the National Science and Technology Progress Award, 6 first prizes and 2 second prizes of provincial/ministerial natural sciences, and 1 first prize and 7 second prizes of provincial/ministerial scientific and technological progress.

During the implementation of the plan, 4 members of the guiding expert group of Heihe Plan were elected as the academicians of the Chinese Academy of Sciences or the Chinese Academy of Engineering; 4 won the National Science Fund for Distinguished Young Scholars; 11 won the Excellent Young Scientist Fund; 1 became the academic leader of the Greafire Research Group; 2 won the He Liang He Li Award; 4 won the National Technology Plan Innovation Leadership; 3 won the leading talent in science and technology innovation of the Ministry of Science and Technology; 1 was awarded the Humboldt Medal of the European Union of Geosciences; 1 won the Hubbert Award in 2013, the US Groundwater Association's highest science award; and 1 won the Meinzer Award in 2013, the International Hydrogeology World's highest honor.

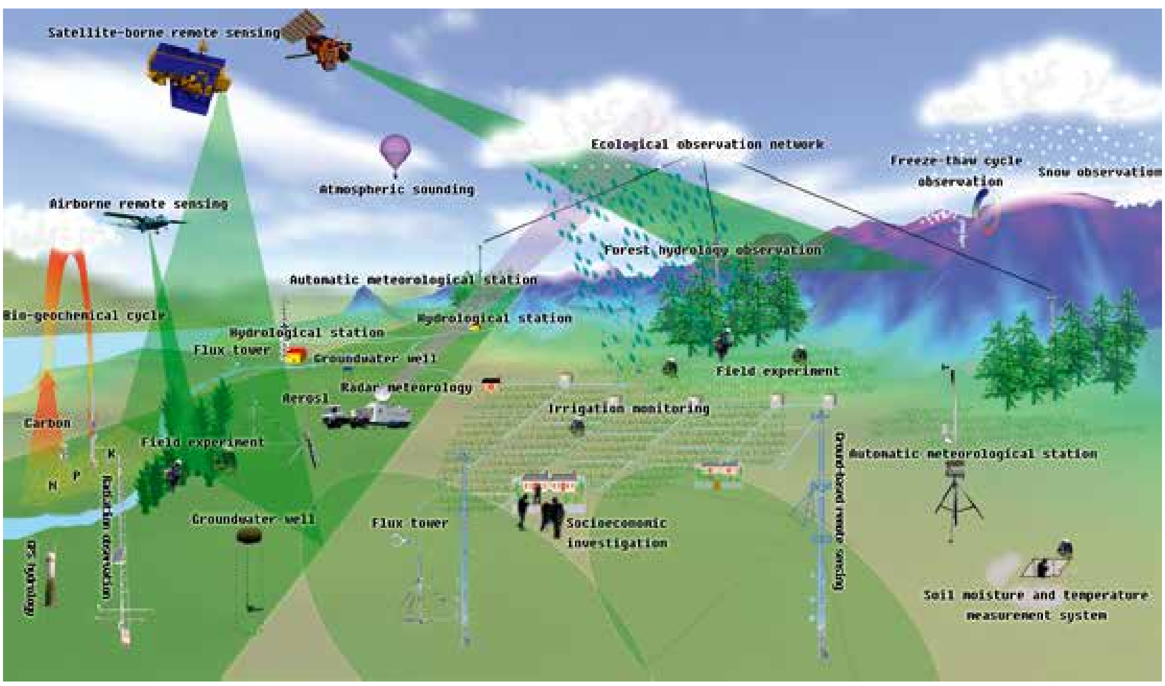


Figure 3-1-5 Watershed observation system and remote sensing experiment in the Heihe River Basin

Regulatory Network for Malignant Transformation of Nonresolving Inflammation and Its Molecular Mechanism

The Major Research Plan of "Regulatory network for malignant transformation of nonresolving inflammation and its molecular mechanism" was officially launched in October 2010. It comprises a total of 157 projects, including Development Projects, Key Supporting Projects, Integrated Projects, and Strategic Research Projects. The Plan supported by a total fund of 200 million yuan, distributed among 119 Development Projects (94.4342 million yuan), 12 Key Supporting Projects (34.80 million yuan), 22 Integrated Projects (57.19 million yuan), and 4 Strategic Research Projects (13.575 million yuan). This Major Research Plan boasts a galaxy of supervising experts headed by Academician Wang Hongyang of the Second Military Medical University, and the participation of 51 Chinese universities and research institutes.

Focused on the key scientific issues concerning the great health demand of Chinese population, this Major Research Plan keeps abreast of the international frontier research in the new era driven by innovation and technology revolution. To address the three key scientific issues of malignant transformation of non-resolving inflammation, i.e., its molecular mechanism, the regulatory network and its critical nodes,the dynamic network regulatory patterns, the program adopts an integrative, cross-discipline and information-oriented research strategy.It has been actively promoting the combination of multiple disciplines, such as oncology, immunology, cell biology, bio informatics, pharmacology, etc.,hence development of new technologies and methods, and establishment of many high-level research platforms with various features and complementary advantages. The plan has cultivated a number of talents with global competitiveness. Furthermore, the plan has made a series of innovative achievements regarding the molecular mechanism of the regulation of malignant transformation of inflammation, its early prevention and diagnosis, and all new tumor prevention and treatment models and intervention policies.

(1) The plan has identified new critical nodes and new regulatory mechanism of the regulatory network for the malignant transformation of non-resolving inflammation. It has also discovered the roles of critical molecules and the dynamic network in the inflammation-cancer transformation.

(2) The plan has annotated the relationship between non-resolving inflammation and cancer in view of the entire process of malignant transformation of inflammation into the prevalent and severe cancers in China, thus laying a pioneering, original and innovative theoretical foundation for the early diagnosis and treatment of the prevalent and severe cancers in China.

(3) The plan has broken through the research bottleneck of inflammation-cancer transformation. It has established a number of disease models, computing models for the dynamic network regulation, as well as new imaging technologies for the inflammation-cancer transformation research. In addition, it has proposed new concepts such as endogenous networks based on random processes and dynamic network markers. Moreover, it has built up a plurality of integrated databases and data analysis platforms.

(4) The plan has intensified the clinical application of the results of the fundamental research on inflammation-cancer transformation, promoted the research and development of new molecular diagnostic reagents and new drugs. Some of the research results have been put into clinical application or clinical trials.

The results of the plan have been published in the form of over 1,300 papers in international SCI journals, including Cell, Nature Medicine, Nature Immunology, Cell Metabolism, and Cancer Discovery. The program has won four Second Class Prizes of the National Natural Sciences Awards, one First Class Prize of the National Awards for Progress in Science and Technology, and four Second Class Prizes of the National Awards for Progress in Science and Technology.

The plan has cultivated a large number of outstanding young and middle-aged Chinese scientists in inflammation-cancer transformation and relevant fields. Among them, six research project directors have been co-opted to either Chinese Academy of Sciences or Chinese Academy of Engineering; fourteen have been supported by the National Science Fund for Distinguished Young Scholars; ten have been supported by Excellent Young Scientist Fund; seven have been appointed Distinguished Professors or Distinguished Young Scholars of the Changjiang Scholar Awards Program; nine have become the academic leaders of the Creative Research Groups supported by NSFC.

Figure 3-1-6 Special issue in *Science China Life Science*

3.2 Achievements of Special Fund for Research on National Major Research Instruments Projects (by Recommendation)

In Situ System for Studying on Relationship Between Properties and Microstructures of Materials for National Strategic Demand under Service Condition

The project of "In situ system for studying on relationship between Properties and microstructures of materials for national strategic demand under service condition" ("in situ system" for short) was started in 2014 by NSFC. The total project funding is 56 million yuan, the period of execution was from January 2014 to December 2018, the project leader is Prof. Zhang Ze from Zhejiang University, with researchers from Beijing University of Technology, Southeast University, Institute of metal research, and Chinese Academy of Sciences also joined the research team.

Development of efficient energy conversion devices is determined by the high-temperature alloy and heat-resisting titanium alloy which affects the national security. However, there is an obviousl gap between China and the developed countries, such as USA, UK, and Russia. The main reason is that traditional materials preparation, processing technology, and properties test under service condition are not based on the systematically microstructure study. According to the traditional research, mechanical property test and microstructure study were carried out independently, results in the difficulty to obtain relationship information between properties and microstructures under the in situ, real time, dynamic, and multi-field effect. Aiming to resolve the bottleneck problem for strategic materials development, it is needed to exploit a set of research instruments integrating mechanical property test and microstructure characterization, by which it is able to be carried out for the in situ study on the relationship of properties and microstructures under service condition, ranging from macroscopic - microscopic - atomic scale. The integrated instrument exploited by in situ system project is a direct charactering system for the relationship between dynamic microstructure evolution and properties under service condition, which includes two subsystems: atomic lattice resolution high temperature mechanics in situ study system, and nanometer resolution high temperature mechanics in situ research system. The former solves a series of technical problems including installing assembly units of heat, driver, thermometry, and sensor within limited space, as well as the mutual effect among these units. It is the first time in the world to realize the coupling loading of high temperature field up to 1238°C and GPa order stress field in TEM, and the coupled temperature is 600°C higher than that of international similar devices. The latter has mastered more than 20 key technologies such as structural stability and stiffness design of mechanical elements in the limited space structure of SEM high vacuum sample chamber, as well as the quality control of in-situ test instrument and reliability guarantee. The high resolution in situ mechanical property test system with maximum temperature up to 1 200°C and maximum applied load up to 3,200 N has been realized for the first time in the world.

During the 5 years, according to the task requirements of the funding plan, the project team fully completed the development task, and 9 development indicators all met the acceptance requirements of the project plan, among which 8 indicators were better than the planned task indicators. The project developed the international leading force and heat coupling MEMS chip with independent intellectual property rights, in situ mechanical test instrument for TEM, multi-channel electrical signal transmission circuit board and other core components and supporting application analysis software. The problem of stability and stiffness of structural elements within finite space for SEM chamber was solved, and the limitation of structure compatibility, electromagnetic compatibility and vacuum compatibility was broken through. In the process of dynamic loading, high-resolution imaging of in-situ field of view of the sample microregion, high-precision measurement of mechanical properties, high stability and long-term operation were realized. By means of automatic potential balance design, the worldwide problem of high temperature hot electron flooding secondary electron imaging signal in SEM above 1,000°C was solved, and high quality SEM imaging was realized at 1,200°C.

The successful development of "in situ system" enables our country to have an international leading platform for dynamic, real-time and cross-scale characterization of material microstructure based on electron microscopy. The integrated equipment has been industrialized and applied to the development and research of high temperature structural materials such as nickel-based single crystal superalloy in China. At the same time, during the development of the project, we have cultivated a number of excellent talents in the development of experimental instruments, some of whom have grown into the world's outstanding academic leaders in this field, laying a good foundation for the development of experimental technology and scientific instruments in this field in China.

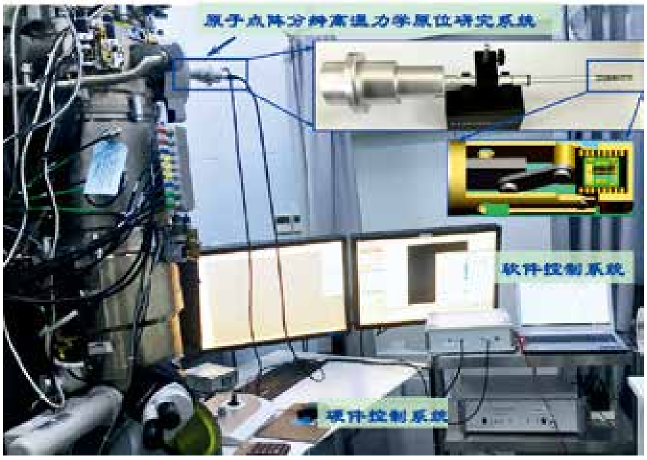


Figure 3-2-1 Atomic lattice resolution high temperature mechanics in situ study system

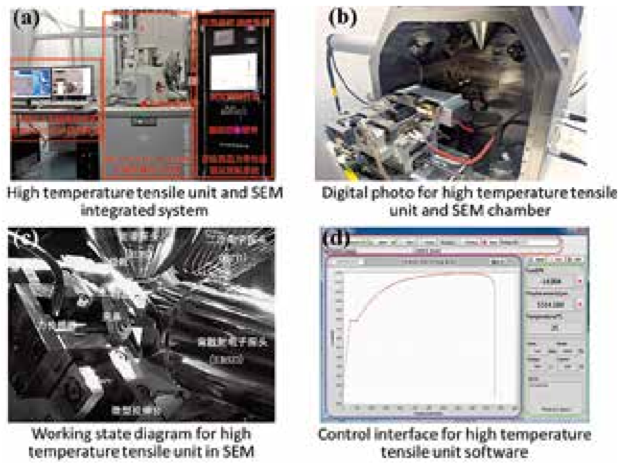


Figure 3-2-2 Nanometer resolution high temperature mechanics in situ research system

Ultrahigh Spatial-temporal Resolution MeV Ultrafast Electron Diffraction and Imaging Facility

The project of “MeV ultrafast electron diffraction and imaging facility” was supported by NSFC with a funing of 85 million yuan. The implementation period was from January 2014 to December 2018. This project was undertaken by Prof. Xiang Dao’s team at Shanghai Jiao Tong University, in collaboration with scientists at Peking University and Tsinghua University.

The goal of the project is to develop new instrument that will meet the challenge to understand and manipulate the intriguing properties of matter emerging from complex correlations of atomic and electronic constituents. The most essential process of the material occurs at the time scale of femto second and the space scale of Angstrom. The science of material, energy and life has developed from observation, understanding to controlling. One of the greatest scientific challenges is to observe the structure and dynamical process of material at atomic spatial scale and femto second time scale. This project applied accelerator technology to solve the grand challenges in probing matter with femto second time resolution and Angstromspatial resolution. The meV ultrafast electron diffraction and imagingfacility can be operated in three modes: ultrafast electron diffraction, ultrafast microscopy and ultrafast lens-less coherent diffraction imaging.

After this project had been completed within the 5-year implementation period, it is then tested and accepted by NSFC. The core subsystems, including ultrafast laser system, high-brightness electron source, high-stability RF system, superconducting magnetic lens system, and other supporting subsystems have been developed and assembled. By developing new techniques for electron bunch pulse compression and arrival time jitter correction, the research team is able to push the time resolution to the 10 fs regime. With this facility, the research team has studied laser induced heating effect in Gold, atomic view of melting and negative expansion of interatomic distances in metallic melts, charge density wave dynamics in $TiSe_2$, diffuse scattering in graphite and Gold, etc. It is expected that this state-of-the-art MeV Ultrafast Electron Diffraction and Microscopy Facility will open up many new opportunities in ultrafast science, making significant contribution to the understanding and manipulation of basic process in physics, chemistry and biology.

Figure 3-2-3 Layout of the MeV ultrafast electron diffraction and imaging facility

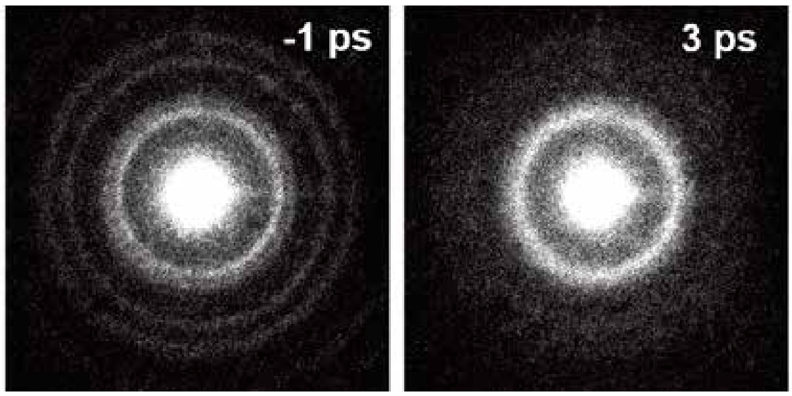


Figure 3-2-4 Atomic view of Aluminium melting: single-shot diffraction pattern before (-1 ps) and after the laser excitation (3 ps)

Development of Cold Neutron Inelastic Scattering Spectrometers

The project of “Development of cold neutron inelastic neutron scattering spectrometer” is granted by NSFC. The project funding is 111 million yuan, from January 2013 to December 2018. Based on China Advanced Research Reactor (CARR) at China Institute of Atomic Energy (CIAE), it is planned to develop a suite of advanced cold neutron inelastic scattering spectrometers consisting of a polarized triple-axis spectrometer "XINGZHI" and a multi-axis crystal spectrometer "BOYA". This project is led by Prof. Bao Wei, Renmin University of China, and carried out by Bao's group and CIAE.

The two complementary spectrometers will incorporate the newest developments in inelastic neutron scattering techniques around the world and take advantage of the characteristics of CARR. Through the innovation of key techniques, the optimization of instrument configuration and the development of control systems, the suite of spectrometers in this project will provide the capacity of polarized neutron scattering, high-resolution neutron spectroscopy and high measurement efficiency, and form a critical scientific platform in the advanced spectroscopic research on microscopic mechanism of magnetic and correlated electronic matters and other novel functional materials.

It takes more than six years to accomplish the construction of "XINGZHI" and "BOYA", based on the requirements of the approval report. All the specifications reach the acceptance requirements, major specifications are world advanced, and the detection efficiency of "BOYA" is leading around the world. The research team creatively propose the concept design of using the S-bender polarizer before and after the sample, and achieve the polarization rate of 90% in the range of total energy, and up to the maximum polarization rate of 96%; By developing the HOPG crystal array and the detector array, 6 different final energies of scattered neutron can be analyzed for the 17 momentum transfers in a total coverage of 120°, and the detection efficiency is up to 80 times as much as that of the traditional triple-axis spectrometer; it is the first time that the up-down type of shielding system with the Sandwich construction is designed and manufactured in China, which improve the range of incident neutron energy greatly; A kind of rotation stage and method is also developed to adjust the sample scattering plane for the first time in China.

Attributed to "XINGZHI" and "BOYA", China owns a world advanced neutron inelastic scattering platform, which has been open to the national users, such as Institute of Physics, CAS, and South University of Science and Technology of China, and will be open to the international users, for the research about the physical properties of magnetism. It is expected to create new research opportunities in the physical, material, and chemical fields in the near future. At the same time, by the construction of the two spectrometers, not only a group of excellent people are trained, but also the factories are bred for manufacturing major scientific research instrument in the field of neutron scattering instrumentation, which lays a good foundation for building instruments in the field of neutron scattering in China.

Figure 3-2-5 Cold neutron polarized triple-axis spectrometer “XINGZHI”

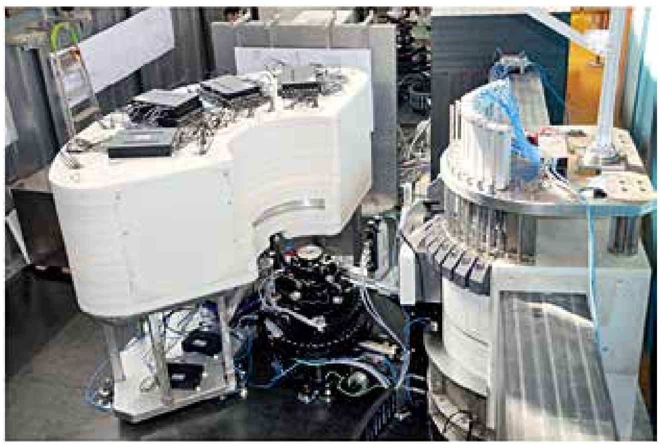


Figure 3-2-6 Cold neutron multi-axis crystal spectrometer “BOYA”

Single-Cell Spatiotemporal-Resolved Molecular Dynamic Analysis System

The project of “Single-cell spatiotemporal-resolved molecular dynamic analysis system” was launched by NSFC in 2013. The total funding for the project is 64 million yuan, with the implementation period from January 2014 to December 2018. Chen Hongyuan, academician of CAS, professor of School of Chemistry and Chemical Engineering of Nanjing University, serves as the project leader, and the research team includes researchers from Tsinghua University, Southeast University, and Chinese Academy of Medical Sciences.

This project takes the dynamic molecular processes in single cells as representative research systems, takes the precise acquisition of weak signals of intercellular and intercellular molecular interactions as the breakthrough points, integrates the unique advantages of electrochemistry, optical spectroscopy and mass spectrometry technologies, and finally develops a high-resolution intracellular biomolecular dynamic analysis instrument—“Single-cell spatiotemporal-resolved molecular dynamic analysis system”. This is the world's first high-resolution instrument for single-cell molecular dynamic analysis combined with the advantages of electrochemistry, optical spectroscopy and mass spectrometry.

Figure 3-2-7 Overall image of Single-cell spatiotemporal-resolved molecular dynamic analysis system

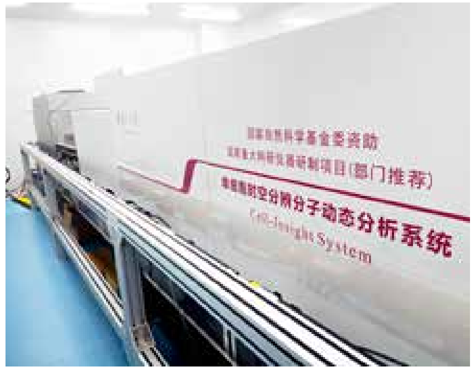


Figure 3-2-8 Part of Single-cell spatiotemporal-resolved molecular dynamic analysis system

During the five-year implementation period, the project has been successfully implemented in accordance with the research plan, with total research strength of more than 2,500 person months. The research team completed the development of single cell electrochemical measurement, single cell spectral imaging, single cell mass spectrometry imaging and other modules, the function optimization of each module, and the assembly of the whole “Single-cell spatiotemporal-resolved molecular dynamic analysis system”. The technical performance indexes have reached or are better than those specified in the plan.

(1) The team developed the world's first “Single-cell spatiotemporal-resolved molecular dynamic analysis system”, which combines the unique advantages of electrochemistry, optical spectroscopy and mass spectrometry in single cell analysis, and solves the problems of high spatiotemporal resolution and precise extraction of weak signals in the dynamic process of intracellular molecular reaction.

(2) A Nano-kit for the analysis of biomolecular chemical activity of single (sub) cell was established, and the electrochemical detection of biomolecular activity in a single organelle of about 50 nm in a single cell was realized for the first time.

(3) The team established the measurement method of energy fluctuation in single cells. The measurement of heat transfer coefficient in different space of single cell is realized for the first time. The heat transfer and dissipation within warm-blood or cold-blood animals are clarified, and a closed-loop control of heat generation and dissipation in single cell is revealed.

(4) An ultra violet VUV mass spectrometry imaging device was developed. The biological molecules were directly ionized by VUV, the ionized fragments were far lower than SIMS, and the imaging spatial resolution was better than 500 nm.

During the development of the instrument, a series of high-level research papers have been published. About 41 invention patents and 1 international patent have been applied, in which 18 has been authorized. The team members have been invited to talk on international academic conference for more than 30 times, and on domestic academic conference for more than 100 times, which has enhanced the academic influence of the research team at home and abroad. The project team has set up the world's top scientists' studio of “chemical basis of neural activities” at Nanjing University (funded by Ministry of Education). The project leader, Prof. Chen Hongyuan organized and held the Xiangshan Scientific Conference of "analytical chemistry for life science" under the promotion of this project.

Electrostatic Levitation System for Rapid Solidification of Metallic Materials

This is a large scale new apparatus for rapid solidification research and space materials science developed under the support of NSFC. The present project was granted in 2013. The total amount of funding is 38 million yuan, and the implementation period lasts from January 2014 to December 2018. It was designed and manufactured by a research team directed by CAS Academician Wei Bingbo from the Laboratory of Space Materials Science and Technology in Northwestern Polytechnical University.

The extraordinary solidification of metallic materials and the ground simulation of microgravity environment are essential subjects for both materials science and space science. According to the National Strategy for Medium and Long-term Scientific Development, China is about to embrace a space station era in the year of 2020 to 2030. This experimental system has been developed on the basis of electrostatic levitation technique, which can simulate outer-space environments like microgravity, containerless state and ultrahigh vacuum, to accomplish the extraordinary solidification of metallic materials. A series of scientific and technological problems such as intrinsic physicochemical properties and rapid solidification mechanisms of liquid alloys are effectively solved by utilizing these extraordinary conditions.

As presented in Figure 3-2-9, this system occupies an area of 110 square meters and exceeds 2 meters in height. The original design ideas, blue prints and kernel control programs are all fulfilled by the research team independently. Several progresses have been made at least in three key techniques and important scientific issues (Figure 3-2-10), which are levitation capability, containerless rapid solidification and thermophysical properties. Firstly, the electrostatic levitation ability has been improved to set a new record of 15 mm sample size, which almost triples the previously published international record. Secondly, the liquid supercooling and containerless solidification of tungsten, which is the most refractory metal in nature with a melting point up to 3,422℃, have been achieved under electrostatic levitation condition. And the in-situ observation and measurement on its rapid solidification have been accomplished for the first time to reveal the dendritic growth mechanism within liquid tungsten. Thirdly, the ultrafast solidification of metallic materials has been realized, where liquid titanium displays a dendritic growth velocity as high as 122 m/s on account of the parallel optical detection and precisely active control performance in the system. Moreover, it integrates the five experimental functions including electrostatic levitation, thermophysical property measurement, rapid solidification, material preparation and realtime data analysis. The relevant investigations are being conducted on thermophysical properties, rapid solidification mechanism and novel material synthesis of refractory alloys, titanium alloys, and nickel based super-alloys.

Figure 3-2-9 Electrostatic levitation system for rapid solidification of metallic materials

The project successfully passed the acceptance test in 2019. On the basis of this innovative instrument, the research on solidification science and space science in China will be facilitated to a desirable extent. It helps to update the preparation technique of traditional materials and push forward the research and development on new materials. Meanwhile, it may also promote the research on fluid science under stimulated space environments. Besides, this system is even capable of evolving into a platform mounted on China's space station after a miniaturization design.

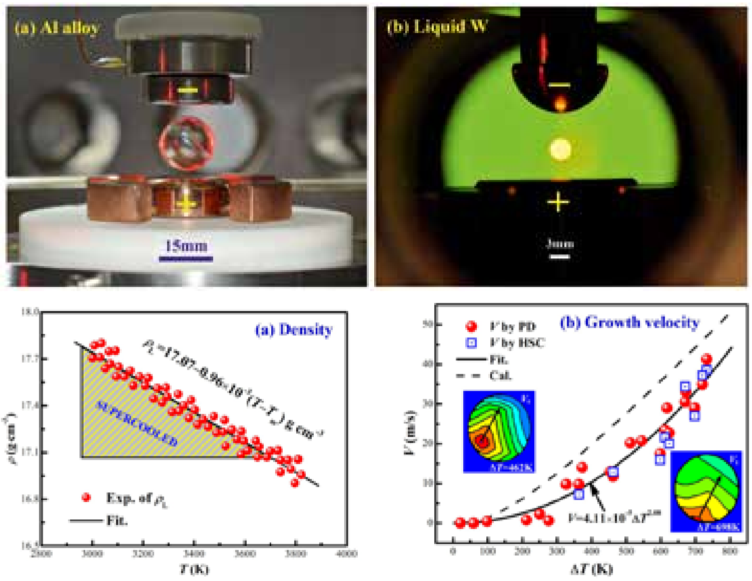


Figure 3-2-10　Investigation of the fast solidification in the electrostatic suspension

Solid-State Multi-Functional Quantum Memory

The project of "Solid-state multi-functional quantum memory" was initiated by NSFC in 2013. This project implementation period is from January 2014 to December 2018, with a special funding of 57 million yuan, which is undertaken by the team led by Academician Guo Guangcan of the University of Science and Technology of China.

Quantum Information Science has revolutionized solutions for secure communications and high performance computation. Based on quantum mechanical principle, unconditional secure key distribution can be achieved by quantum key distribution. Meanwhile quantum parallelism enables quantum bit processors to generate much higher computing power than classical computers. The quantum repeater based on quantum memory can overcome the problem of exponential loss of photon in the transmission channels and make the long distance quantum communication network over 500 kilometers possible. Distributed quantum computation network based on quantum memory can carry out quantum parallel computation among different places. Therefore quantum memory is the core element of quantum networks, and the construction of practical quantum networks relies on the physical implementation of high-performance quantum memory. In order to promote the construction process of practical quantum networks, the team of this project has developed the solid-state multi-functional quantum memory with high fidelity, wide bandwidth, multimode capacity and long storage time, which specifically includes a long-lived solid-state quantum memory and a broadband solid-state quantum memory, based on two types of rare earth ions doped crystals.

After five years of work, the team successfully developed the solid-state multi-functional quantum memory; all figure-of-merits fulfill the requirements of the funding plan and some of them are among the best performances in the community worldwide. The solid-state quantum memory has a storage time of 2.067 ms, a slow light transmission speed of 700 m/s, a storage bandwidth of 1,046 MHz, a storage fidelity of 99.8%, a storage mode number of 100, and a photon pair brightness of 3,025 photon pairs/s/100MHz. The relevant achievements and core technologies have been published in some famous academic journals such as *Nature Photonics*, *Nature Communications* and *Physical Review Letters*. Several important results have been reported: (1) The solid-state quantum memory for deterministic single photon generated by quantum dot is realized, and a prototype quantum network based on two heterogeneous solid-state systems is constructed. (2) The solid-state quantum memory for high-dimensional orbital-angular-momentum encoded quantum state. (3) The multifunctional and multiple-degree-of-freedom quantum memory. (4) A rigorous test of macro reality (LG inequality) is realized using the solid-state quantum memory.

The successful development of the multi-function solid-state quantum memory enables the high-performance quantum storage of single-photon, which provides a core device for the large-scale quantum network and distributed quantum computing, and promotes the construction process of long-distance quantum communication in China. At the same time, in the project development process, a series of key technologies such as high-dimensional quantum memory, multiple-degree-of-freedom quantum memory, narrow linewidth high-energy laser pulse generator, ultralow temperature electron and nuclear double resonance were developed. Many young researchers with specialty of instruments construction are well trained during this project, who may contribute a lot to the quantum information field in China.

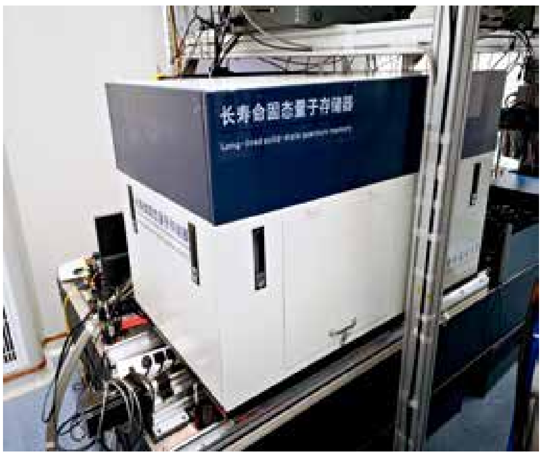


Figure 3-2-11 Long-lived solid-state quantum memory

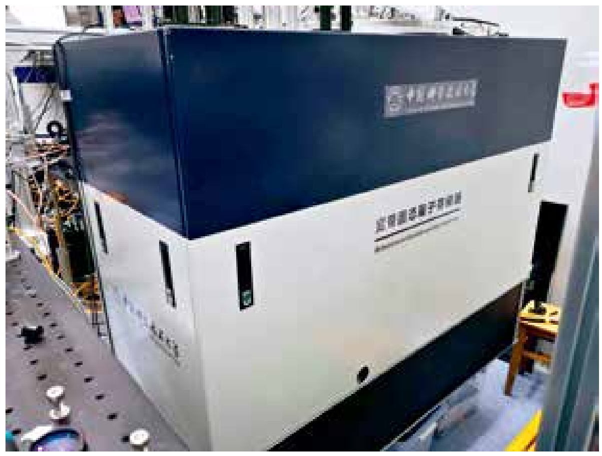


Figure 3-2-12 Broadband solid-state quantum memory

Real-Time, Ultra-Large-Scale, Imaging at High-Resolution Macroscope RUSH

The project of "Real-time, ultra-large-scale, imaging at high-resolution macroscope" (referred to the "RUSH" thereafter) is granted by NSFC in 2013. The implementation of the project began in January 2014 and ended in December 2018, with a special funding of 80 million yuan. The project was led by Academician Dai Qionghai's team at Tsinghua University and was jointly constructed by Zhejiang University, Shanghai Institute of Optics and Fine Mechanics of CAS, Army Medical University, Huazhong University of Science and Technology, and Shanghai Institute of Life Sciences of CAS.

Aiming at the urgent requirements of life science and medicine, especially for neuroscience and oncology, working through the interdisciplinary studies of optics, microelectronics, computer vision, and signal processing, and treating the principles of computational photography as the core, the whole team of the project successfully established a compressed-sensing-based model, proposed a computational framework composed of light field detections, structured illuminations, and compressive reconstruction, and explored the techniques such as temporal focusing and multispectral relighting. In addition to a custom-designed large-scale image sensor array and a distributed, high-throughput, parallel computing and storage architecture, the team finally constituted a giga-pixels-level multi-dimensional and multi-scale imaging instrument with both a wide field of view and high speed. This new-generation imaging instrument has achieved the goal of simultaneous observation of macroscale field of view and high-resolution microscale details, which accomplished the tasks and objectives of the project with groundbreaking progresses. The project emphasized on the construction of the prototype with a field of view of 1 square centimeter and a resolution of 0.4 micron. In order to overcome the inherent tradeoff between the wide field of view and high resolution, the team completed the objective design with a centimeter-scale field of view and micron-scale resolution through curved-surface imaging and field-division detection. The intermediate image of the curved surface was obtained, and then the intermediate image was acquired by multiple image sensors in parallel corresponding to different regions to achieve full-field-of-view coverage. The team fabricated and assembled an objective of 14 lenses (total 11 groups), with the numerical aperture of 0.43. The curved surface radius of the intermediate image was 2016 mm, while the Modulation Transfer Function (MTF) at the sample surface was more than 25% @ 500lp / mm, with the distortion less than 0.5%. In the meantime, through the precise co-calibration of multiple image sensors, whose re-projection error is only 0.2 pixel, the team realized the assembly of 28 high-sensitivity image sensor modules, and the construction of the software and hardware platform for computational light field. By integrating both optics and computation, the team realized the adaptive high-speed concurrent storage, reconstruction, and display of large-scale giga-pixel image files.

Figure 3-2-13 Real-time, ultra-large-scale, high-resolution macroscope

The instrument attained multi-scale high-speed observation of both systematic morphology and detailed structures, across temporal, spectral, and spatial dimensions for the dynamics ranging from subcellular structures (submicron level) to tissue (centimeter level). As for applications, the team has made full use of the multi-dimensional and multi-scale imaging ability in both neural recording and tumor metastasis in mice. The results was used to for many studies including virus genetics, neuron-damage mechanism, neuropathology, and neuron-regeneration mechanism. In addition, the team has established and improved multiple in vitro and in vivo models of tumor invasion and metastasis, and built the basic database of the large-scale observation of tumor metastasis, which could be of great significance to the life science and medicine, especially to neuroscience and oncology.

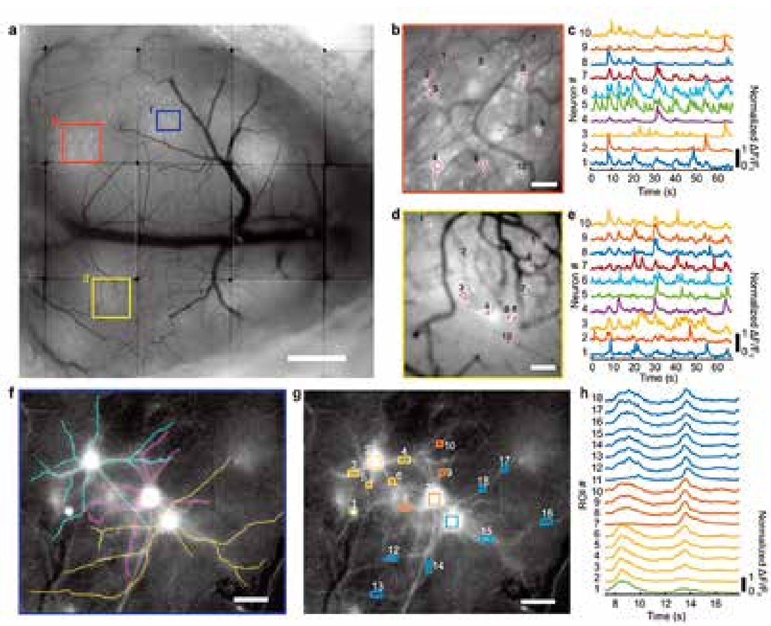


Figure 3-2-14 Dynamic imaging results of neural activity whole cerebral cortex in mice

Ultrahigh Sensitive Magnetic Field and Inertial Measurement Experimental Research Device Based on Atomic Spin Effect

The project of "Ultrahigh sensitive magnetic field and inertial measurement experimental research device based on atomic spin effect" is initiated by NSFC in 2012. The total funding of the project is 88.5 million yuan, and the implementation period is from January 2013 to December 2018. The project is initiated by the team led by Academician Fang Jiancheng of Beihang University, and jointly undertaken by Shanxi University, East China Normal University, Institute of Chemistry, Institute of Physics, and Academy of Mathematics and Systems Science of CAS.

Breakthroughs in the field of fundamental physics, brain science and medicine, and high precision inertial navigation, etc. urgently need ultrahigh sensitive measurement unit for magnetic field and inertial detection. Based on atomic spin effect, ultrahigh sensitive detections on magnetic field and inertia can be realized. Its theoretical sensitivity can be substantially beyond the existing method, thereby promoting the discovery of new natural phenomenon, new scientific laws, and in the service of our country's national defense. The project lasted 6 years, and fully completed the set objectives according to the task requirements of the funding plan. The project based on atomic spin effect, an ultra-high sensitive magnetic field and inertial measurement technology were development in-depth. The problems on precision control of spin polarization and high precision detection of atoms spin were explored. The key technologies on anti-relaxation alkali vapor cell, high performance magnetic shielding and magnetic compensation, SERF atomic spin polarization and precision detection, diamond NV center quantum state control and detection, etc. were broken through. Three platforms including ultrahigh sensitive magnetic field measurement based on the spin of SERF atoms, ultra-high sensitive inertial measurement based on the spin of SERF atoms, and inertial measurement controlled by structure-limited medium materials and embedded atoms were successfully developed. Among them, the ultrahigh sensitive magnetic field measurement platform based on the spin of SERF atom has a sensitivity of 0.089 fT/Hz1/2, the ultra-high sensitive inertial measurement platform based on the spin of SERF atom has a sensitivity of 6.8 e-8 o/s/Hz1/2, and the inertial measurement sensitivity of the platform controlled by structurally-limited medium materials and embedded atoms is 4.6 e-5 o/s/Hz1/2.The indexes of the three platforms are all greater than the highest reported index abroad that demonstrate the research group reaching the international advanced level.

The projet has fostered a number of talents on quantum precision measurement. Lots of research achievements are put into practice successively. Based on the ultrahigh sensitive magnetic field

Figure 3-2-15 Ultrahigh sensitive magnetic field measurement platform based on the spin of SERF atom (left), ultra-high sensitive inertial measurement platform based on the spin of SERF atom (middle), and inertial measurement sensitivity of the platform controlled by structurally-limited medium materials and embedded atoms (right)

measurement technique, the project team has developed miniaturized SERF magnetometers used in Tiantan hospital for heart and brain magnetic field measurement of rats, and in the tenth people's hospital of Tongji university for the cell magnetic measurement. Based on the ultra-high sensitive inertial measurement technique, the project team has improved the measurement sensitivity of exotic spin-spin-velocity-dependent interactions significantly, and developed miniaturized atomic spin gyroscopes, which would support the long time and high precise inertial navigation. Inertial measurement technology based on structure-limited medium materials and embedded atoms, the project team has developed miniaturized NV magnetometers. They have merits of large measurement range and low requirement for the environment magnetic field, and are suitable for array-magnetometer detecting the heart and muscle magnetic field.

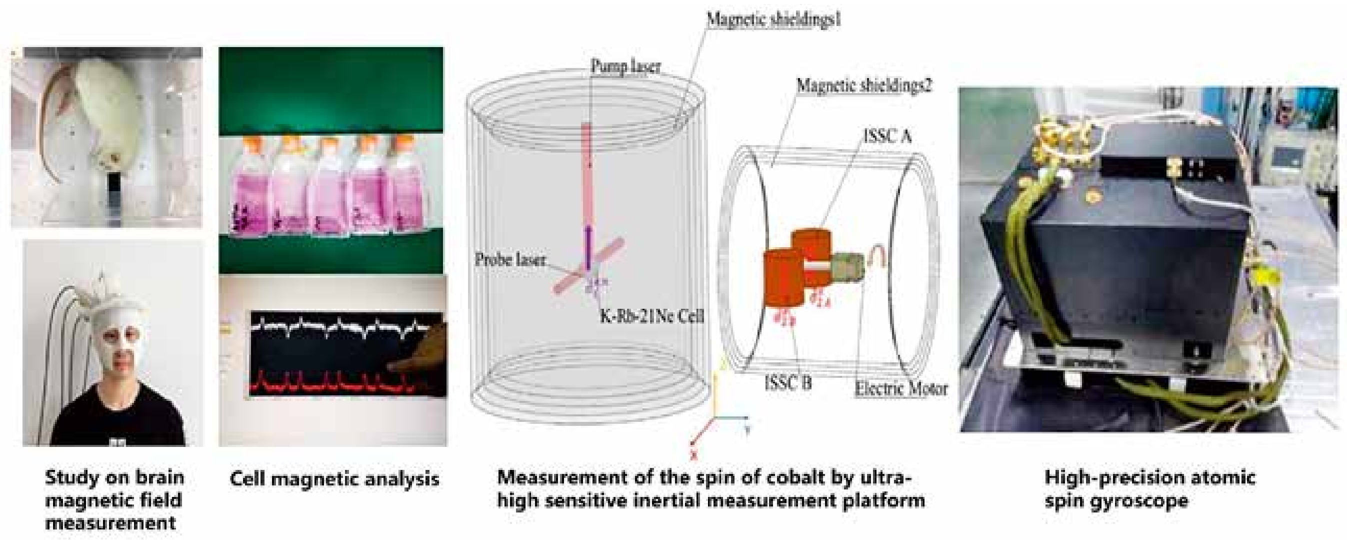


Figure 3-2-16 Applications of this project

Introduction to New Generation of Time/Frequency System

The project of "New generation of time/frequency system" is granted by NSFC in 2011. This project which has been carried out and completed by Professor Zhang Shougang's team from the National Time Service Center of CAS, with a total funding of 35 million yuan and duration from January 2012 to December 2018.

Time is the basic physical quantity that characterizes the movements of matters. Defined by the period of matter movement, frequency and period are inversely related to each other. The time/frequency is the physical quantity with the highest measurement accuracy. Signals of time/frequency can be transmitted by electromagnetic waves and applied directly to scientific research and engineering. High-precision time/frequency has become a vital parameter to a nation's science and technology, economy, military and social life, linking the security and stability of the country and society.

Facing the urgent need of the high-precision time-frequency instruments for the important basic research and engineering application, Zhang Shougang's team spent 7 years on systematic and in-depth research on theory and method regarding to signal generation, transmission and measurement with a series of breakthroughs in key technologies independently and controllably. Based on this, a new generation time-frequency system has been developed, including the cesium atomic fountain clock device, the strontium optical atomic clock device, the fiber optic time-frequency transfer device and the time-frequency measurement device, some indicators of which have reached the international leading position. The successful development of the cesium atomic fountain clock device calibrates the national standard time UTC (NTSC) and fosters a capability of automatically calibrating the national standard time UTC (NTSC) to support the construction of the self-dependent national time-frequency system. In cooperation with Chengdu Tian'ao, the largest atomic clock manufacturer in China, The research team developed the self-controllable and small optical pumping cesium beam atomic clock, and achieved mass production. It breaks the foreign technology blockade against China and has been used in navigation and many other fields. The research team successfully developed the strontium optical atomic clock device, reaching a system uncertainty E-17. The research team proposed and demonstrated a new method for the generation of cooling light sources for optical atomic clocks which used cascaded optical pumping to select and amplify the modes of the optical frequency comb, successfully realizing the cooling light source with a narrow line-width. And The research team also completed a series of physical investigations such as the precise measurement of the Lande-g factors of the clock transition states. Through cooperation with companies, The research team have mastered the design, processing and coating technology of ultra-high-fine optical reference cavities, breaking the foreign technology blockade; the fiber optic time-frequency transfer equipment and high-precision time-frequency measurement equipment developed by them can meet the urgent needs of the country: A two-way optical phase comparison based on local measurement and a scheme of relay station for unidirectional optical amplification and noise amplification suppression were proposed, and an automatic frequency-locked ultra-stable laser system was developed, so that the problems in accurate compensation of phase noise and high-reliability optical frequency cascade transfer relay within long-distance fibers, time and frequency signal synchronous transmission and other key technology areas could be solved.

Through the implementation of the project, a scientific experimental platform based on time-frequency precision measurement has been established. Some of the devices developed in this project have been used in the "space station time-frequency science experiment system", the 13th "Five-year" national major science and technology infrastructure-"high-precision ground-based time service system", and the national major science and technology infrastructures-the traceability of the long and short wave time service system, the time monitoring of the Beidou navigation system, the monitoring of the integrity of the on-board time-frequency signals and others. This has provided great support for the construction of the national major engineering projects.

Figure 3-2-17 Developed atomic fountain clock

Figure 3-2-18 Optical fiber time transfer device being applied to the time monitoring of the Beidou satellite navigation system

3.3 Selected Excellent Research Achievements funded by NSFC

Study of Three-Dimensional Quantum Hall Effect

Quantum hall effect (QHE) is one of the most important scientific discoveries in condensed matter physics since the 20th century. In the past, the observation of the QHE was limited to two-dimensional systems. Although more than 30 years has passed since the QHE in three-dimensional systems was first put forward, due to the dissipative motion of electrons in three-dimensional space, it has not been realized in experiments, and thus it has become a research field of intense competition among scientists worldwide. Supported by the programs from NSFC, the scientists have creatively proposed a new quantization theory and an experimental scheme, and took the lead in observing the three-dimensional QHE in the world. The achievements are as follows:

(1) Prof. Lu Haizhou and his collaborators predicted a new mechanism of three-dimensional QHE in theory. Previously, the two-dimensional QHE is originated from the two-dimensional cyclotron motion of electrons in a strong magnetic field. They proposed to construct a three-dimensional cyclotron motion by using the Fermi-arc surface states on the upper and lower surfaces of topological semimetals and the "quantum wormhole tunneling effect", so as to realize the quantization of Hall conductance in three-dimensional systems. This mechanism provides a new way to realize three-dimensional QHE.

(2) The research team of Prof. Xiu Faxian of Fudan University has achieved the quantized conductivity in the topological semimetal cadmium arsenide with a thickness of 100 nm and realized the three-dimensional QHE. By constructing the Weyl orbit composed of the Fermi arcs on the upper and lower surfaces and the chiral Landau levels, the electrons in the Fermi arcs can tunnel up and down through the chiral Landau levels, forming the three-dimensional quantized orbit unique to the topological semimetal. The team further proposed the idea of using wedge-shaped samplesfor the low-temperature transport and revealed the electron tunneling process in three-dimensional space. And the team finally confirmed that the QHE in the three-dimensional topological semimetals originates from the quantized Weyl orbit in the three-dimensional space.

(3) Prof. Zhang Liyuan of South University of Science and Technology and Prof. Qiao Zhenhua of University of Science and Technology of China, together with Prof. Yang Shengyuan of Singapore University of Science and Technology, realized the three-dimensional QHE by the electron correlation mechanism under the action of strong magnetic fields in the three-dimensional electron gas system of high-quality zirconium telluride crystals. This verified the theoretical prediction of Professor Bertrand Halperin in 1987. Through quantum transport experiments, the three-dimensional structure of the electronic state and its topological evolution process are reconstructed. Different from the two-dimensional system, a two-dimensional conducting state protected by topology is formed at the side edge of the system, and more abundant electronic states are presented.

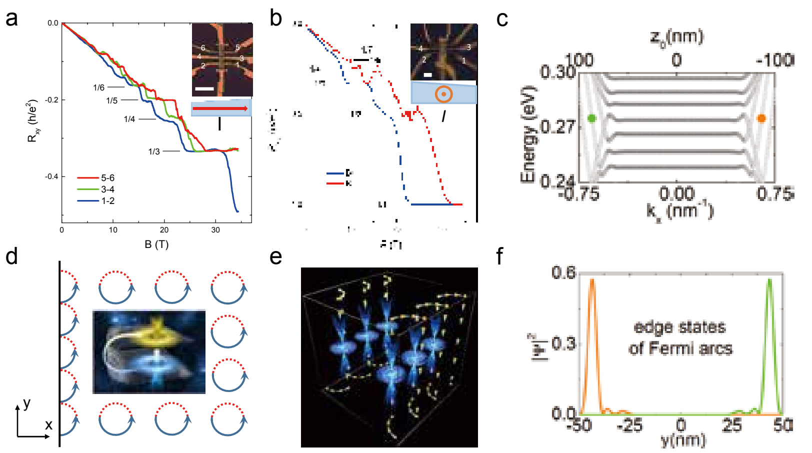


Figure 3-3-1 The three-dimensional quantum Hall effect based on Weyl orbits

The experimental realization of three-dimensional QHE provides a new idea and experimental basis for the future three-dimensional quantum transmission. Research results were published in *Nature* (2 articles), *Nature Materials* (1 article), *Nature Communications* (2 articles), *Physical Review Letters* (1 article), and *National Science Review* (1 article). Two papers were selected as ESI highly-cited papers.

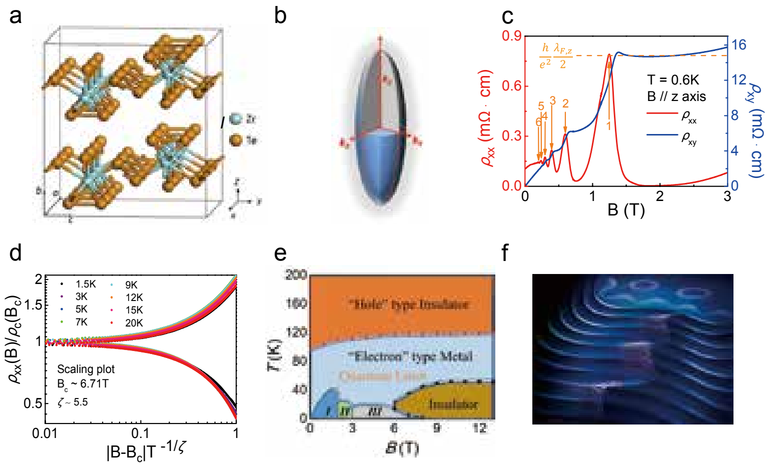


Figure 3-3-2 The three-dimensional quantum Hall effect in $ZrTe_5$

Research on Modular Structures of Kloosterman Sums

Motivated by the Sato-Tate conjecture for elliptic curves, Nicholas Katz formulated the Sato-Tate conjecture for the horizontal distribution of Kloosterman sums in 1980, for which he also proposed a problem on modular structures of Kloosterman sums: Whether there exists a certain Hecke-Maass form, for which the Hecke eigenvalue of the p-th Hecke operator can coincide with the Kloosterman sum mod p? If yes, one could construct an Euler product with such Kloosterman sums as local factors, and this would be essentially the L-function of some Hecke-Maass cusp forms, which is believed to be a very strong analytic tool for the resolution to Sato-Tate conjecture for Kloosterman sums.

The celebrated Taniyama-Shimura conjecture asserts that elliptic curves over the field of rational numbers can be related to modular forms, so that the Hasse-Weil zeta functions for such elliptic curves correspond to L-functions of some modular forms (Andrew Wiles proved this modularity theorem for semistable elliptic curves, which was enough to imply Fermat's last theorem, and the proof for the full modularity theorem was later completed by Christophe Breuil, Brian Conrad, Fred Diamond and Richard Taylor). Moreover, the Sato-Tate conjecture for elliptic curves over Q has been proven by Laurent Clozel, Michael Harris and Richard Taylor based on their deep investigations on the relevant symmetric power L-functions. Compared with the case of elliptic curves, however, analytic tools that are ready for studying the Sato-Tate conjecture for Kloosterman sums are quite limited, and this phenomenon motivated Katz to propose his problem on modular structures.

The modular structure of Kloosterman sums has remained mysterious for quite a long time before 2000, when Andrew Booker made a first progress. Roughly speaking, he can prove that if Kloosterman sums and Hecke eigenvalues could do coincide at prime arguments, then the relevant Maass form should have a very large conductor. This provides some evidences for the negative solution to Katz's problem from a numerical aspect.

Supported by NSFC, Xi Ping in Xi'an Jiaotong University made a recent breakthrough in the problem of modular structures of Kloosterman sums, and the relevant work has been published online by *Inventiones* *mathematicae*. A special case of Ping Xi's work asserts that for any given Hecke-Maass cusp form, there do exist infinitely many almost primes (integers with a bounded number of prime factors) such that relevant Kloosterman sums and Hecke eigenvalues cannot coincide. As pointed out by the referee, "The main result of the paper under review is an evidence that the answer to Katz's question is likely negative, for Maass cusp forms as well.""An important aspect is that very little is known about Hecke eigenvalues of Maass forms (the analogue of Deligne's bound, for instance, is still a conjecture). The results of this paper seem to be the first of their kind in this problem", and "the fact that one can successfully estimate of $H(N)$ for $\eta \neq 0$ is surprising, given how little information is known on $\lambda f(p)$, and in my point of view it is the main innovation of the paper."

The above work by Ping Xi can convince us that it seems unlikely to establish the modular structures of Kloosterman sums following Katz's original path, and a new approach is highly desired. A new weighted Selberg sieve is introduced in this work combining with the *l*-adic cohomology in algebraic geometry and spectral theory of automoprhic forms. This progress is a typical instance that analytic number theory can be employed effectively to demonstrate some objects in arithmetic geometry, and the underlying methods can also be utilized to attack many other problems in number theory.

Thanks to the infiltration of algebraic geometry, harmonic analysis, dynamical system, representation theory, probabilistic theory, combinatorics and also many other branches with strong interactions, modern analytic number theory has been enjoyed more powerful tools and has a very broad research domain without any well-defined boundary. All of these have proven analytic number theory to be an ambitious area of pure mathematics with vitality and a bright future.

Time Resolved Protein Activation in Situ

Protein is the main executor of life and precise perturbation of protein function with high selectivity and temporal resolution, especially in the gain-of-function manner, and is crucial to dissect various dynamic biological processes. However, for most of proteins, a "universal" protein activation strategy that could be used broadly in living systems is still lacking.

With the support of NSFC, the research teams led by Prof. Chen Peng developed a series of methods of *in situ* protein activation, conducted the study of selective kinase activation *in vivo* and proposed the concept of "bioorthogonal cleavage reaction" and "chemical decaging".

Although the chemical decaging of the active site has emerged as effective strategy for protein activation, only limited caged amino acids can be genetically encoded, as well as many enzymes do not have well-defined catalytic sites, rendering them incompatible with direct decaging. Therefore, a "universal" protein activation strategy that does not directly rely on catalytic residues is highly desired.

To address this challenges, the research teams led by Prof. Chen Peng and Prof. Wang Chu at Peking University collaborated together to develop a time-resolved protein activation strategy based on bioorthogonal decaging and computational design that is both broadly applicable in living system. This general "proximal decaging" strategy is called CAGE-prox with the basic concept that a universal "proximal cage" of unnatural amino acid (UAA) can be introduced by genetic code expansion in close proximity with a protein's functional site for temporal blockage of its activity until being rescued by photo-decaging. In order to identify such an "anchor site" in a protein of interest (POI) and avoid the exhaustive experiments, they first developed a straightforward computational method to figure out at which position in POI the universal "proximal cage" UAA should be introduced. Since the computational method requires no information about a protein's mechanism of action, the CAGE-proxstrategy can therefore be applied to an amazingly wide range of target proteins. Moreover, after CAGE-prox's activation the resulting POI analogue differs from the native counterpart by at most one single amino-acid residue, it can preserve the surface structure, shape and protein-protein interaction almost as the same as the WT protein.

The generality of CAGE-prox was validated in functional manipulation of diverse POIs including GTPases, kinases, RNA demethylases, caspases and bacterial effector protein. The broad applications of the method was demonstrated for selective, temporal probing and/or perturbing of diverse biological processes, including constructing orthogonal kinase signaling cascades, temporal profiling of proteolytic substrates, as well as on-demand liberation of bacteria effect or as the protein-based pro-drug therapy.

With the remarkable simplicity and generality, CAGE-prox offers a new way to studies of previously inaccessible cellular pathways and biological processes in a spatio-temporal manner.

The research was recently published online in *Nature* in 2019, and Prof. Klaus Hahn, an authority in the field at the University of North Carolina Chapel Hill, wrote a highlight of this work in the same issue.

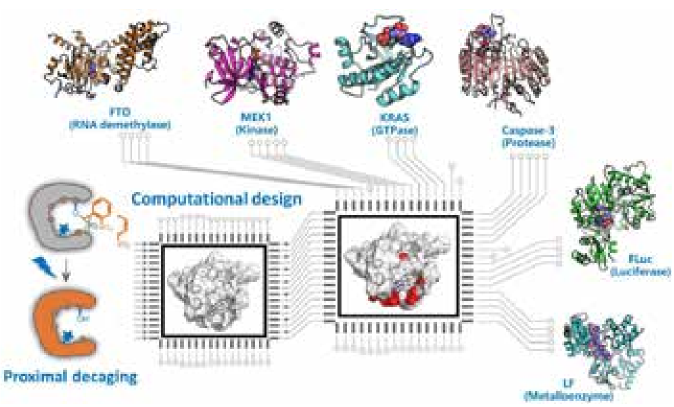
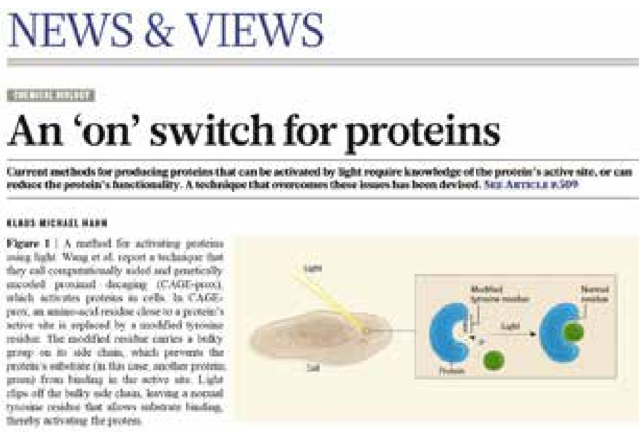


Figure 3-3-3 Computer aided proximal decaging - a general method for *in situ* protein activation



NEWS & VIEWS

An 'on' switch for proteins

Current methods for producing proteins that can be activated by light require knowledge of the protein's active site, or can reduce the protein's functionality. A technique that overcomes these issues has been devised. SEE ARTICLE P.509

KLAUS MICHAEL HAHN

Figure 1 | A method for activating proteins using light. Wang et al. report a technique that they call computationally aided and genetically encoded proximal decaging (CAGE-prox), which activates proteins in cells. In CAGE-prox, an amino-acid residue close to a protein's active site is replaced by a modified tyrosine residue. The modified residue carries a bulky group on its side chain, which prevents the protein's substrate (in this case, another protein; green) from binding in the active site. Light clips off the bulky side chain, leaving a normal tyrosine residue that allows substrate binding, thereby activating the protein.

Figure 3-3-4 The highlight of this research on *Nature*

Scientific Breakthrough in Inorganic Synthesis

Inorganic chemistry and polymer chemistry are two different disciplines in traditional chemistry, especially for their different synthesizing methods. The preparation of inorganic materials in laboratories generally follows classical crystallization while that of polymeric materials follows polymerization/crosslinking. Different crystallization, the polymeric pathway benefits the manufacture of moldable monolithic materials. The moldable construction of inorganic materials remains as a great challenge except in natural biomineralization processes. It is recognized that the learning from nature may realize the moldable construction of inorganic material. In January 2016 and January 2019, NSFC initiated a National Science Fund for Distinguished Young Scholars entitled "Biomineralization" and a Young Scientists Fund entitled "Biomimetic reconstruction of tooth enamel structure by calcium phosphate nanoclusters", respectively. Prof. Tang Ruikang and Dr. Liu Zhaoming from Zhejiang University are these projects' PIs. Their studies aim to develop novel ionic cluster based materials as precursor phases for biomimetic moldable construction of inorganic materials. Three important achievements have been obtained during the studies:

(1) A totally new concept of inorganic polymerization/crosslinking is created, which arises from a fusion of classic inorganic and polymer chemistry by employing the same pathway for material manufacturing. By using end-capping strategy inspired from polymer chemistry, *inorganic ionic oligomers*are firstly demonstrated theoretically and experimentally, which can act as conformable precursors to enable polymerization/cross-linking reactions in inorganic chemistry (Figure 3-3-5).

(2) Inorganic polymerization/crosslinking provides a feasible method for moldable and continuously structured construction of inorganic functional materials from inorganic ionic oligomers, and even can obtain their single crystalline materials readily (Figure 3-3-6). The resulted continuous internal structure within the newly resulted bulk materials at multiple scales can significantly improve inorganic material properties to reach their ideal levels.

(3) Inorganic polymerization/crosslinking can be developed to a new technology to duplicate biomaterials with hierarchical and complicated structure. Particularly, using polymerization/crosslinking of ionic oligomers, the researchers have successfully achieved the biomimetic regeneration of biological tissues, especially human enamel (Figure 3-3-6). These achievements lead an evolution of biomedical repair from *filling* to *regeneration*.

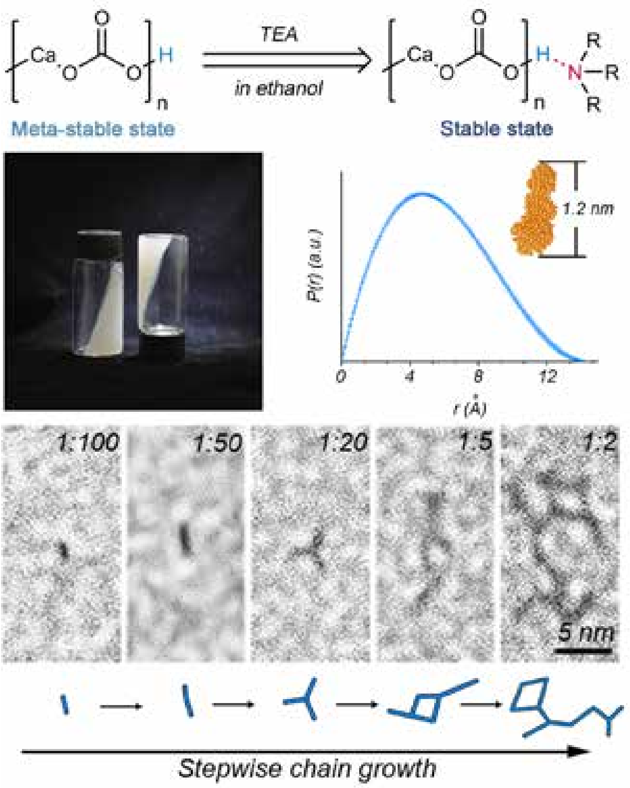


Figure 3-3-5 Inornic oligomers and their polymeraizaiton/crosslinking

With the funding support, these findings have been published in *Nature* and *Science Advances*, as well as 2 patents have been granted. The discovery of inorganic ionic oligomers and the concept establishment of inorganic polymerization/crosslinking are breakthroughs for inorganic chemistry since they enable the syntheses of inorganic materials via a new route analogous to that for organic polymers. They also provide fundamental support to ensure moldable and additive manufacturing of various inorganic materials. More generally, this scientific breakthrough follows a fusion of inorganic chemistry and polymer chemistry with a new overview of synthetic chemistry.

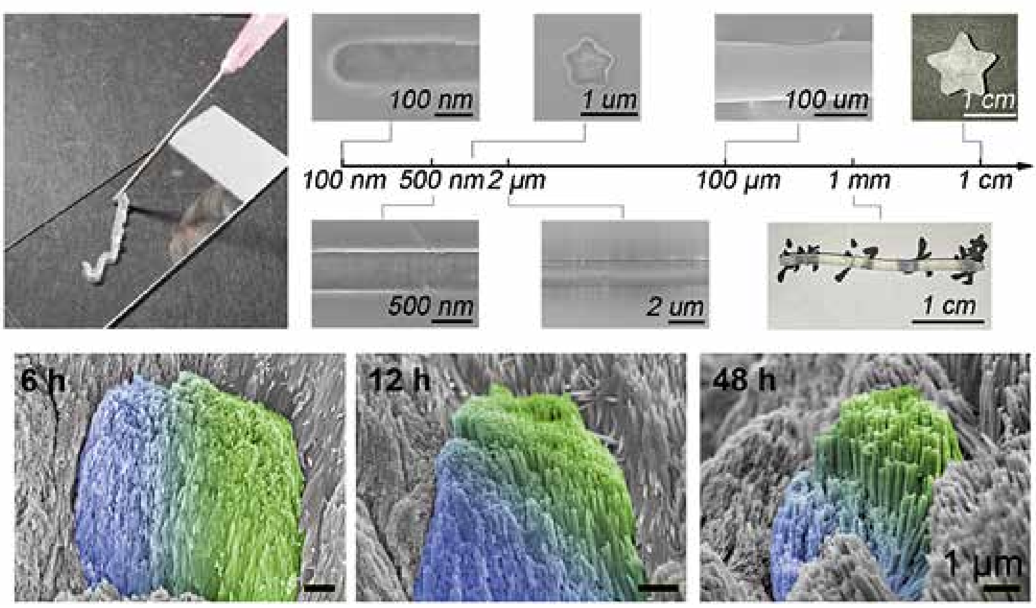


Figure 3-3-6 Moldable Construction of inorganic materials and biomimetic regeneration of human tooth enamel by using inorganic oligomers and their polymerization/crosslinking

Molecular Mechanism Controlling Conspecific Pollen Precedence

One hundred and sixty years ago, Charles R. Darwin described a very interesting phenomenon in his famous "On the Origin of Species" as follows: "It is well known that if pollen of a distinct species be placed on the stigma of a flower, and its own pollen be afterwards, even after a considerable interval of time, placed on the same stigma, its action is so strongly prepotent that it generally annihilates the effect of the foreign pollen; so it is with the pollen of the same species, for legitimate pollen is strongly prepotent over illegitimate pollen, when both are placed on the same stigma" (quoted from Chapter 8 'Hybridism'). Many years later, this phenomenon that the legitimate pollen is strongly prepotent for fertilization over the illegitimate pollen was defined as "conspecific pollen precedence". Conspecific pollen precedence represents one of the prezygotic genetic barriers that lead to isolation of different species, therefore playing a critical role in species formation and evolution. Despite of the discovery of "conspecific pollen precedence" for over one century, the regulatory mechanism controlling this phenomenon at the molecular level is poorly understood. It would have significant impact on application of distant hybridization in crop breeding if the regulation mechanism of conspecific pollen precedence is dissected at the molecular level. Supported by NSFC under two projects entitled "Functional analysis of embryo sac specifically expressed cysteine-rich peptides in Arabidopsis reproduction" and "Functional study of RALF peptides and their receptors in sexual reproduction of Arabidopsis", Prof. Qu Lijia and his research team in Peking University has conducted a systematic study on biological functions of different families of peptides involved in regulation of plant sexual reproduction. They recently made a breakthrough in dissecting the molecular mechanism controlling conspecific pollen precedence in the model dicots plant *Arabidopsis thaliana*. The major novelties of their work are as follows:

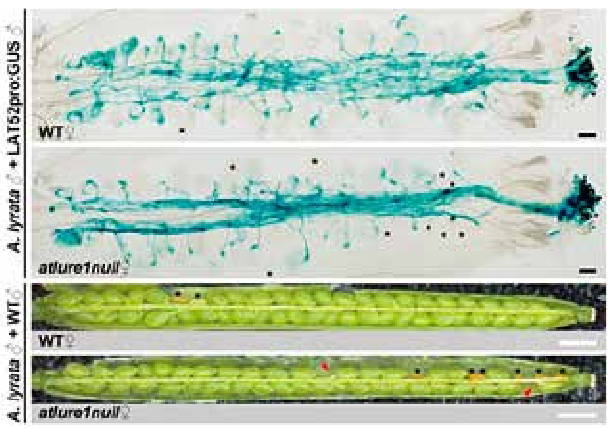


Figure 3-3-7 Pollen tube competition assays revealed that AtLURE1s promoted conspecific pollen precedence for fertilization

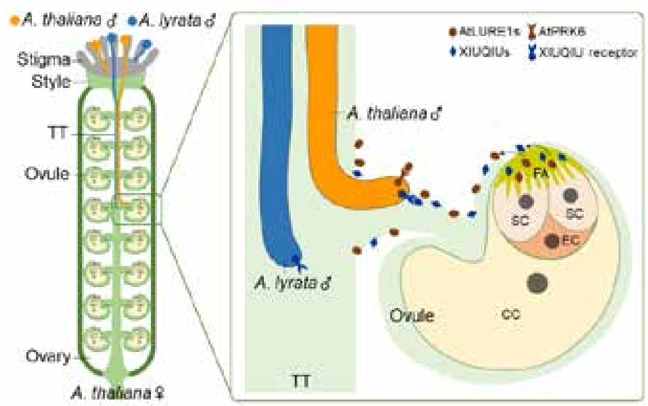


Figure 3-3-8 Working model of AtLURE1/PRK6-mediated conspecific pollen precedence in *Arabidopsis thaliana*

They have characterized the seven pollen tube attractants, AtLURE1 peptides, and their receptor in the pollen tube membrane PRK6, as the signal molecules and receptor, respectively, that are involved in the control of conspecific pollen precedence. Meanwhile, they have revealed that, rather than attraction of pollen tubes to achieve fertilization, the real biological function of AtLURE1/PRK6-mediated signaling is to promote conspecific pollen precedence, elaborating the evolutionary significance of pollen tube guidance in plant species isolation and formation.

They have identified a group of cysteine-rich peptides XIUQIUs that attract pollen tubes in anon-species-specific manner, establishing a new working model of pollen tube guidance-mediated control of fertility. It would provide a new theoretical base and an important reference for the work to overcome the distant interspecific barriers in order to facilitate crop breeding through hybridization.

They have proposed a new experimental protocol, which has greatly improved the micromanipulation efficiency in semi-*in vivo* pollen tube attraction assays. This newly modified protocol improved both the efficiency and the number of pollen tube samples for experimental repeats, which greatly facilitated the identification of conspecific pollen precedence factors as well as non-species-specific pollen tube attractants.

They have developed, through modification, the novel dual-staining methods which combined the GUS-staining assays and aniline blue staining assays for pollen tube treatment. This newly developed dual-staining method, for the first time, allows direct comparison of the growth competitiveness of pollen grains/tubes two different genotypes or from two different species, which has a significant impact on verifying the conspecific pollen precedence phenomenon.

On May 31,2019, these discoveries were published in *Science* as an online research article. This work was initially submitted as a report (2500 words + 4 figures), but was requested by the *Science* editor to change into an online research article (8000 words + 8 figures), showing the significance and the great importance of the scientific question addressed by these discoveries. The conclusions of this work, which would significantly reshape the field and potentially rewrite the textbooks and reviews published after 2009, has been highly evaluated by the international community. The paper was selected and awarded by Chinese Society for Plant Physiology and Molecular Biology as one of the top ten papers published by Society members from 2014 to 2019. Prof. Qu Lijia was also invited to write an Insight review paper for Science China Life Sciences to introduce the work.

Improving the Resolution of Single Molecule Localization Microscopy

In the past decade, although various images based central position estimation (termed "centroid fitting") such as 2D Gaussian fitting methods have been commonly used in single molecule localization microscopy (SMLM) to precisely determine the location of each fluorophore, improving the single molecule lateral localization precision to molecular scale (< 2 nm) for high throughput cellular nanostructure imaging remains a challenge.

In a recently study which was published online in Nature Methods. Prof. Xu Tao and Prof. Ji Wei from Institute of Biophysics (IBP) of CAS developed a new interferometric single molecule localization microscopy with fast modulated structured illumination which named Repetitive Optical Selective Exposure (ROSE). This technique pushed the resolution of the single molecule localization microscopy (SMLM) to less than 3 nm (~1 nm localization precision). This work was supported by NSFC.

ROSE utilized six different direction and phase interference fringes to excite the fluorescent molecules, the intensity of the fluorescent molecules is closely related to the phase of the interference fringes. A fluorescence molecule is located by the intensities of multiple excitation patterns of an interference fringe, providing around two-fold improvement in the localization precision.

The authors demonstrated that ROSE could resolve 5 nm structure at a resolution of ~3 nm over a large field of view of 25 × 25 μm^2, which mean that ROSE has the ability to push the resolving power of SMLM to the molecular scale. They also showed that ROSE has advantages in resolving the hollow structure of single microtubule filaments, small clathrin-coated pits (CCPs) and cellular nanostructures of actin filament. They envisioned that this method could extend the application of SMLM in biomacromolecule dynamic analysis and structural studies at molecular scale.

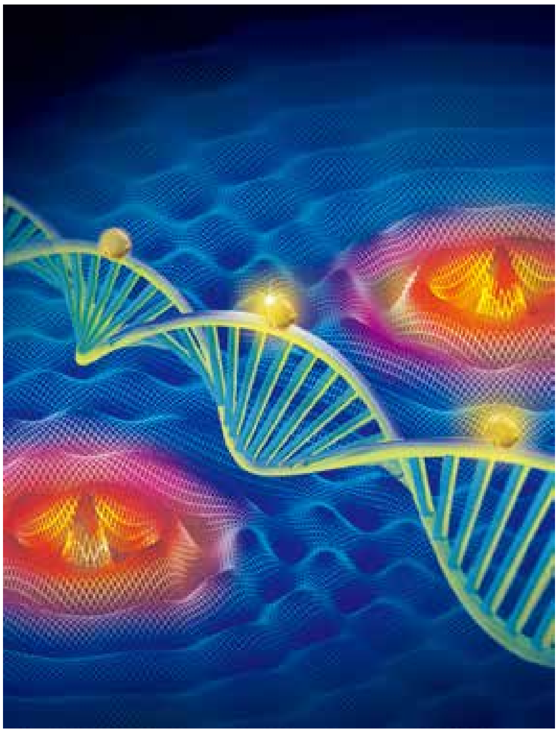


Figure 3-3-9 Schematic diagram of ROSE (Image by Guoyan Wang and Nanjun Ou)

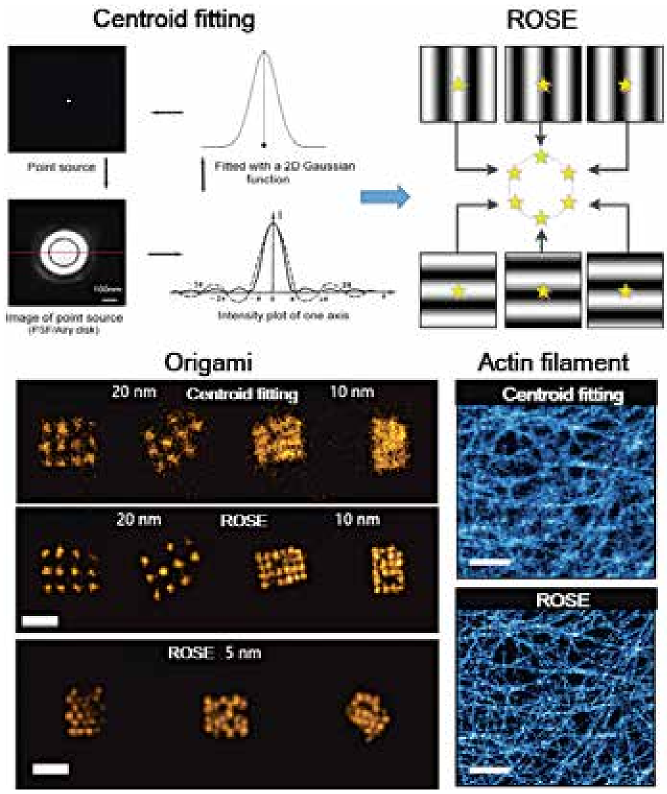


Figure 3-3-10 The principle and imaging results comparison of ROSE and centroid fitting with DNA origami and cells

Study of Ammonia Emission Reductions and the Associated Environmental Effects

Effectively controlling air pollution in China is urgent for the country's ecological civilization. Ammonia, as the most abundant alkaline gas in the atmosphere, plays important roles in secondary aerosol formation, precipitation acidity neutralization, and global nitrogen cycle, which exert significant impacts on human and ecosystem health (Figure 3-3-11). Intensive agricultural activities including mineral nitrogen fertilizer application and livestock manure management make China a hotspot with high ammonia emissions and concentrations in the worldwide. China plans to regulate ammonia emissions in the future, but the effectiveness of ammonia emission control and associated complex environmental effects are poorly understood.

Funded by the Major Research Plan Program of NSFC, i.e., the fundamental research on the forming mechanism and control techniques of atmospheric combined pollution in China, the research teams led by Prof. Song Yu and Prof. Zhu Tong focus on the potential reduction in ammonia emissions and the associated environmental effects across China. They integrate a chemical transport model, nationwide measurements, and a sophisticated ammonia emission model, and provided the scientific evidences on the rationalize ammonia control strategies for China.

The results demonstrate that, if nationwide ammonia emissions are reduced by 50% along with concurrent reductions in sulfur dioxide and nitrogen oxides, the annual mean PM2.5 concentrations will drop by 11% to 17% over the regions of interests (Northern China, Southern China, and the Sichuan Basin), which are mainly contributed by the inhibition of ammonia nitrate formation. Specifically, during the heavy pollution episodes that frequently occur in autumn and winter in Northern China, the fine particulate nitrate mass concentrations will decrease by up to 40% via the control of ammonia emissions from the livestock industry. High decreases of more than 20 μg/m^3 are distributed in central south of Hebei and northern Henan provinces. However, in the meantime, the ammonia reduction (-50%) would worsen the acid rain problem, a significant side effect that is mainly found in the Sichuan Basin and the lower and middle reaches of Yangtze River. As shown both in the nationwide acid rain observation network and the model simulation, the mean precipitation pH over China are mostly larger than 5.0, implying a weak acid rain pollution; but with the significant reductions in ammonia emissions, the pH values generally decline, even to 4.5, indicating the severe precipitation acidification.

These findings have been published by Proceedings of the National Academy of Sciences of the United States of America. This work suggests that region-specific ammonia-control strategies can provide a more rational and effective way to achieve the dual benefits of protecting human and ecosystem health in China.

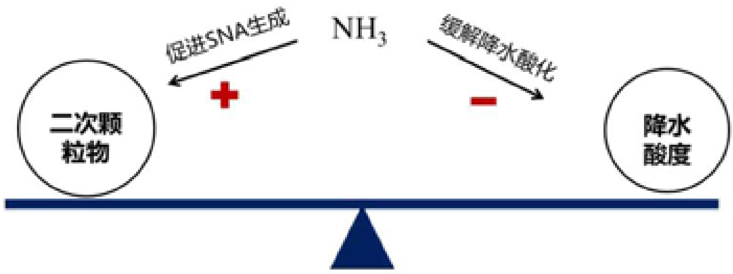


Figure 3-3-11 "Seesaw" effect of Ammonia emissions on the atmosphere in China

High Resolution Shape of the Pacific Slab in the Izu-Bonin Subduction Zone

Subduction is a key part of the plate tectonic cycle. During subduction, the slab transports a variety of different materials, including volatiles that cause volcanism. The motion of slabs in the mantle is controlled by many things, including their rheology, their density relative to the surrounding mantle and the motion of the surrounding mantle. Usually, earthquake locations tell us where the slab is cold and deforming, but earthquake distributions are patchy, giving at best an incomplete picture of slab shape. Seismic tomography can be also used to locate the slab that shows higher wave speed anomalies. However, conventional techniques image subducting slabs with relatively low resolutions, making interpretations of slab shape and deformation history extremely difficult.

Supported by NSFC, the research group of Prof. Zhang Haijiang at the University of Science and Technology of China collaborated with Dr. Robert Myhillat the University of Bristol to make a great progress on determining the slab morphology of the Izu-Bonin subduction zone. They applied a new tomographic technique, known as double-difference tomography, which uses the difference in travel times between pairs of earthquakes to more accurately determine seismic wave speeds close to seismic activity. They imaged high-resolution seismic velocity structure of the subducting Pacific slab, from which the slab deformation and rheology can be constrained in the deep upper mantle and the transition zone.

The team reveals that the Izu-Bonin slab has become torn in the deep upper mantle and transition zone (300–650 km in depth). The two sides of the tear have behaved very differently (Figure 3-3-12). The slab on the northern side of the tear is buckling as it interacts with the deep mantle, and the deepest portions are lying almost flat at the base of the transition zone. On the southern side of the tear, the slab is folded in the opposite direction, and actually lies upside down at the base of the mantle transition zone—the first time this has ever been documented in any subducting slab. The shape of the subducting slab is in remarkably good agreement with numerical studies that suggest that interaction between the Izu-Bonin slab and the Philippines slab has caused the shallow Izu-Bonin slab to advance over the deeper portions of the slab. The presence of buckling and the narrow slab tear supports experimental studies that predict that shear localization should be a key mechanism of deformation in cold subducting slabs. In addition, the new high-resolution images also help resolve a modern enigma of deep earthquake, which occurred in 2015 and was a very large earthquake occurred in a previously aseismic part of the Izu-Bonin region at > 650 km depth. Contrary to previous interpretations, the earthquake ruptured the core of the overturned slab, close to the imaged slab tear. This location puts the 2015 earthquake into a growing group of very large, very deep isolated earthquakes which rupture close to the edge of a subducting slab (Figure 3-3-13).

This study was recently published on *Nature Communications* with the title "Slab Morphology and Deformation Beneath Izu-Bonin". The results firstly imaged slab tear and overturn of the Pacific slab in the Izu-Bonin subduction zone, which enriched the research on the deformation and rheological properties of the subduction plate in the deep upper mantle and transition zone.

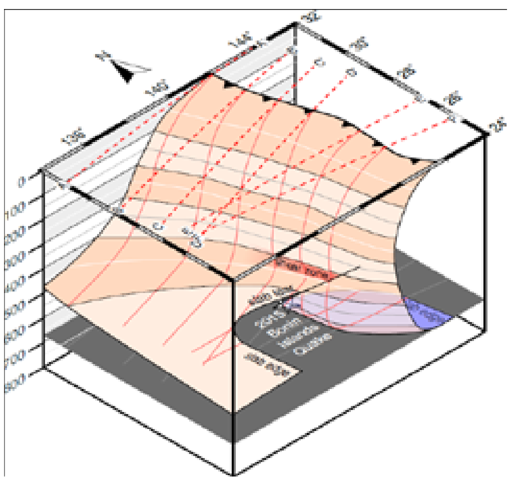


Figure 3-3-12 Isometric cartoon of the surface of the present-day Izu-Bonin slab based on the tomographic images. The blue region marks where the slab is overturned. The dark grey surface marks the 660km-depth isocontour

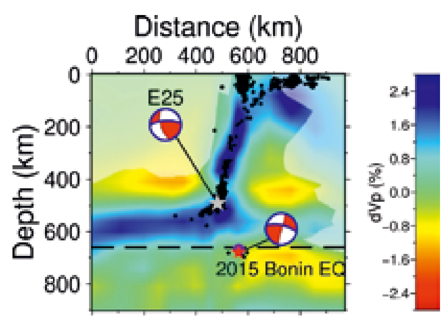


Figure 3-3-13 Profile of the P-wave velocity anomaly of 2015 Bonin Islands M7.9 earthquake, the left dipping blue high-speed represents the subduction plate

Dissociation Evolution Theory and Regulation Method for Marine Natural Gas Hydrates

Natural gas hydrates (NGH) are being considered as a potentially enormous energy source for the future. NGH reserves in South China Sea (SCS) are about 80 billion tons of oil equivalent. Exploitation of NGH is a vital strategic demand for China. Barriers in the exploitation of marine NGH include complexities, challenges and stabilities associated with gas production, heat and mass transfer, and geomechanical strength, respectively, which could lead to low productivity, unsustainability and safety risks such as collapse of NGH-bearing sedimentary deposits. Hence, it is a worldwide challenge to exploit this energy source in a safe and efficient manner. Supported by NSFC, the research group led by Prof. Song Yongchen at Dalian University of Technology has been making efforts to address key scientific issues on NGH exploitation in SCS. This research group has achieved the following major scientific breakthroughs and discoveries:

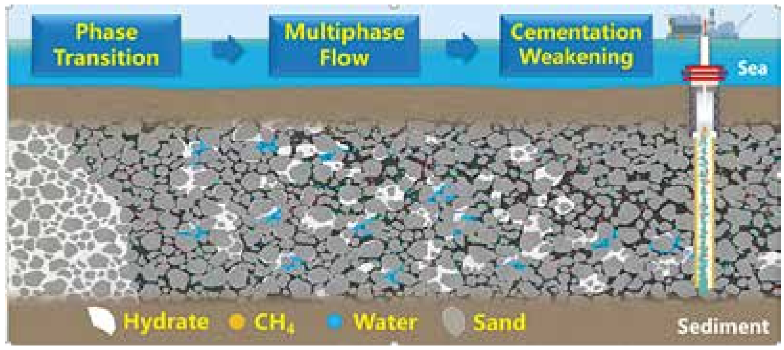


Figure 3-3-14 Phase transition, gas and water multiphase flow and cementation weakening process of marine natural gas hydrate

(1) The understanding of the guest molecules effects on the cage occupancy and structure was furthered. The thermodynamic behavior of the phase transition of multi-component hydrate systems was revealed. Based on the morphological transition behavior of hydrates, a prediction model for permeability coupled with the phase transition was developed. A cluster-migration mode of the grains during hydrate dissociation was also found, which illustrated the evolution mechanism of the cementation structure during its deformation.

(2) The 3-stage dynamic processes of hydrate dissociation including the pressure-driven, the sensible heat dominated, and the heat transfer controlling stages was discovered. Additionally, a combined pressure and heat controlling method was proposed to enhance the hydrate dissociation process, and the interaction model between reservoir and structure was established. The influential boundary of the hydrate dissociation zone was also determined for the safety of submarine structures.

(3) The coupling and evolution of the thermal, hydraulic, and mechanical fields during the hydrate dissociation was revealed. A production and safety evaluation simulator was also developed for marine gas hydrate exploitations. An on-board analysis of the natural cores from SCS was accomplished. The behaviors of gas-water production and reservoir deformation were characterized.

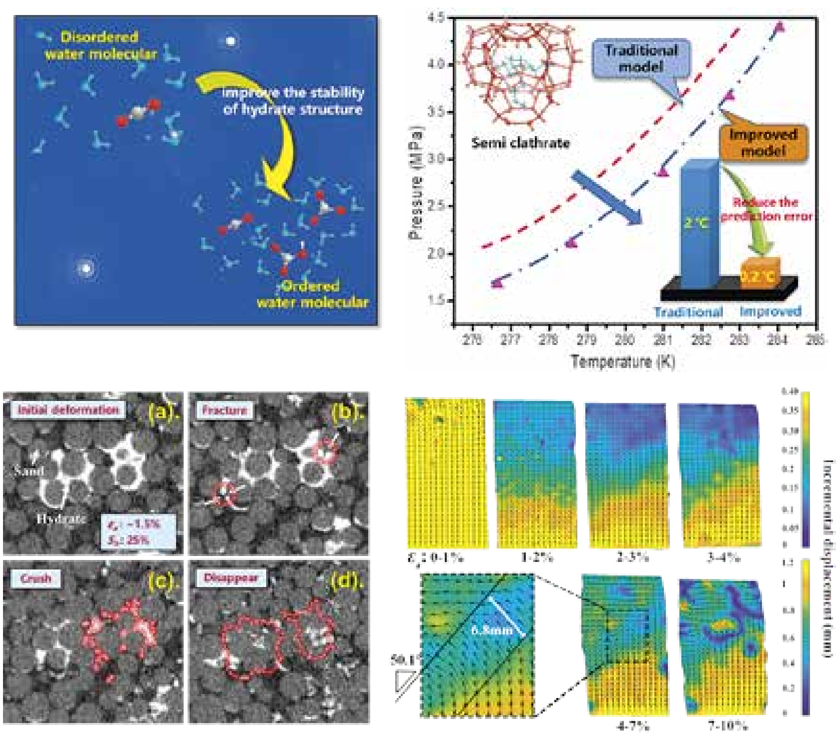


Figure 3-3-15 Phase state prediction model of gas hydrate and evolution of its cementation structure during dissociation

The efforts have been granted the First-Class Award of the Natural Science Award from the Ministry of Education, One Top-Class and One First-Class Award of Ocean Engineering Science and Technology, and Second-Class Award of the National Natural Science. In the past years, 162 research papers have been published, with 3 of them selected as ESI highly cited papers and 2 as Hot Papers. The designed on-board detection system of marine gas hydrate breaks blockade on techniques and was granted the Gold Medal AFJ Award - Avec les Felicitations du Jury. The research group has also participated in the field test of gas hydrate exploitation project in SCS, providing significant supports in the project design and engineering operations. The results strongly confirm the successful field test of gas hydrates in SCS.

Theoretical Research on Shale Gas Development

As an important unconventional natural gas resource, shale gas is from shale formations . At the beginning of this century, the shale gas revolution was triggered by technological breakthroughs in US shale gas development, which has profoundly affected the global oil and gas energy structure. China and the United States are both big countries in shale gas resources, and have huge potential for shale gas development. However, China's shale gas reservoirs are deeply buried, complex in structure, coexist with multi-scale fractures, strong heterogeneity, mostly hilly surface, and scarce water resources, which are significantly different from the US shale gas development conditions. Establishing a development theory suitable for the conditions of shale gas reservoirs in China is the prerequisite and basis for achieving efficient shale gas development. Supported by the NSFC project "Basic Theoretical Research on the High Efficiency Development of Shale Oil and Gas" (Award No.: 51490650), the research team of China University of Petroleum (Beijing) led by Professor Chen Mian conducted in-depth development of shale reservoir physics Theoretical research on key applications of mechanochemical nonlinear feature evolution, wellbore instability under multiple couplings, fracture network expansion in well factory mode, and multiscale and multiphase flow in shale gas reservoirs. The main innovations achieved are as follows:

(1) Proposed a unified topological structure model of shale rock fractures and a unified theory of formation pore pressure. And discovered the phenomenon of multi-scale time series failure caused by the interaction between shale and fluid under micro-nano characterization. Develop an integrated design method for engineering desserts, geological desserts. This theory breaks through the limitations of traditional brittleness evaluation methods of mineral composition, strength or hardness, and provides a theoretical basis for the efficient development and design of shale. The new method is widely used in China's national shale gas demonstration area.

(2) Based on the study of the ultra-strong spontaneous infiltration capacity of special shale gas accumulation, the multi-field coupled borehole instability mechanism of strong interaction between drilling fluid and shale reservoirs to induce local high pore pressure, bedding and fracture strength weakening was revealed. Based on the principle of polymer micro-nano particle plugging, a new type of environmental-friendly water-based drilling fluid has been developed and produced industrially, achieving a technological breakthrough in water-based drilling fluid for shale horizontal wells.

Figure 3-3-16 The integrated design method was applied in Weiye 23-1HF, which achieved a breakthrough of 260,000 cubic meters per day of testing

(3) Based on large-scale fracturing physical simulation experiments, a numerical model of natural shale fractures with macro-scale statistics and a model of dynamic spatial particle movement and settlement in the fractures were established. And constructed shale reservoir-fracture network expansion theory with fully coupled rock-fluid-supporting particles, revealed the dynamic evolution mechanism and controlling factors of shale hydraulic fracture under multi-well mode. Its theoretical method is widely used by many shale gas development companies all around the world, which has promoted the development of control technology for complex shale fracture network reformation.

(4) The gas-liquid-solid three phase coupled adsorption / desorption characteristics of shale reservoirs were discovered for the first time in the world. Established experimental simulation methods and prediction theories for shale gas adsorption under different water cut conditions. A multi-phase and multi-component fluid-solid coupling numerical simulator for shale oil and gas reservoirs was developed. A numerical model of shale oil and gas reservoirs and a well-factory optimization design method for fracturing fracture propagation-flow numerical simulation-productivity evaluation of shale gas reservoirs were established. The results have been highly evaluated by the international academic community, providing a scientific basis for the development and optimization design of shale gas well plants.

The above research results won the first prize of the National Science and Technology Progress Award in 2017 and the second prize of the National Science and Technology Progress Award in 2018. The research results have published 404 papers in well-known petroleum engineering journals, of which 140 are indexed by SCI, with 5506 cites by others, and 14 indexed as highly cited papers by ESI. Besides, 10 monographs were published and 111 invention patents / 69 were authorized. The well-known journals of the international petroleum engineering community "Journal of Natural Gas Science and Engineering", domestic high-level journals "Chinese Science: Physics, Mechanics, Astronomy" and "Petroleum Drilling Technology" make special issues for research results. In the past 5 years, two of the research team members were invited by the Yangtze River Scholars, three were awarded the Excellent Young Scientists Fund, and one was awarded the Excellent Young Scientists Fund. Key theories and technological achievements were included in the national shale gas drilling and production technology standards led by the National Energy Administration, which promoted the development of industry technology in an orderly manner. Based on the theoretical research results, a series of methods such as engineering geological dessert evaluation, high-performance water-based drilling fluids, full-well fracture network fracturing, and three-dimensional development of well factories have been formed. The development of block-scale applications has provided important technical support for the improvement of China's medium-deep / deep shale gas drilling and production technologies.

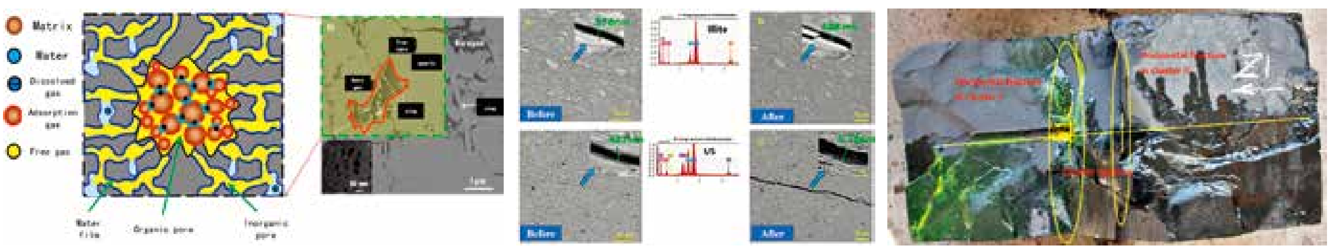


Figure 3-3-17　Shale reservoir multiscale physico-mechanical nonlinear characteristics evolution characteristics

Theory and Practical Research of Operating System

For years, the information industry of China is on the status of “Absence of Heart and Soul”. As the “Soul” of information industry, operating systems is one of the key bottlenecking technologies in China. With the support from National NSFC and under the leadership of Professor Haibo Chen, the research team from Shanghai Jiao Tong University has been long focused on the penetration of key technologies of operating systems, and conducted deep industry-university collaboration to transform research results into industry products. The main achieved innovation results include:

(1) A trusted computing base (TCB) minimization approach for operating systems: the approach exploits nested protection to separate security isolation from resource management, which reduces the TCB of traditional operating systems from tens of millions of lines of code to only tens of thousands of lines of code.

Through a deep collaboration among university-industry collaboration, Prof. Chen leads the operating system group at Huawei to propose new operating system architecture based on TCB minimization, which fuses the best of multiple operating system architectures. The new operating system architecture embodies a new scheme called "one kernel kit for all" and is a microkernel-like, cross-device operating system with deterministic latency support.

(2) A formal verification approach for general-purpose operating systems: the team designs a practical formal verification approach for production operating system that proves the consistency from design down to implementation, which significantly improves the security and reliability. The approach provides a key pillar to enable the first CC EAL 5+certification of a production-level operating system in the terminal product area. The approach also enables the first verified concurrent file systems with mechanized proofs.

(3) Low-latency operating system technologies: Prof. Chen leads the design and implementation of a new file system called EROFS, which has been the top selling point of Huawei P30 series. It not only leads to significant improvement of user experiences and saves multi-GB flash spaces for users, but also is the first file system being merged to the mainstream Linux (4.19).

(4) A differentiated data partitioning approach: the approach significantly reduces the data transfer cost caused by imbalanced data partitioning. It has been integrated into Tencent's Wechat graph-structed data analytics platform, which has been supporting anomaly detection of hundreds of millions of users.

The above research results lead to several awards including the first prize of technology innovation award from China Ministry of Education and Huawei's highest technical achievement award. The team is the first in Asia to publish in the ACM Symposium on Operating System Principles (only 27 papers accepted at that year). According to the statistics of csrankings.org, Prof. Chen is among the most prolific authors in top operating system conferences (SOSP/OSDI, EuroSys, Usenix ATC, FAST) in the past 5 years (2015-2019). The research results have been positively commented by renowned scholars including the Turing Award Winner Mike Stonebraker. Prof. Chen is also the only editor and area co-chair of ACM's flagship magazine *Communications of the ACM*.

Basic Research on Deep Learning Processor Architecture

Intelligent processing, including perception, memory, learning, language, thinking and problem solving, is the mainstream calculation method in the age of artificial intelligence. However, the traditional general-purpose CPUs/GPUs fail to meet the increasingly harsher requirements of intelligent computing on the performance and power dissipation under most circumstances. Supported by the National Science Fund for Distinguished Young Scholars, and the State Key Program of National Natural Science of China, the research team led by Chen Yunji, Institute of Computing Technology of CAS, has been carrying out in-depth and systematic research on the deep learning processor architecture, and the main innovations achieved are as follows:

(1) Chen and his colleagues proposed the first deep learning processor architecture in the world. Which is a great breakthrough on a number of key techniques which can be applied in domain-specific processors and provides inspirations for the design of domestic multi-core processors.

(2) The first deep learning processor instruction set in the world, Cambricon, was proposed. Simulation experiments show that the deep learning processor using the Cambricon instruction set has two orders of magnitude performance improvement over the CPU of the x86 instruction set. Chen and his research team achieved pioneering progress on the research of deep learning processor instruction set, which provides technical support for China to further expand in the intelligent industry ecology as a leader.

(3) Developed the world's first deep learning processor chip, whose intelligent processing energy efficiency is over one hundred times of CPU and GPU.

The above research results have broken through the three key challenges of scale, adaptation and energy efficiency in the deep learning processor architecture researching field, and have influenced the research direction of deep learning processors in the world. Relevant work won the Best Paper Award at the Top International Conference on Computer Architecture twice, and was widely quoted by nearly 200 well-known institutions (Harvard, Stanford, Google, etc.) in more than 30 countries around the world. Related research results are called "creative progress" by Science. Chen and his research team have been commented as "by all accounts among the leaders" and "pioneering in terms of specialized chip architecture".

Figure 3-3-18 The Best Paper Award of ASPLOS 2014 and MICRO 2014

CHINA'S AI IMPERATIVE

The country's massive investments in artificial intelligence are disrupting the industry—and strengthening control of the populace

By Christina Larson, in Beijing

In a gleaming high-rise here in northern Beijing's Haidian district, two hardware jocks in their 30s are testing new computer chips that might someday make smartphones, robots, and autonomous vehicles truly intelligent. A wiry young man in an untucked plaid flannel shirt watches approvingly. The onlooker, Chen Yunji, a 34-year-old computer scientist and founding technical advisor of Cambricon Technologies here, explains that traditional processors, designed decades before the recent tsunami of artificial intelligence (AI) research, "are slow and energy inefficient" at processing the reams of data required for AI. "Even if you have a very good algorithm or application," he says, its usefulness in everyday life is limited if you can't run it on your phone, car, or appliance. "Our goal is to change all lives."

In 2012, the seminal Google Brain project required 16,000 microprocessor cores to run algorithms capable of learning to identify a cat. The feat was hailed as a breakthrough in deep learning: crunching vast training data sets to find patterns without guidance from a human programmer. A year later, Yunji and his brother, Chen Tian- [illegible]

Tech companies and computer science departments around the world are now pursuing AI-optimized chips, so central to the future of the technology industry that last October Sundar Pichai, CEO of Google in Mountain View, California, told The Verge that his guiding question today is: "How do we apply AI to rethink our products?" The [illegible]

Such groundbreaking advances far from Silicon Valley were hard to imagine only a few years ago. "China has lagged behind the U.S. in cutting-edge hardware design," says Paul Triolo, an analyst at the Eurasia Group in Washington, D.C. "But it wants to win the AI chip race." The country is investing massively in the entire field of AI, from chips [illegible]

Last summer, China's State Council issued an ambitious policy blueprint calling for the nation to become "the world's primary AI innovation center" by 2030, by which time, it forecast, the country's AI in-

Figure 3-3-19 comments on Cambricon in *Science*

Study on the Scaling Relation in Traffic Resilience

Biological systems can spontaneously recover from virus invasion or environmental perturbation, which is so-called "resilience". Since its appearance in ecosystems, the resilience theory has been generalized to climate, economics and even brain research, suggesting a new direction for system reliability management. The increasing contradiction between supply and demand of public transportation service causes the accumulation of systematic risk. Definition and measurement of traffic resilience is fundamental and urgent, to help avoid large-scale congestion or recover soon from function degradation.

Supported by NSFC, Prof. Huang HaiJun and Prof. Li Daqing from Beihang University, together with their research teams, have uncovered the scaling relation in traffic resilience. Their study, entitled with "Scale-free resilience of real traffic jams", has been published in *Proceedings of the National Academy of Sciences of the United States of America* on April 12, 2019.

Different from previous researches, this study defines traffic resilience based on the spatio-temporal propagation of congestion, which reflects the adaptation and recovery of traffic system in a stereo way. Based on real-time data and the defined resilience, we found universal scaling relations in the recovery of traffic congestion (i.e., the power-law distribution of traffic resilience). Besides, it also unveils the scaling relations in recovery time. These results demonstrate similar traffic adaptation behavior across different spatio-temporal scales, which is verified by the scaling between traffic resilience and recovery time. These identified scaling relations indicate the inherent nature of traffic resilience, which suggests a new paradigm of traffic resilience management and provides decision-making support for traffic reliability management in city or city-agglomeration scale.

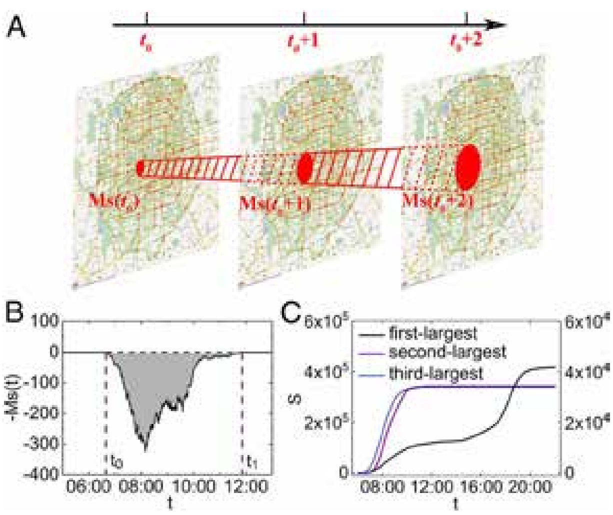


Figure 3-3-20 Traffic spatio-temporal resilience. (A) Illustration oftraffic jam evolution in a city; (B) The cross-section area Ms(*t*) of a jammed cluster as a function of time. The grayarea represents the traffic resilience; (C) The sizeof the first, second and third largest jammed cluster as a function oftime

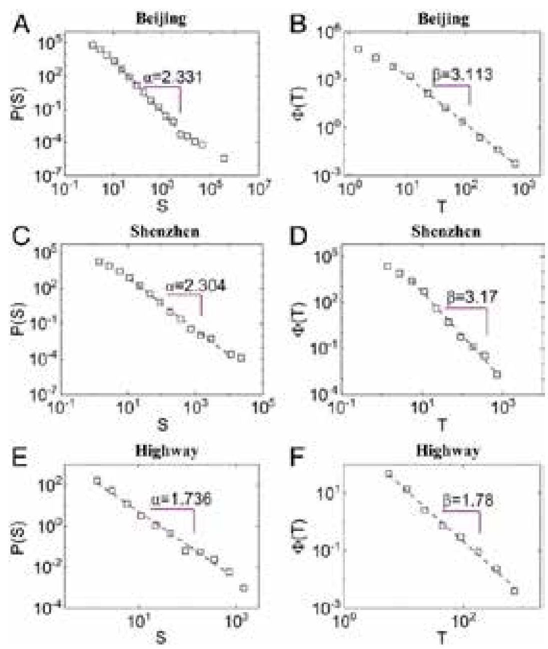


Figure 3-3-21 Scale-free distributions of traffic resilience. (A)(C)(E) The distribution of the jammed cluster size in Beijing,Shenzhen, and Beijing-Shenyang Highway; (B)(D)(F) The distribution of the recovery duration in Beijing, Shenzhen, and Beijing-Shenyang Highway

Research on Solar PV Power Potential and Cooperation Opportunities Along the Belt and Road Initiative

Since the Belt and Road Initiative (BRI) was launched in 2013, the construction of electric power infrastructure has been an important area for cooperation in order to meet future electricity demand and boost regional economic growth. Green BRI construction has become a key feature for addressing the challenges of regional sustainable development, as well as global climate change. Solar photovoltaic (PV) power has been the fastest growing renewable energy in recent years. With continuous technological progress and cost reduction, solar PV is expected to play an important role in future low-carbon power transition in the BRI countries.

With the support of NSFC (Excellent Young Scientists Fund and Major Program), the research team of Associate Prof. Lu Xi from the School of Environment, Tsinghua University has carried out fundamental and forward-looking research on the potential and opportunities for solar energy development in the countries along the Belt and Road routes. The key findings of the analysis are as follows:

(1) The research quantified the solar PV power potential for 66 countries along the BRI for the first time. The results show that the total annual power generation potential of the BRI region amounts to 448.9 PWh, which is equivalent to 41.3 times the total power demand of the region that occurred in 2016. Tapping that 3.7% of the potential through deploying 7.8 TW capacity could satisfy the regional electricity demand projected for 2030, requiring an investment of approximately 11.2 trillion USD and a commitment in land area of 88,426 km2, approximately 0.9% of China's total.

(2) The research further revealed the mismatch between solar potential and electricity demand. Countries endowed with 70.7% of the overall potential consume only 30.1% of regional electricity. The imbalance underscores the advantage of regional cooperation and investments in regional interconnected grids.

(3) The research found that the utilization of multiple time zones and differentiated weather conditions of the BRI region to transmit complementary solar power will not only meet the overall power demand in the region, but also reduce the impact of solar fluctuations on the grid. This will help break through the technical bottleneck of large-scale application of solar PV generation in the BRI region.

The research was published on August 21, 2019 as a cover paper in *Joule*, the flagship journal of Cell Press. The analysis has been positively reported by *China Daily, Forbes, The Conversation, Yahoo* and other media. The research provides new perspectives on jointly developing the regional solar resources of the BRI region at national, industrial and organizational levels, as well as insightful information to the exploration of green and low-carbon development paths for countries of the BRI.

Mammalian Near Infrared Light Perception and Image Vision

Humun of animals' perception is limited by the intrinsic physical and chemical constrains of the biological system. Extending this limit is the ever lasting goal of mankind. The visible light spectrum of mammals is between 390 and 760 nm. Near infrared light over 760 nm is invisible to mammals and color blind diseases further reduced the visible spetrum range. Supported by NSFC, a research team led by Prof. Xue Tian from University of Science and Technology of China collaborated with a team led by Prof. Han Gang from University of Massachusetts Medical School to create mammalian near infrared light perception and image vision with innovative nanotechnology.

In this collaboration, the researchers delivered upconversion nanoparticles to the retina, where near infrared light can be converted to visible light and activate the visual system. This delicate and creative idea extended the visible spectrum to near infrared range simply by translating near infrared light to the photoreceptors in the retina without changing the whole biological system from retina to the brain. This method to create near infrared image vision in the naked eyes does not need external energy supply and is compatible for near infrared and visible light, which is superior to the existing near infrared goggles. To promote the senstivity of the system to the near infrared light, researchers attached ConA molecules to the upconversion nanoparticles on their surface to make them conjugate to the surface protein of the photoreceptors. This surface modification enabled nanoparticles staying close enough to the photopigment of photoreceptors and decreased the distance between the upconverted visible light and the photopigment. This surface modification technique can be adapted to other applications of the nanoparticles, for example drug delivery.

This work has potential application in encryption, security and hunman-machine interface. Through nanoparitcle enginnering, the researchers are able to make various versions of nanoparticles with different spectrum properties, which can be used to help the color blind patients. This work was published in *Cell* in April, and the researchers were invited to write a review article by *Advanced Healthcare Materials*. Following the publication of this work, *Nature*, *Science* and many other journals and medias made reports on this work. The Director of The US National Institute of Health, Dr. Francis Collins, highly praised the significance of this work.

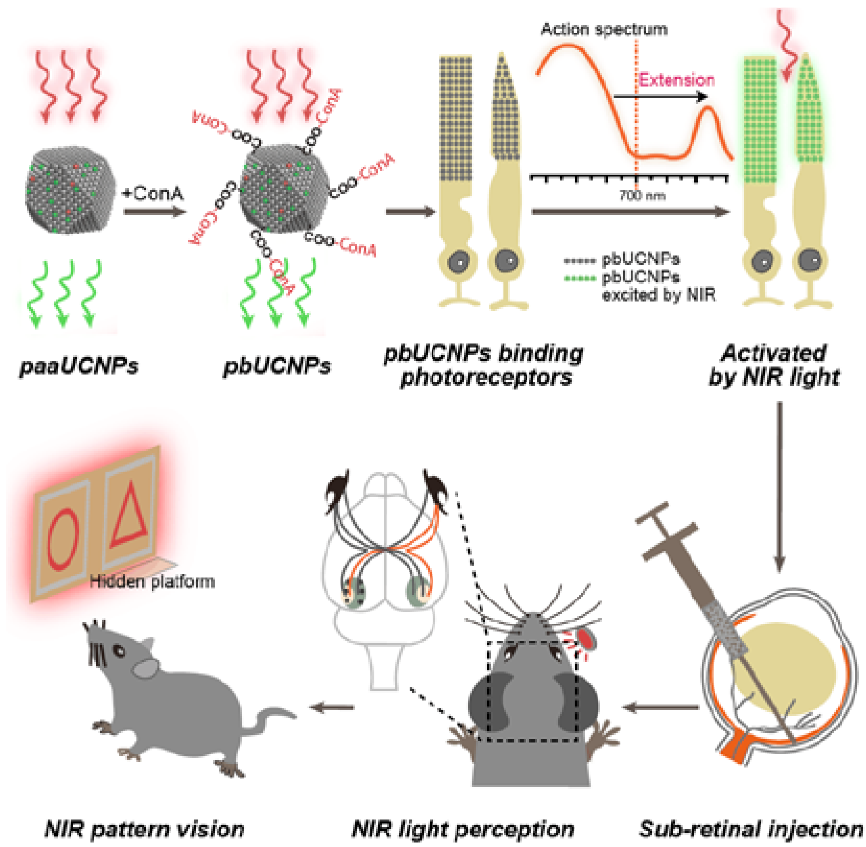


Figure 3-3-22 Photoreceptor binding upconversion nanoparticle (pbUCNPs). Mice received injection of pbUCNPs in the retina obtained near infrared light perception and image vision

Figure 3-3-23　The report in *Nature* and *Science* as featured news

Research on the Molecular Control of T Cell Dysfunction

By means of blocking checkpoints such as PD-1, loss-of-function T cells can be reinvigorated, and is beneficial for many cancer patients. However, the molecular mechanism underlying T cell dysfunction still remains unclear. Supported by Major Research Plan, Key Program, Science Fund for Creative Research Groups, and General Program of NSFC, Dong Chen's group at the Institute of Immunology, Tsinghua University, together with the research groups led by Bian Xiuwu and Liu Xindong at the First Affiliated Hospital of Army Medical University has made substantial progress in understanding the transcriptional and epigenetic mechanism of T cell dysfunction. These achievements include:

(1) Nuclear receptor family transcription factor Nr4a1 is identified as a key factor in regulating T cell dysfunction. Overexpression of Nr4a1 can repress the T cell proliferation and effector function, while depletion ofNr4a1 impedes T cell dysfunction in the context of viral infection and tumor.

(2) Mechanistically, Nr4a1 is able to compete for AP-1 binding sites, which leads to the downregulation of effector molecule expression. On the other hand, recruitment of NR4A1 to chromatinelevates the H3K27ac level at Super Enhancer (SE) region, thereby upregulating the dysfunction-related gene.

This study has identified Nr4a1-centerd regulatory circuitry in inducing T cell dysfunction formation. Thus, Nr4a1 can be potential target for tumor immunotherapy. This study entitled "Genome-wide analysis identifies NR4A1 as a key mediator of T cell dysfunction", was published on *Nature* on Feburary 27, 2019. Similar findings were also reported in a 'back to back' paper from Anjana Rao's group in USA. These findings have been highlighted by *Nature Reviews Cancer* and *Nature Reviews Immunology*.

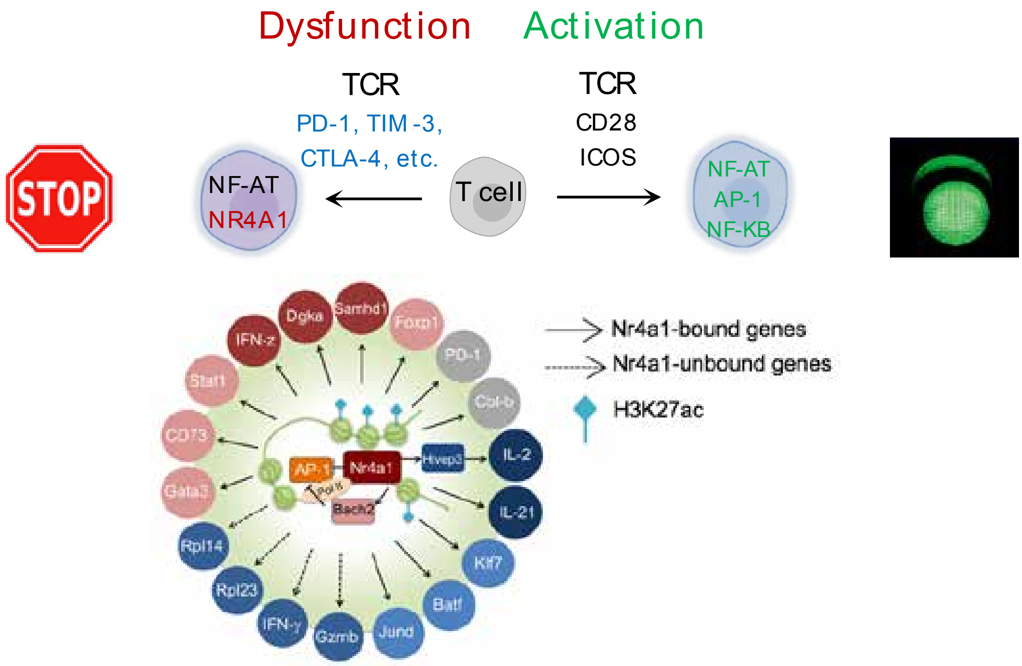


Figure 3-3-24 Molecular mechanism of regulating T cell dysfunction by NR4A1

Part 4

International (Regional) Cooperation and Exchange

NSFC

2019 ANNUAL REPORT

In 2019, focusing on the reform plan of science funding for the new era, NSFC systematically deepened international cooperation and exchange, strengthened the forward-looking layout, enriched and optimized the mechanism of cooperation with its overseas counterparts, intensified talents exchanges and training based-on projects, increased efforts to attract overseas talents of different levels to China, actively expanded the scope of the Young Scientists Fund, and vigorously promoted international collaborative scientific initiative for sustainable development of science funding in order to serve the Belt & Road Initiative of China.

1. Systematically Deepening International Cooperation and Exchange

1.1 Strengthening Forward-Looking Layout for International Cooperation

Under the background of the rapid development of global science and technology and the shift of scientific research paradigm, NSFC organized a series of international seminars on the science funding reform and policy to actively explore the mechanism of policy dialogue with foreign science funding agencies in an open manner so as to strengthen international exchanges and cooperation on strategy and policy. The seminars have contributed to the forward-looking planning and layout of NSFC's international cooperation, strengthened exchanges with foreign science funding agencies and the scientific community as well as enhanced understanding and friendship, and created a better atmosphere for open cooperation.

NSFC and the major science funding agencies in the Nordic countries jointly held the *China-Nordic Symposium on funding policies for interdisciplinary research*, to explore the opportunities and challenges brought by the profound transformation of scientific research paradigm in the new era, to exchange policy measures and review mechanism on promoting interdisciplinary research, and to promote bilateral and multilateral collaborative research between China and the Nordic countries under the framework of the UN Sustainable Development Goals. Some discussions on the development of science funding were made with the experts from the National Institutes of Health (NIH) of the United States and the delegates of Sino-German Joint Panel Meeting of the Sino-German Science Research Center (hereinafter referred to as Sino-German Science Center). The 17th Meeting of Heads of Research Councils in Asia (A-HORCs) was jointly held in Beijing by the NSFC, the Japan Society for the Promotion of Science (JSPS) and the National Research Foundation of Korea (NRF), where participants conducted an in-depth discussion on funding policy issues such as *how to improve the evaluation mechanism*. NSFC also participated in the discussion on topics of the social and economic impact of the reform and science funding at the Global Research Council (GRC) Annual Meeting. Meanwhile, NSFC and the UK Research and Innovation (UKRI) jointly held the *Forum on Science Fund Reform and Development*, inviting major funding agencies around the world to focused on topics of common challenges in global research funding, shared experiences in research funding and talent foster and discussed the reform plan of the global research paradigm innovation. NSFC leaders have twice attended the Executive Committee of International Institute for Applied Systems Analysis (IIASA) for decision-making on relevant issues.

1.2 Deepening the Cooperation Mechanism under the Memorandum of Understanding (MoU)

The sustained expansion of international collaborative network is the cornerstone for deepening international cooperation. Up to now, NSFC has already signed 97 memorandums of understanding (MoU) or agreements with 51 countries (regions). In 2019, 5 new MoUs or agreements were signed with Sao Paulo Research Foundation (FAPESP), Bulgarian National Science Fund (BNSF),Gordon and Betty Moore Foundation (GBMF), and the Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES). NSFC also renewed its agreements or MoUs with BMGF, CNRS, RS, BC and CNR. In addition, NSFC maintains multiple channels to promote the international cooperation of science and technology, with a new MoU signed with Gordon and Betty Moore Foundation in 2019, which is yet another partnership with non-governmental agency since its collaboration with the Bill and Melinda Gates Foundation.

In 2019, NSFC continued to deepen bilateral/multilateral cooperation, with specific implementation items listed in Table 4-1-1.

Table 4-1-1 Progress on Bilateral/Multilateral Collaboration of NSFC and its International Partners in 2019

No.	Country/ International Orgnization	Funding Agency	Activities
1	U.S.	National Institutes of Health (NIH)	Completed joint research call, review and funding
2	U.S.	National Science Foundation (NSF)	Completed joint research call, review and funding
3	U.S.	Bill and Melinda Gates Foundation (BMGF)	Held the first bliateral workshop and agreed on funding plans for FY 2020
4	U.S.	Gordon and Betty Moore Foundation (BMGF)	Jointly funded the 2019 Science Forum on the Thirty-meter Telescope
5	Canada	Canada Institutes of Health Research (CIHR)	Jointly organized scientific workshop and projects assessment meeting
6	Canada	Quebec Research Foundation (FRQ)	Implemented the first round call, review and funding on management science
7	Chile	National Commission for Scientific and Technological Research of Chile (CONICYT)	Completed the second round joint research call, review and funding
8	Agentina	National Scientific and Technical Research Council of Argentina (CONICET)	Completed the second round joint research call, review and funding
9	Mexico	National Council for Science and Technology of Mexico (CONACYT)	Set out future working plan on personnel exchanges and workshops
10	Cuba	Ministry of Science, Technology and Environment of Cuba (CITMA)	Set out future working plan on personnel exchanges and workshops
11	Sweden	Swedish Foundation Foundation for International Cooperation in Research and Higher Education (STINT)	Jointly organized the China-Nordic Interdisciplinary Funding Policy Workshop
12	U.K.	UK Research and Innovation (UKRI)	Jointly plan on interdisiplinary collaboration on medical and management research as the theme of China-UK flagship challenge initiative
13	Russia	Russian Foundation for Basic Research (RFBR)	Established a multi-level cooperative mechanism which includes bilateral exchange and research program, young talents program, multi-lateral program and strategic dialogue
14	International Organization	European Organization for Nuclear Research	Supported Chinese scientists' participation of the phase II upgrade and construction of CERN
15	Germany	German Research Foundation (DFG)	Supported bilateral research, workshops and exchanges
16	Japan	Japan Society for the Promotion of Science (JSPS)	Jointly supported research projects
17	Israel	Israel Science Foundation (SF)	Deepened bilateral cooperation

1.3 Promoting the "Belt And Road" International Cooperative Science Plan for Sustainable Development

Targeting at the Sustainable Development Goals (SDG) set by the United Nations, and the major global challenges shared by countries and regions along the Belt and Road, NSFC has lunched the Belt and Road SDG Funding Framework under the principle of "joint funding and mutual benefits", and takes it as a platform to cooperate with global funders and international organizations along the Belt and Road and beyond on coordination of scientific research and talent-training, so as to promote science development, culture exchange, cooperation and mutual benefits. There have been more than 20 research funders expressing interest in the Framework. In addition, Joint Funding Projects under the MoU of 2019 was integrated into the Belt and Road SDG Funding Framework, which include funders such as CGIAR, UNEP, BNSF, TUBITAK, NCN, BRFFR, FAPESP and CONICET.

2. Successfully Completing the Project Reviewing and Funding

Cooperation with overseas science funding agencies is a major means for NSFC to realize its strategic goal for international cooperation. The MoU based joint research and exchange program reflects NSFC's strategic goal and highlights its guiding role in the sense that the whole process, from research themes selection, application acceptance, review and funding decision-making to after-award management and assessment is all jointly carried out by NSFC and its international funding partners.

In 2019, 1,140 international cooperation and exchange projects have been approved with a direct cost of 1.009 billion yuan, which includes: 255 million yuan for 103 Key International (Regional) Cooperative Research projects, 639 million yuan for 325 International (Regional) Joint Research projects under MoUs, 37 million yuan for 252 Exchange projects under MoUs (including Sino-German Center projects), 15 million yuan for 298 Bilateral or Multilateral Conference projects, and 50 million yuan for 161 Research Fund for International Young Scientists projects.

3. Steadily Strengthening Cooperation with Hong Kong, Macao and Taiwan

NSFC and funding agencies in Hongkong jointly organized academic symposiums for young scientists. In addition, to promote mutural understanding and trust between young people in the Mainland and Hongkong and build a platform for them, NSFC released new fundig policies which allow each expert participant to bring no more than two young scholars or students to attend the symposium and lay the foundation for them to become the backbone of scientific and technological cooperation between the two places in the future.In terms of cooperation with The Science and Technology Development Fund (FDCT) in Macao, the two funding agencies co-organized the Forum on Discipline Frontier and set up a platform for the exchange between scholars and promoted the development of scientific research cooperation between the two places as well. For cooperation with Taiwan, NSFC and the K. T. Lee Science and Technology Development Fund conducted in-depth and productive discussions on the promotion of cooperation both at the agency-level and at the scientific commuties-level, which brings closer the communication between the two sides. In 2019, NSFC has launched a pilot program for scientists from host institutions in Hong Kong and Macao to apply for Excellent Young Scientists Fund (Hong Kong and Macao), aiming at encouraging high-quality scientific and technological scientist to actively contribute for China to becoming a powerful nation of science and technology.

4. Sino-German Center for Research Promotion (SGC) Playing a Role of Bridge as an International Platform

The SGC completely accomplished its first phase reform on funding framework in accordance with the SGC's Joint Committee's requirements and development strategy. It optimized program clusters of "post-meeting program" and "talents program" focusing on the funding position of the Sino-German cooperation network and young scientists in both countries. A funding pattern has been formed, with centralized and uncentralized acceptance of proposals complementing each other depending on different types of projects. With a series of workshops on collaboration and broadcast activities for annual strategy held, the cooperation on strategy and management between NSFC and DFG was promoted and international impacts was extended with an increasing number of scientists being aware of the funding channel of the SGC and the cooperation of basic research between scientists in China and Germany being facilitated. In addition, the SGC continued to organize outstanding Chinese doctoral students to participate in the Lindau Nobel Prize Laureates Meeting.

5. Typical Achievements

5.1 Identification of Neurotransmitter GPCR Dimers or Oligomers as Novel Drug Targets

Supporting by Key International (Regional) Cooperative Research Program of NSFC "Identification of neurotransmitter GPCR dimers or oligomers as novel drug targets", Prof. Liu Jianfeng's team (Huazhong University of Science and Technology) in collaboration with University of Michigan have found that a neurotransmitter receptor senses cold through G proteins signaling. This work was published in *Cell* entitled "A cold-Sensing receptor encoded by a glutamate receptor gene". This study applied an unbiased genetic screen in *Caenorhabditis elegans* and identified glutamate receptor protein GLR-3, which can directly sense the low temperature in peripheral sensory neuron and mediate the escaping response of the nematode. In addition, GLR-3/Gluk2 can sense the low temperature below 18℃, and it is the first low temperature cold receptor discovered up to now. This study identified the kainic acid glutamate-like receptor homologue GLR-3 as a cold receptor and opened the door to Pandora in this field (Figure 4-5-1). Furthermore, with the support of the same project, Prof. Liu's team in collaboration with Institute of functional genomic (IGF) of CNRS in France have discovered the important neurotransmitter GPCR, γ-aminobutyric acid type B receptor (GABAB receptor) oligomers, displaying a significant rearrangement of its transmembrane upon activation. The interaction interface between its transmembrane domains provides important information for a better understanding of the allosteric effects within GPCR dimers and oligomers. The work was published in *Nature Communications* (Figure 4-5-2).

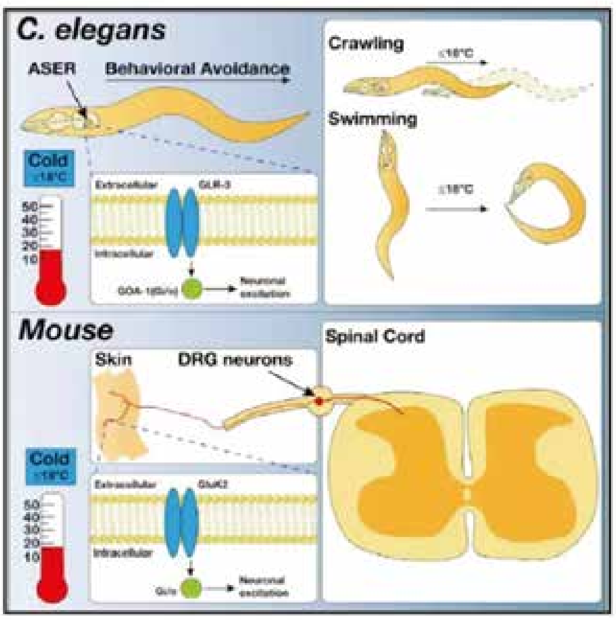


Figure 4-5-1 The glutamate receptor is very conserved and sensitive to cold signals. GLR-3 (nematode)/Gluk2 (mouse) transmits cold signals by coupling downstream G proteins and mediates the animal's escape behavior

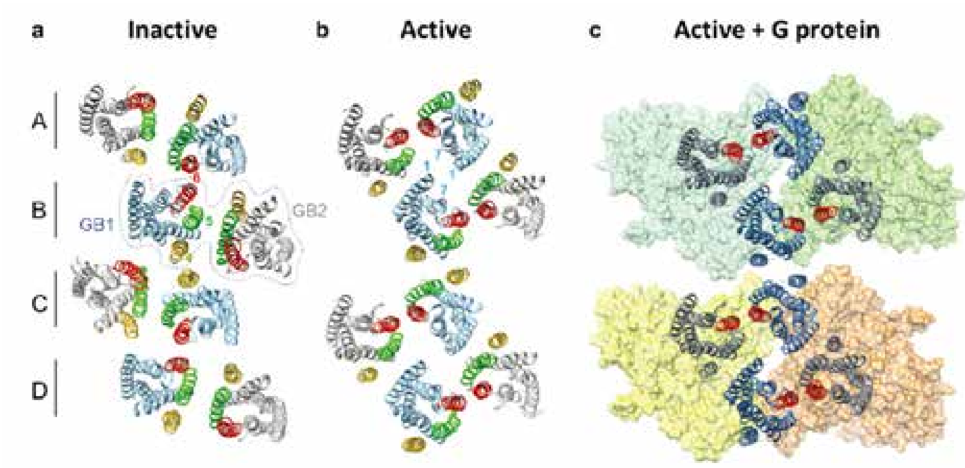


Figure 4-5-2　The top view of the GABAB receptor transmembrane region in the inactive and activated state

5.2　Chemical & Synthetic Biology of Natural Products (NP) from Actinomycetes

Supported by NSFC, the project entitled “A3 Foresight network on chemical and synthetic biology of natural products” was launched in 2016, and Prof. Deng Zixin’s group from Shanghai Jiao Tong University is taking lead in establishing an Asian research network on NPs from actinomycetes. Recently his group has made a few breakthroughs, including the biosynthetic mechanism of protein synthesis inhibitor anisomycin, the enzymatic formation of 2-oxindole moiety in maremycin, an oxidative rearrangement involved in the formation of angular aromatic polyketide murayaquinone, and yield improvements of antitumor ansamitocin and geldanamycin via alleviation of post-PKS bottlenecks or in situ promoter swapping.

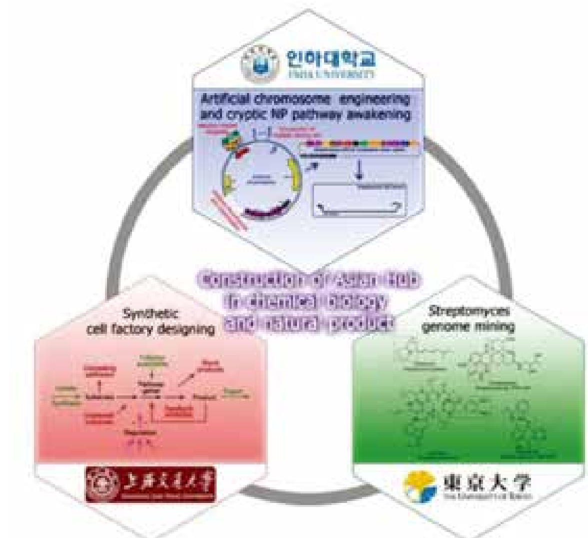


Figure 4-5-3　Asian research network on NPs from actinomycetes

5.3　Augmenting Capabilities of Surveillance Cameras with Data from Moving Sensors for Computation of Metric Information

The program aims to develop technologies to enable the extraction of metric information from multi-source and multi-modality vision sensors. It builds a China-Israel corporation team co-executive by Prof. Tan Tieniu (Institute of Automation of CAS) and Prof. Shmuel Peleg (Hebrew University, Israel). The team integrates technique advantages from both sides, e.g. Prof. Tan's group is proficient at machine learning and neural networks, while professor Shmuel's group is good at multi-modality signal processing. The program has achieved some significant progress on object detection, semantic segmentation, person ReID, etc. For instance, the proposed object detection algorithm, Trident Net, holds the first place of WS COCO ranking list for six months and gains over 2,300 stars on Github, as it is now the most downloaded object detection open-source codes of MXNET platform. The progress of this program will help to break through the bottleneck problems in vision perception and measurement and also provide advance solutions for the national strategical projects, i.e. large-scale video surveillance, complex environment perception and understanding, smart city, etc.

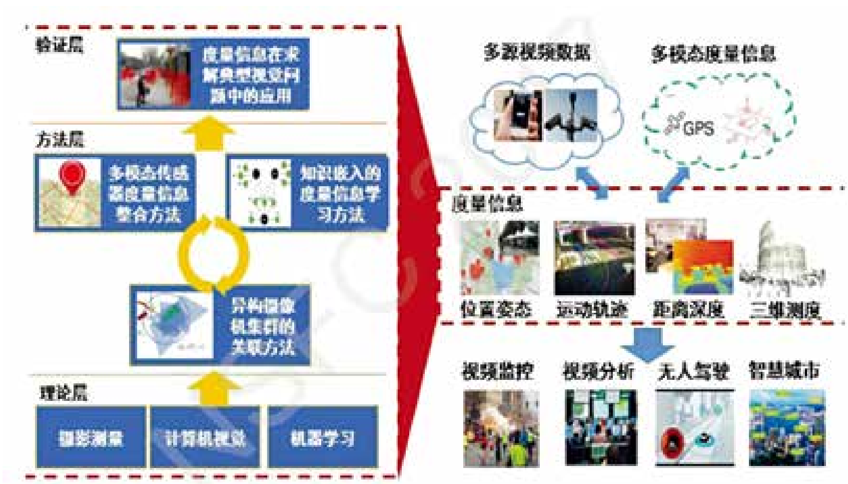


Figure 4-5-4 Measurement times of multi-source heterogeneous visual information association, multi-modal measurement information integration and knowledge embedding

5.4 Adaptation, Prediction and Interaction of Cross-Modal Learning

With the support of the "Adaptation, prediction and interaction of cross-modal learning" project of the Sino-German Interdisciplinary Cooperative Research Project, the research team led by Prof. Sun Fuchun of Tsinghua University and the German partners jointly developed the cross-modal tactile sensor and a multi-finger dexterous hand with integrated "sensing-association-cognition-control" (as shown in Figure 4-5-5). The cross-modal tactile sensors can be used to get the spatial-temporal information about texture, softness, roughness, temperature and three-dimensional force information of the contacted objects. Such information can be used to assist the robot to understand the environment and provide a priori knowledge for robot manipulation. The multi-finger dexterous hand integrating "sensing-association-cognition-control" is the first anthropomorphic dexterous hand with multi-modal percpetion capability. It has high-resolution multi-modal interactive exploration capabilities, which can acquire force perception, vision, tactile and sound information, record information data and learn manipulation optimization through a multi-sensor tracking system. It can be utilized to perform a variety of fine manipulation tasks in unknown and unstructured environments.

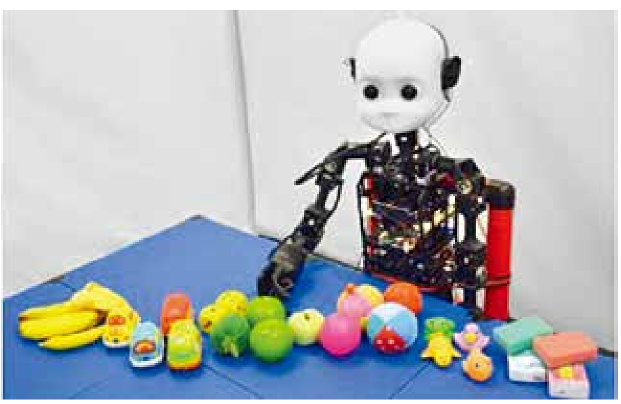


Figure 4-5-5

Part 5

Research Integrity

NSFC

I. Academic Atmosphere Construction Action Plan Launched to Advance the Construction of NSFC Research Integrity System Based on Principles of Education, Motivation, Regulation, Supervision and Punishment

Through in-depth study and implementation of General Secretary Xi Jinping's important instructions on basic research and academic atmosphere construction, as well as earnest implementation of the "Opinions on Further Strengthening the Construction of Research Integrity" and "Opinions on Further Promoting the Spirit of Scientists and Strengthening the Construction of Work Style and Academic Atmosphere" jointly released by the General Office of the CPC Central Committee and the General Office of the State Council, NSFC launched the Academic Atmosphere Construction Action Plan to advance the construction of NSFC research integrity system based on principles of education, motivation, regulation, supervision and punishment, in view of the new tasks and requirements put forward by the new era on the strengthened construction of work style and academic atmosphere, research integrity, research ethics, and supervision system construction. During 2019, NSFC formulated Work Plan on Implementing Opinions on Further Strengthening Research Integrity Construction, drove the revision of Regulations on Adjudicating Research Misconducts Related to NSFC-Funded Projects and the Charter of NSFC Supervision Committee, and initiated the establishment of Management Measures for the Supervision of the National Natural Science Fund as well as Code of Conduct for Researchers Funded by NSFC.

II. In-Depth Research Integrity Education Geared up through Popularization

1. Strengthen international exchanges and publicize the policies and measures taken by NSFC for research integrity construction.

During June 2–5, 2019, NSFC Vice President in charge of research integrity construction led a team to participate in the 6th World Conference on Research Integrity held in Hong Kong and briefed on the perspectives and measures taken by NSFC on responsible conduct of research, as well as the efforts made in the construction of research integrity and promotion of responsible conduct of research. On June 14, Ms. Zoe Hammatt, member of the Board of Trustees of the World Conference on Research Integrity and former head of the Education and Integrity Division of the Office of Research Integrity of the US Department of Health and Human Services, was invited to visit NSFC for an intensive discussion and exchange of views on research integrity.

2. Implement instructions by leading comrades of CPC Central Committee.

On September 17, 2019, a symposium on "Promoting the Spirit of Scientists and Establishing a Good Style of Work and Research" was jointly held by NSFC and CAS. At the meeting, 10 scientists such as Sun Changpu, Mei Hong, Zhang Xuemin, Zhou Zhonghe, Ding Kuiling, Chen Yeguang, Li Ruxin, Fu Xiaolan, Sun Binyong and Chen Yunji successively spoke on the theme of the symposium and jointly launched an initiative for the scientific community to promote the spirit of scientists and establish a good style of work and research, in an effort to promote responsible conducts of scientific research, academic review and research management (Figure 5-2-1). The initiative was co-signed by over 50,000 people through WeChat.

Figure 5-2-1 Initiative co-signed by 10 scientists on Promoting the Spirit of Scientists and Establishing a Good Style of Work and Research on September 17, 2019

3. Take an active part in popularization and education activities as one of the deputy leader unit of the National Leading Group on Scientific Ethics and Academic Norms Popularization and Education.

During September 21–23, 2019, relevant NSFC leaders participated in the Special Seminar for Graduate Student Supervisors and Forum for Graduate Students on Scientific Ethics and Academic Norms organized by the National Leading Group on Scientific Ethics and Academic Norms Popularization and Education, hosting the opening ceremony and giving a wrap-up talk.

Fourthly, gear up research integrity education through popularization and interagency cooperation. Under the normalized mechanism of popularization, full advantage of varied working meetings and training workshops was taken to publicize research integrity, raise the awareness of academic self-discipline, and strengthen consciousness of responsibility in the management and use of NSFC funds. Besides, lectures on code of conduct, conflict of interest, and confidentiality were also arranged during the on-site supervision of panel review meetings, requiring all panel reviewers to strictly abide by relevant regulations and properly perform their duties. On November 13, 2019, the annual Scientific Ethics and Academic Norms Popularization and Education Conference was jointly held by China Association for Science and Technology, Ministry of Education, Chinese Academy of Sciences, Chinese Academy of Social Sciences, Chinese Academy of Engineering, Beijing Municipal Government and NSFC (Figure 5-2-2).

Figure 5-2-2 Scientific ethics and academic norms popularization and education conference on november 13, 2019

4. Gear up research integrity education in an effort to raise researchers' awareness of research integrity.

Under the normalized mechanism of popularization, full advantage of varied working meetings and training workshops was taken to publicize NSFC's practice and measures in promoting research integrity, as well as typical cases of research misconduct and new tasks and requirements in the new status quo. Besides, lectures on code of conduct, conflict of interest, and confidentiality were also arranged during the on-site supervision of panel review meetings, requiring all panel reviewers to strictly abide by relevant regulations and properly perform their duties.

5. Strengthen information disclosure of research misconduct in timely response to online public opinions.

Information on the investigation and adjudication of research misconducts was disclosed on NSFC's website, with a view to warning. Close attention was paid to public opinion related to NSFC, rational measures and positive guidance were adopted accordingly.

6. Dive deep into the situation on the ground and bounce ideas off the frontline researchers and administrative staff.

Symposia were held in 22 awardee institutions based in Shanghai and provinces of Hubei, Guangxi, etc, in order to dive deep into the situation on the ground and bounce ideas off the frontline researchers and administrative staff on research integrity, research ethics, and management of NSFC awards, which provided wrap-up reports for policy making reference.

III. Actively Promote Whole-Process and Full-Coverage Management of Research Integrity

NSFC's Open Letter on All Parties Seriously Performing Their Compliance Assurance and Creating a Clean and Positive Review Environment was released. The "Four-Party Assurance" (four parties refers to applicants, applicants' home institutions, review experts and NSFC staff) continued to be fully implemented. Alongside the mail review, NSFC issued a reminder to the scientific community to resolutely resist any form of requesting the reviewers to give favored ratings through Chinese Science News on May 16, 2019. During the panel review process, a series of new measures were taken to enhance the effectiveness of the on-site supervision of panel review meetings.

IV. Maintain the Rigor of Investigation and Punishment of Research Misconducts

In 2019, NSFC accepted a total of 489 allegations and clues of research misconducts. NSFC has always regarded the serious investigation and punishment of scientific misconduct as the last resort for the effective operation of NSFC research integrity system, and maintained high-pressure investigation and punishment of the misconduct cases, which played a key role in ensuring a healthy academic ecology. In 2019, NSFC Supervision Committee held 3 plenary sessions to deliberate more than 200 cases and form recommended adjudication suggestions (Figure 5-4-1). Over the year 2019, a total of 83 respondents and 9 awardee institutions were punished, of which 10 responsible persons were notified of criticism, 32 persons were internally notified of criticism, 15 persons received written warnings, and 20 persons received oral warnings, 28 persons were debarred from applying for NSFC programs for a period of 1-7 years, and 2 persons were struck from review capacity for 2 and 7 years respectively.

Continued efforts were made to revise the Charter of NSFC Supervision Committee, bringing

Figure 5-4-1 Third Plenary Session of 5th NSFC Supervision Committee Held in Beijing during March 26–27, 2019

appropriate reforms of its operation mechanism in order to drive up the deliberation and adjudication of research misconduct cases to meet the requirements in the new situation.

V. Strengthen the Oversight and Inspection of Awarded Funds

Firstly, NSFC completed random inspections of 533 projects (with a total funds of 750 million yuan) from 34 awardee institutions in Shanghai and Guangxi provinces. Secondly, wrap-up report and analysis of the random inspections of projects in Shandong province, and rectification notices were issued to relevant awardee institutions, with their rectification reports being required. Thirdly, the targeted inspections of allegations concerning projects based in Hunan and Guangdong provinces were completed, and responsible persons and awardee institutions were punished for improper management and use of NSFC awarded funds in line with relevant regulations, policies and procedures. Fourthly, the Information System for Oversight and Inspection of NSFC Awarded Fund (version 1.0) with a visual interface was developed to assist with the selection and analysis of NSFC funded awards during the routine inspections and random inspections.

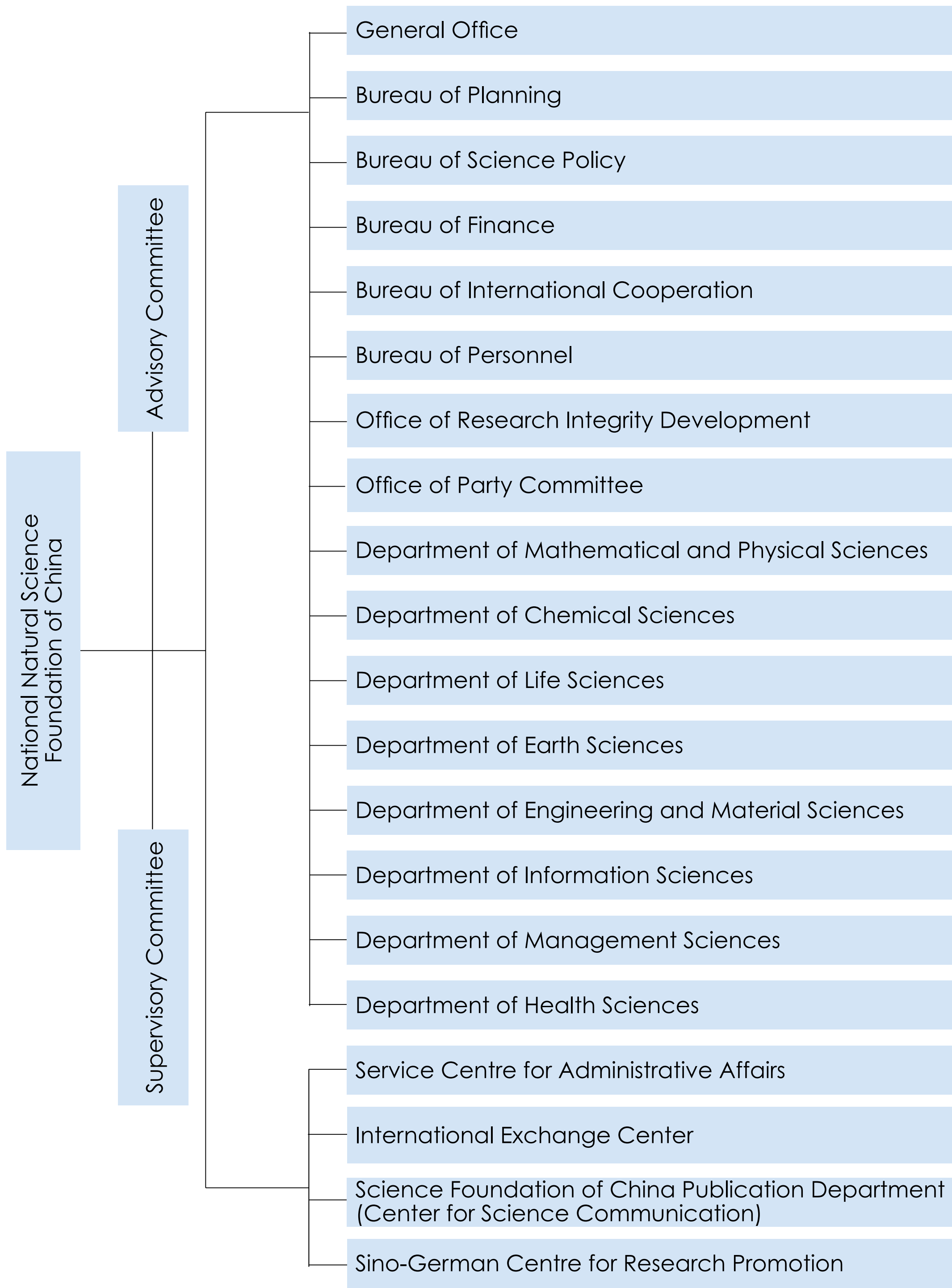
Part 6

Organizational Chart

NSFC

2019 ANNUAL REPORT

1. Organizational Chart



2 Members of the 8th Council of NSFC

President: Li Jinghai
Vice Presidents: Gao Fu, Xie Xincheng, Hou Zengqian, Gao Ruiping, Wang Chengwen, Lu Jianhua
Secretary-General: Han Yu
Members: Wang Hongyang, Wang Enge, Zhu Rixiang, Wu Hao, Liu Changsheng, Sun Changpu, Yan Chunhua, Song Jun, Zhang Guangjun, Zhang Xi, Zhang Liangrui, Chen Zuoning, Chen Xiaohong, Zhao Xiaozhe, Zhong Denghua, Kang Le, Tong Aiping

3 Members of the 5th Supervisory Committee of NSFC

Director: Chen Yiyu
Deputy Director: Zhu Zuoyan, He Minghong
Members: Wang Yizheng, Wang Yuefei, Zhu Bangfen, Zhu Weitong, Liu Ming, Liu Zhihua, Yan Shouke, Su Xianyue, Li Zhaohu, Li Zhenzhen, Zhou Xingshe, Zheng Yongfei, Yao Zhujun, Huang Haijun, Cui Xiang, Jiao Nianzhi

4 NSFC Staff

(1) Full Time Staff

By December 31, 2019, NSFC has 208 full time staff, with 130 males and 78 females and 194 with professional and technical titles. The average age is 46.

(2) Rotational Program Directors in NSFC

By December 31, 2019, there are 106 Rotational Program Directors on duty, and 104 of them have a

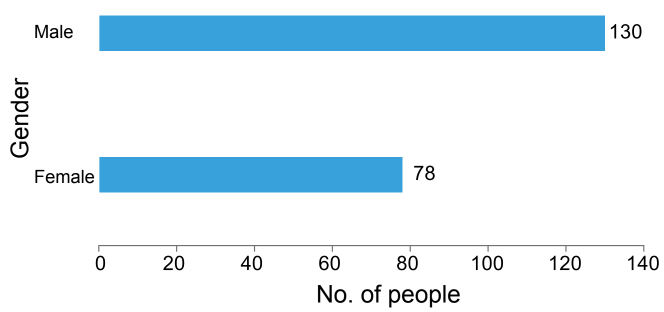


Figure 6-1-1 Gender Distribution of NSFC Staff

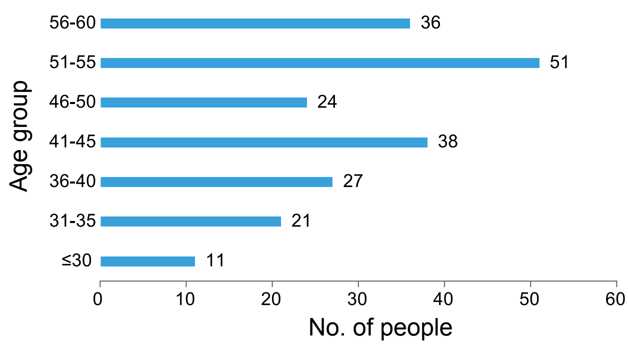


Figure 6-1-2 Age Distribution of NSFC Staff

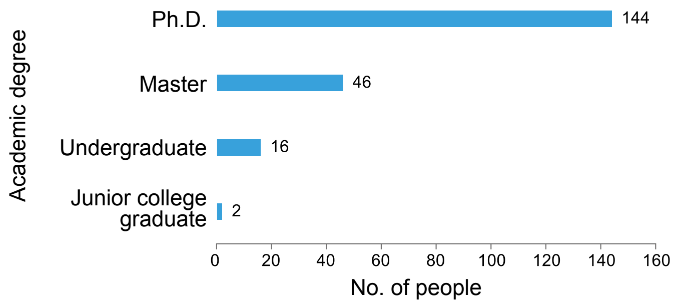


Figure 6-1-3　Aeademic Degree of NSFC Staff

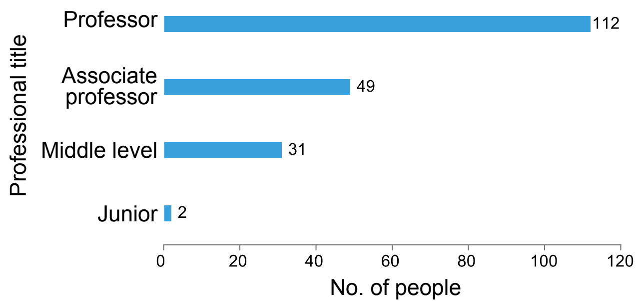


Figure 6-1-4　Profeasional Fitle of NSFC Staff

Ph.D. degree. Among the Rotational Program Directors, 80 are males and 26 females; 40 are professors or research fellows, and 66 are associate professors.

5　Leaders of NSFC's Bureaus, Departments and Subordinate Units

Leaders of NSFC's Bureaus and Departments (by December 31, 2019)

Units	Leaders
General Office	Han Zhiyong (concurrently), Lyu Shumei (F), Zhang Yongtao, Liu Ke (Director of Information Center)
Bureau of Planning	Wang Changrui, Che Chenwei, Wang Yan (F)
Bureau of Science Policy	Zou Liyao, Yu Sheng
Bureau of Finance	Zhang Xiangping (F), Xing Hairu (F)
Bureau of International Cooperation	Yang Junlin, Fan Yingjie (F)
Bureau of Personnel	Zhou Yanze, Zhu Weitong (F), Wang Cuixia (F), Liu Ning (Director of Office of Retirement Affairs)
Office of Research Integrity Development	Guo Jianquan, He Jie
Office of Party Committee	Han Zhiyong, Fang Yudong
Department of Mathematical and Physical Sciences	Jiang Song (concurrently), Dong Guoxuan, Meng Qingguo, Pu Men
Department of Chemical Sciences	Yang Xueming (concurrently), Chen Yongjun
Department of Life Sciences	Li Peng (F, concurrently), Feng Xuelian (F), Gu Ruisheng
Department of Earth Sciences	Guo Zhengtang (concurrently), Wang Qidong, Yao Yupeng
Department of Engineering and Materials Sciences	Qu Jiuhui (concurrently), Li Ming, Gao Tiyu, Wang Guobiao
Department of Information Sciences	Hao Yue (concurrently), Zhang Zhaotian, Li Jianjun
Department of Management Sciences	Wu Qidi (F, concurrently), Yang Liexun, Liu Zuoyi
Department of Health Sciences	Zhang Xuemin (F, concurrently), Sun Ruijuan (F), Xu Yanying (F), Zhu Weitong (F)

Leaders of NSFC's Subordinate Units (by December 31, 2019)

Units	Leaders
Service Centre for Administrative Affairs	Feng Wenan, Yang Tao, Shi Xinghe
International Exchange Center	Shi Xinghe (concurrently)
Science Foundation of China Publication Department (Center for Science Communication)	Tang Longhua, Peng Jie (F)
Sino-German Centre for Research Promotion	Fan Yingjie (F, concurrently)

Appendix

NSFC

I. NSFC's Important Activities in 2019

January

January 31, the first plenary and the inaugural meeting of the Advisory Committee of NSFC was held in Beijing. Party Secretary and President Li Jinghai, Party Member and Vice President Gao Fu, Hou Zengqian, Gao Ruiping, Vice President Xie Xincheng, Secretary-General Han Yu attended the meeting.

February

February 10–14, Party Secretary and President Li Jinghai attended the meeting of officials of the International Council for Science in Oman.

February 22, Party Secretary and President Li Jinghai, Party Member and Vice President Gao Ruiping attended the 2019 Management Committee meeting for Regional Innovation and Development Joint Fund and the 2019 Management Committee meeting for Enterprise Innovation and Development Joint Fund.

February 25, Vice President Xie Xincheng participated in the fourteenth session of the Sino-French Joint Committee Meeting on Science and Technology Cooperation and signed the Scientific Cooperation Framework Agreement between NSFC and French National Center for Scientific Research (CNRS) with CNRS chairman Antoine Petit.

February 28, Party Secretary and President Li Jinghai, Party Member and Vice President Gao Ruiping and Wang Chengwen attended and spoke at the 2019 NSFC Review Deployment Meeting. The meeting was chaired by Han Yu, member of the party group and Secretary-General.

March

March 15, Li Jinghai, Party Secretary and President, chaired the meeting of all staff members of NSFC and conveyed the spirit of the National People's Congress and the Second Session of the 13th National People's Congress. Comrade Yang Wei conveyed the spirit of the Second Session of the 13th CPPCC National Committee. Party Member and Vice President Hou Zengqian, Gao Ruiping, Wang Chengwen, Vice President Xie Xincheng, Party Member and Secretary-General Han Yu attended.

March 18, Party Members and Vice President Gao Fu, Gao Ruiping, Wang Chengwen, Vice President Xie Xincheng, Party Member and Secretary-General Han Yu investigated the 2019 application of NSFC.

March 26, the second session of the Eighth National Natural Science Foundation Committee was convened. The meeting reviewed and approved the report on the work of the whole committee made by Party Secretary and President Li Jinghai, the report on the work of the Supervisory Committee made by Chen Yiyu, the chairman of the Supervisory Committee. Party Member and Secretary-General Han Yu reported the *Constitution of the NSFC (Revised Draft)* and submitted in written form *the Report on the Implementation of the 2018 Science Fund Budget and Funding Plan and the Report on the 2019 Budget and Funding Plan*. Party Secretary and Minister of the Ministry of Science and Technology Wang Zhigang attended and addressed the meeting. The members of the 8th NSFC Committee, the relevant comrades of the Discipline Inspection and Supervision Group of the National Commission for Discipline Inspection of the Central Commission for Discipline Inspection in the Ministry of Science and Technology attended the meeting; the consultants of NSFC, the members of the 5th Supervision Committee, the directors of the scientific departments (part-time) and comrades from various departments attended the meeting throughout the session; all cadres and employees attended the opening ceremony. The meeting was chaired by Gao Fu, member of the party group and Vice President.

April

April 22, Wang Chengwen, member of the party group and Vice President, presided over the first of a series of meetings on "Promoting the spirit of science and deepening fund reform".

April 28, NSFC convened the 2019 Party Construction Work and Party Conduct and Clean Government Construction and Anti-Corruption Work Conference. Wang Binyi, leader of the Discipline Inspection and Supervision Group of the National Commission for Discipline Inspection of the Central Commission for Discipline Inspection in the Ministry of Science and Technology, attended the conference and delivered a speech. Party Secretary and President Li Jinghai and the relevant comrades signed a letter of responsibility for comprehensively managing the party and delivered speeches. Party group member and Vice President Wang Chengwen made a summary report on the 2018 Party construction and anti-corruption work. Party group member and Vice President Lu Jianhua, party group member and Secretary-General Han Yu attended the meeting and party group member and Vice President Bureau Ruiping presided over the meeting.

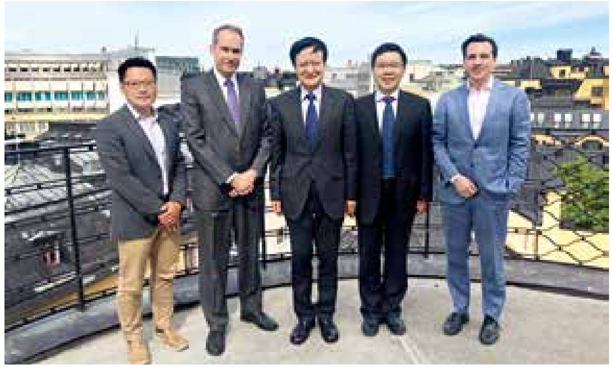
May

May 20, Party Secretary and President Li Jinghai, Party Leader and Vice President Gao Ruiping attended the Forum for National Outstanding Youth Science Fund Project and Outstanding Youth Science Fund Project Grantees.

June

June 11, NSFC organized the Deployment meeting on the theme of "Remain true to our original aspiration and keep our mission firmly in mind". Party Secretary and President Li Jinghai made a pep speech, Lin Jun, leader of the 21st Central Guiding Group, attended the meeting and delivered a speech, and Deputy Leader Zhuge Caihua attended the meeting. Party group member and Vice President Hou Zengqian, Gao Ruiping, Wang Chengwen, Lu Jianhua, party group member and Secretary-General Han Yu attended the meeting.

June 18–28, Party Secretary and President Li Jinghai visited France, Denmark and Sweden, attending the meeting of the International Council for Science Executive Committee held in France, visited the Danish scientific funding agency, and led a delegation to participate in "The Next 100 Years" and the International Conference of the Centennial Celebration of the Royal Swedish Academy of Engineering and made keynote speeches at the conference and forum.



July

July 3, the Party Secretary and President Li Jinghai, Party Member and Vice President Gao Fu, Hou Zengqian, Gao Ruiping, Wang Chengwen, Lu Jianhua, Vice Presidents Xie Xincheng, Party Member and Secretar-General Han Yu, continued to examine problems and consider specific measures, centering on strengthening theoretical studies and improving political awareness, elevate mental state, complete missions and tasks, implement reform and deployment. Lin Jun, leader of the 21st Central Guiding Group, attended the meeting.

July 4, Wang Binyi, the leader of the Discipline Inspection and Supervision Group of the National Commission for Discipline Inspection of the Central Commission for Discipline Inspection, gave a lecture on the theme of "Never forget why you started, and your mission can be accomplished" for all party members and cadres of the NSFC. The meeting was chaired by Party Secretary and President of NSFC Li Jinghai. Party Member and Vice President Gao Fu, Hou Zengqian, Gao Ruiping, Wang Chengwen, Lu Jianhua, Hou Zengqian, Gao Ruiping, Wang Chengwen and Lu Jianhua, Secretary-General Han Yu, and relevant comrades of the Discipline Inspection and Supervision Group of the National Commission for Discipline Inspection of the Central Commission for Discipline Inspection in the Ministry of Science and Technology attended the meeting.

July 19, Wang Binyi, Team Leader of Discipline Inspection Supervision of the Ministry of Science and Technology of the Central Commission for Discipline Inspection of the Central Commission for Discipline Inspection, went to the on-site investigation of the review meeting of the Ministry of Management Science to discuss with project review experts, supervisors and staff members of the meeting.

August

August 8, Party Member and Vice President Hou Zengqian, and Vice President Xie Xincheng attended the first meeting of the Scientific Expert Group of the International Cooperation Science Program for Sustainable Development.

August 15th, Party Secretary and President Li Jinghai attended the NSFC's "Never forget why you started, and your mission can be accomplished" Education and Deepening Reform Promotion Conference, and gave an in-depth explanation of the NSFC's deepening reform implementation program outline, to deploy the theme education of "Never forget why you started, and your mission can be accomplished" and put forward clear requirements. Party member and Vice President Wang Chengwen presided over the meeting, and party member and Secretary-General Han Yu attended the meeting.

August 30, Party Secretary and President Li Jinghai presided over the convening of the education summary meeting on the theme of "Never forget why you started, and your mission can be accomplished" of the party group of the NSFC. Lin Jun, leader of the 21st Central Guiding Group, attended and delivered a speech. Zhuge Caihua, deputy leader of the guidance group, Hu Zhigang and Wang Zhihui, staff of the guidance group, and Xuan Hongyun, deputy leader of the Discipline Inspection and Supervision Group of the Ministry of Science and Technology of the Central Commission for Discipline Inspection, attended the meeting for supervision and guidance. Party group member and Vice President Gao Fu, Hou Zengqian, Gao Ruiping, Wang Chengwen, Lu Jianhua, party group member and Secretary-General Han Yu attended the meeting.

September

September 2, the State Council Prime Minister Li Keqiang chaired National Science fund for Distinguished Young Scholars Working symposium. Party Secretary and President Li Jinghai made a report on work at the symposium. Party members and Vice Presidents Gao Fu, Hou Zengqian, Gao Ruiping, Wang Chengwen, Lu Jianhua, Vice President Xie Xincheng, party group member and Secretary-General Han Yu attended the meeting.

September 5, NSFC convened the first congress of the National Communist NSFC Party Committee. Party Secretary and President Li Jinghai attended the opening ceremony and delivered a speech. Li Guihua, executive deputy secretary of the Party Committee of the agency directly under the Ministry of Science and Technology, and the National Commission for Discipline Inspection Xuan Hongyun, deputy leader of the Discipline Inspection and Supervision Group of the Commission in the Ministry of Science and Technology, attended the meeting. The meeting was chaired by Wang Chengwen, member of the party group and Vice President, and Han Yu, member of the party group and Secretary-General, attended the meeting.

September 11, Li Jinghai, secretary and President of the Party Membership Group, presided over the convening of the Second Inspection Team of the Central Committee to inspect the inaugural meeting of the Party Committee of NSFC. Xue Litong, leader of the second inspection team of the Central Committee, carried out inspection tasks and overall arrangements, and raised demands on the cooperation of the committee for the inspection work. Li Jinghai made a statement. Zhang Zhong and Xing Konghao, deputy leaders of the Second Central Inspection Group, relevant comrades of the Second Inspection Group, relevant comrades of the Central Inspection Office, and responsible comrades of the Discipline Inspection and Supervision Group of the National Discipline Inspection Commission of the Central Commission for Discipline Inspection in the Ministry of Science and Technology attended the meeting. Party Member and Vice President Gao Fu, Hou Zengqian, Gao Ruiping, Wang Chengwen, Lu Jianhua, Party Member and Secretary-General Han Yu attended the meeting, Vice President Xie Xincheng also participated in the meeting.

September 16, Gao Ruiping, member of the party group and Vice President, attended the 2019 review meeting for NSFC's Excellent Young Scientists Fund (Hong Kong and Macao).

September 20, Party Secretary and President Li Jinghai, Party Leader and Vice President Gao Ruiping attended the 2019 Review Committee meeting for the National Science Fund for Distinguished Young Scholars.

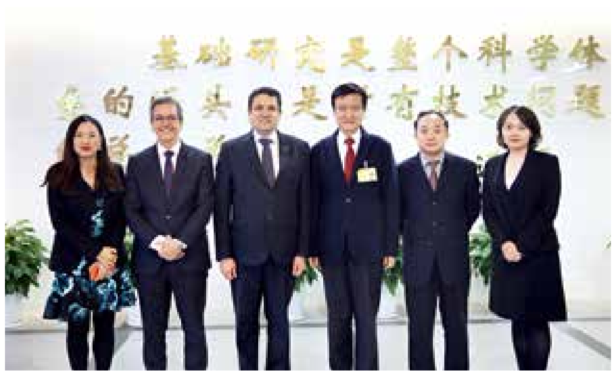
September 21, the Party Member and Secretary-General Han Yu attended the National Medicine Development Forum and the 3rd Zhan Bradur Gimeng Pharmaceutical Industry Development Symposium in Naiman Banner, conducted a special poverty alleviation survey and visited the poverty alleviation cadres.

September 29, the eighth meeting of the joint leading group of NSFC and CAS on discipline development strategy research was held in Beijing. Ding Zhongli, the leader of the joint leading group and vice president of CAS, and Li Jinghai, Party Secretary and President of the Party group of NSFC attended the meeting and delivered speeches. Han Yu, deputy leader of the joint leading group, member of the Party group of NSFC and Secretary-General, presided over the meeting.

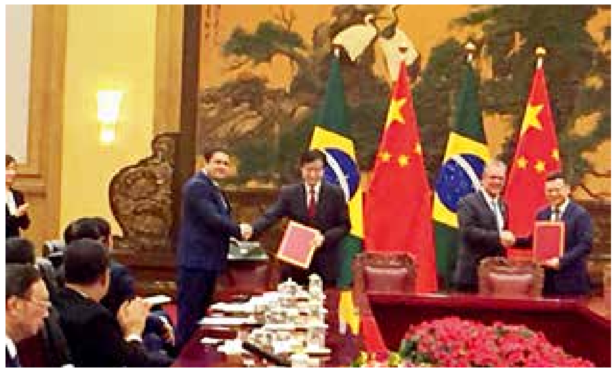
October

October 8, NSFC held a flag raising ceremony to celebrate the 70th anniversary of the founding of the People's Republic of China. Li Jinghai, Party Secretary and President, attended the ceremony and delivered a speech. Hou Zengqian, Gao Ruiping, Wang Chengwen and Lu Jianhua, Party Member and Vice President of the Party group, and Xie Xincheng, Vice President, attended the ceremony. Han Yu, member of the Party and Secretary-General, presided over the flag raising ceremony.

October 24, Li Jinghai, Party Secretary and President of the Party group, met with Anderson Ribeiro Gorreia, President of the Brazilian Association for the promotion of higher education personnel (CAPES).



October 25, Li Jinghai, Party Secretary and President, attended the signing ceremony of signing the agreement between China and Brazil in the Great Hall of the People, and signed a Memorandum of Understanding on behalf of NSFC and CAPES.



October 25, Li Jinghai, Party Secretary and President of the Party group, and Gao Ruiping, Member Party and Vice President, attended the forum and agreement signing meeting on Guangxi Zhuang Autonomous Region's inclusion to the Joint Fund for Regional Innovation and Development.

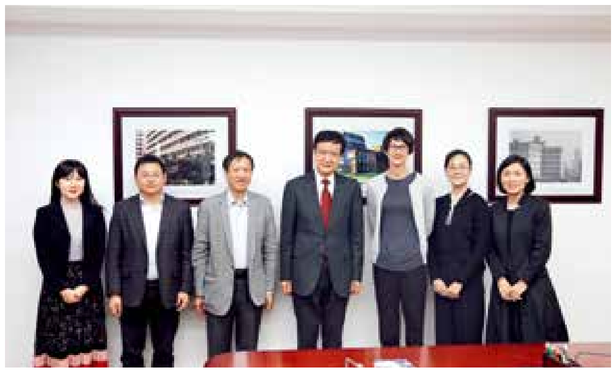
November

November 11, Li Jinghai, Party Secretary and President, and Gao Ruiping, Party Member and Vice President attended the signing ceremony of the Ningxia Hui Autonomous Region's inclusion in the Joint Fund for Regional Innovation and Development.

November 12-15, Party Secretary and President Li Jinghai presided over the 2019 National Party Committee (Expanded) Meeting of the National Natural Science Foundation of China, held in-depth discussion of the implementation plan of the deepening reform of the Science Fund, and systematic planning of the mid- and long-term development plan of the Science Fund from 2021 to 2035 and the "14th Five-Year" development plan. Party members and Vice President Gao Fu, Hou Zengqian, Gao Ruiping, Wang Chengwen, Lu Jianhua, Party Members and Secretary-General Han Yu and Vice President Xie Xincheng attended the meeting.

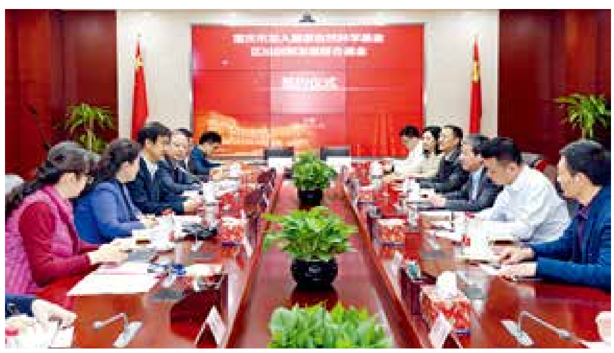
November 18, the second meeting of the Joint Leading Group of the National Natural Science Foundation of China and the Chinese Academy of Engineering Sciences on the Development Strategy of China's Engineering Science and Technology for the next 20 years was held in Beijing. The leader of the joint leadership group of the two parties, Secretary of the Party and President of the Chinese Academy of Engineering Sciences Li Xiaohong, and Secretary of the Party and President of NSFC Li Jinghai attended and addressed the meeting. Zhong Zhihua, deputy head of the joint leadership group and vice president of the Chinese Academy of Engineering Sciences, chaired the meeting.

November 21, Party Secretary and President Li Jinghai met with Helen Pearson, chief editor of *Nature*, Helen Pearson-OK.



November 21, Party Secretary and President Li Jinghai met with Bill and Melinda Gates Foundation Founder Bill Gates (Bill Gates) and renewed the MOU.

November 22, Party Secretary and President Li Jinghai, Party Member and Vice President Gao Ruiping attended the signing ceremony of Chongqing Municipal's inclusion in the Joint Fund for Regional Innovation and Development.



November 28, Party Secretary and President Li Jinghai, Party Leader and Deputy Director Gao Ruiping Visited to Hangzhou to attend the signing ceremony of the Zhejiang's inclusion in the Joint Fund for Regional Innovation and Development.

November 29, Gao Ruiping, Party Member and Vice President, Visited to Jiaxing to attend the meeting of National Science Fund for Distinguished Young Scholars Zhejiang branch and the Achievement Exhibition of Scientific Instrument programs.

December

December 5–6, Party Secretary and President Li Jinghai and Vice President Xie Xincheng attended the meeting on the discussion of International Symposium on the Reform and Development of the Science Fund.

December 9, Li Jinghai, Party Secretary and President, and Han Yu, party member and Secretary-General, Visited Naimanqi for field research and poverty alleviation work guidance. They also held a workshop on rural revitalization and on poverty alleviation to actively promote the precision poverty alleviation of Naimanqi and targeted at poverty alleviation, rural revitalization and sustainable development.

December 11, the 2019 National Natural Science Foundation Management Working Conference was held in Beijing. Party Secretary and President Li Jinghai, Party Members and Vice Presidents Gao Ruiping and Wang Chengwen attended the meeting. Representatives from 81 host institutes across the country, 28 local science and technology management offices, comrades of various bureaus (offices), Scientific departments and directly affiliated units participated in the meeting.

December 25–26, the Natural Science Foundation Committee Female Cadres' Management Ability Training course was held in Beijing. Gao Ruiping, member of the party group and Vice President, Wang Chengwen, member of the party group, Vice President and secretary of the party committee of the organization attended the opening ceremony of the training course.

II. Shuangqing Forum

The "Shuangqing Forum" is a high-level academic exchange platform set up by NSFC to promote the development of discipline research, promote interdisciplinarity and integration, improve the development strategy and management operation mechanism of the science fund and improve the management level of science fund. The forum adheres to the principle of “a hundred flowers blossom, a hundred schools of thought contend”, and strives to create a good academic atmosphere of rigorous, realistic and equal consultation, encourages experts to fully exchange and collide ideas, and discuss forward-looking and cross-cutting basic scientific issues facing the world's scientific frontiers and national strategic needs, as well as major policy issues related to the management of science fund, and for the construction of a new era of science fund system with advanced concepts, institutional norms, fairness and efficiency.

In 2019, the Shuangqing Forum serves as a platform for implementing the major deployment of the deepening reform of the Science Fund, and the new era science funding orientation of “encouraging exploration, highlighting originality, focusing on the frontier, opening new paths, demand traction, breaking through bottlenecks, common orientation, and cross-combination”. Throughout the year, a total of 31 sessions of the Shuangqing Forum (No. 221−251, Table A-2-1) and 2 sessions of the Poverty Alleviation Strategy Seminar were held, with a total number of 1,224 attending experts. Among the total of 31 sessions, 29 sessions were hosted by the scientific departments and 4 sessions hosted by the adminstrative bureaus. 19 sessions involved basic scientific issues at the frontiers of science, 8 issues involving deep-level scientific issues facing the needs of national development strategies, 4 issues related to major policy and management issues related to the development and improvement of the science fund system, and 2 issues related to industrial poverty alleviation development strategies

Figure A-2-1 Policies and measures for deepening reform of the Science Fund

Figure A-2-2 Functional primitives and order structure of materials

Table A-2-1 2019 "Shuangqing Forum" Themes Directory

No. 221: Integration of Modern Engineering Technology and Basic Science (January 16–17, 2019)	No. 237: Chinese Chemistry Research in the Age of AI (May 25–26, 2019)
No. 222: Frontiers and Crossovers of Instinct Behavior Research (February 25–26, 2019)	No. 238: Molecular Chemistry and Molecular Engineering Under the New Research Paradigm (August 28–29, 2019)
No. 223: Cancer Research Driven by Frontier Crossing Technology (February 26–27, 2019)	No. 239: Important Fundamental Problems of Chemical and Chemical Industries Driven by Industrial Bottlenecks (September 9–10, 2019)
No. 224: Key Scientific Issues in Vaccine Research on Major Diseases (February 28–March 1, 2019)	No. 240: Mechanical Behavior of Key Nuclear Component Structures and Materials in Service (September 21–22, 2019)
No. 225: "Belt and Road" Dynamic Coupling of Internal and External Disaster-Causing Mechanisms and Disaster Reduction of Major Projects (February 23–24, 2019)	No. 241: Frontiers and Future of Evolutionary Biology (September 26–27, 2019)
No. 226: Functional Primitives and Order Structure of Materials (March 2–3, 2019)	No. 242: Data Driven Earth Science: From Tradition to the Data Age (September 22–23, 2019)
No. 227: Deep Frontier Science Forum (March 19–20, 2019)	No. 243: Operations Research: Opportunities and Challenges (October 24–25, 2019)
No. 228: Ubiquitous System Software and Software Definition Method (March 28–29, 2019)	No. 244: Characteristics of the Interaction Between the Physical and Biogeochemical Processes of the Indian Ocean in the Context of Global Change (October 26–27, 2019)
No. 229: Human-Earth System Coupling Mechanism and Regional Sustainable Development Simulation (March 29–30, 2019)	No. 245: Cell Biology Basis of Plant Developmental Plasticity (October 30–31, 2019)
No. 230: Construction and Development of Modern Marine Ranch (March 31–April 1, 2019)	No. 246: Main Issues in Basic Research Development and Strategic Research on Science Fund Development Planning (October 30–31, 2019)
No. 231: Microelectronics Development Path Beyond Moore's Law (April 12–13, 2019)	No. 247: Frontier Scientific Issues on the Basics of Green Prevention and Control of Agricultural Pests and Diseases (November 15–16, 2019)
No. 232: Frontiers and Challenges of Full-Dimensional Data and Intelligent Diagnosis and Treatment (May 11–12, 2019)	No. 248: Key Basic Scientific Issues in Composite Material Manufacturing (November 18–19, 2019)
No. 233: Basic Scientific Issues in Distributed Energy (May 7–8, 2019)	No. 249: National Nutrition and Food Security in the New Era (November 21–22, 2019)
No. 234: Urban Management and Decision-Making Methods in the Process of New Urbanization (May 9–10, 2019)	No. 250: Practice and Challenges of Indirect Cost Management of Science Fund (November 26, 2019)
No. 235: Science Fund Deepening Reform Policies and Measures (May 23–24, 2019)	No. 251: Build a Scientific Fund Organization and Human Resources Security System for the New Era (December 2, 2019)
No. 236: Innovation-Driven Major Entrepreneurial Theory and Key Scientific Issues (May 16–17, 2019)	

III. Administrative Normative Document System of NSFC

Administrative Normative Document System of NSFC

- **Organization and Management**
  - National Natural Science Foundation of China Regulations
  - Regulations of the Supervisory Committee of NSFC
  - Regulations of the Advisory Committee of NSFC
  - Management Measures for NSFC
  - Working Methods of the Expert Advisory Committee of Scientific Departments in NSFC
  - Management Measures for Evaluation Experts of NSFC
- **Procedure Management**
  - Management Measures for General Program of NSFC
  - Management Measures for Key Program of NSFC
  - Management Measures for Major Program of NSFC
  - Management Measures for International (Regional) Cooperative Research Program of NSFC
  - Management Measures for International (Regional) Exchange Program of NSFC
  - Management Measures for Fund for Less Developed Regions of NSFC
  - Management Measures for Young Scientists Fund of NSFC
  - Management Measures for National Science Fund for Distinguished Young Scientists of NSFC
  - Management Measures for Excellent Young Scientists Fund of NSFC
  - Management Measures for the Research Fund for International Young Scientists of NSFC
  - Management Measures for Tianyuan Fund for Mathematics of NSFC
  - Management Measures for Science Fund for Creative Research Groups of NSFC
  - Management Measures for Joint Funds of NSFC
  - Management Measures for Major Research Plan of NSFC
  - Management Measures for Special Fund for Research on National Major Research Instruments of NSFC
  - Management Measures for Special Projects of NSFC
- **Fund Management**
  - Measures for Fund Management of NSFC
  - Supplementary Notice of Minister of Finance on Issues Relevant to Fund Management of NSFC Funded Projects
  - Notice of the Ministry of Finances to NSFC on Further Improving Science Fund Projects and Fund Management
- **Supervision and Guarantee**
  - Management Measures for Information Disclosure of NSFC
  - Measures for Evasion and Confidentiality Management in Project Evaluation of NSFC
  - Measures for Project Review Management of NSFC
  - Measures for the Management of Research Achievements of NSFC Funded Projects
  - Rules for the Implementation of the Supervisory Work of NSFC Subsidized Projects Assessment Meeting
- **Other**
  - Code of Conduct for Project Evaluation Experts of NSFC
  - Rules for the Management and Implementation of the Regional Liaison Network of NSFC
  - Rules for the Implementation of the Registration Administration of Dependent Units of NSFC

IV. National Award Recipients supported by NSFC

In 2019, the recipients for 1 first prize, 45 second prizes for National Award for Natural Sciences, 1 first prize for National Award for Technological Invention, along with the 7 out of 13 first prizes for Reward of Natianal Science and Technology Progress, have all been supported by NSFC at different stages (see Tables A-4-1 to A-4-4).

Table A-4-1 First Prize of National Award Recipients Supported by NSFC

No.	Name of Award-Winning Achievement	Main Participants	Name of Major Project Funded by NSFC	Number of Projects Funded
1	Discovery of an efficient chiral spiral catalyst	Zhou Qilin (Nankai University) Xie Jianhua (Nankai University) Zhu Shoufei (Nankai University) Wang Lixin (Nankai University)	Novel chiral catalyst studies for highly enantioselective organic reactions	47

Table A-4-2 Second Prize of National Award Recipients Supported by NSFC

No.	Name of Award-Winning Achievement	Main Participants	Name of Major Project Funded by NSFC	Number of Projects Funded
1	Mathematical theory of stochastic control and nonlinear filtering	Tang Shanjian (Fudan University)	Control theory of stochastic systems	6
2	Study of efficient algorithms for several types of partial differential equations	Huang Yunqing (Xiangtan University)	Numerical calculation of a partial differential equation	16
3	Pinka-Sterling conjecture and the study of hypersurface geometry	Li Haizhong (Tsinghua University)	Conformal geometry and invariant theory	9
4	Experimental study of topological quantum material preparation and quantum properties	Jia Jinfeng (Shanghai Jiao Tong University) Qian Dong (Shanghai Jiao Tong University) Liu Canhua (Shanghai Jiao Tong University) Gao Chunlei (Shanghai Jiao Tong University) Guan Dandan (Shanghai Jiao Tong University)	Novel quantum material physics and devices	49
5	Modulation of electromagnetic waves by superconfigured surfaces	Zhou Lei (Fudan University) Sun Shulin (Fudan University) He Qiong (Fudan University) Hao Jiaming (Fudan University) Xiao Shiyi (Fudan University)	Basic theory and key technologies of new artificial electromagnetic media	23
6	Theoretical studies on the interaction between iron-based superconducting electronic structures and magnetism	Lu Zhongyi (Renmin University of China) Xiang Tao (Institute of Physics, CAS) Ma Fengjie (Institute of Theoretical Physics, CAS) Yan Xunwang (Institute of Theoretical Physics, CAS) Gao Miao (Renmin University of China)	Study of spin dynamics and underlyimg superconductivity mechanism of new unconventional superconducting materials	35

(continued)

No.	Name of Award-Winning Achievement	Main Participants	Name of Major Project Funded by NSFC	Number of Projects Funded
7	CALYPSO crystal structure prediction method and application	Ma Yanming (Jilin University) Wang Yanchao (Jilin University) Lju Jian (Jilin University) Liu Hanyu (Jilin University) Wang Hui (Jilin University)	Method and application of structural prediction for complex system	43
8	Study on electrochemical surface enhanced Raman spectroscopy	Tian Zhongqun (Xiamen University) Ren Bin (Xiamen University) Li Jianfeng (Xiamen University) Wu Deyin (Xiamen University) Liu Guokun (Xiamen University)	Study on time-resolved Raman spectroscopy and fourier transform infrared spectroscopy of electrochemistry	101
9	Controlled growth of graphene and its performance regulation	Liu Yunqi (Institute of Chemistry, CAS) Yu Gui (Institute of Chemistry, CAS) Wu Bin (Institute of Chemistry, CAS) Wei Dacheng (Institute of Chemistry, CAS) Chen Jianyi (Institute of Chemistry, CAS)	Controllable preparation of graphene-based materials and the physical and chemical basis of field-effect transistor devices	48
10	Fluoride oxidation	Qing Fengling (Shanghai Institute of Organic Chemistry, CAS) Chu Lingling (Shanghai Institute of Organic Chemistry, CAS) Chen Chao (Shanghai Institute of Organic Chemistry, CAS) Jiang Xinyi (Shanghai Institute of Organic Chemistry, CAS) Wu Xinyue (Shanghai Institute of Organic Chemistry, CAS)	Controllable synthesis and application of fluorine-containing organic functional molecules	21
11	Functional dye stability enhancement principle and application basic research	Zhu Weihong (East China University of Science and Technology) Guo Zhiqian (East China University of Science and Technology) Wu Yongzhen (East China University of Science and Technology) Xie Yongshu (East China University of Science and Technology) Zhao Chunchang (East China University of Science and Technology)	Mechanism of photothermal stability of functional organic pigments	36
12	Research on methods and mechanisms of structural defects control of solid catalysts	Gong Jinlong (Tianjin University) Ma Xinbin (Tianjin University) Zou Jijun (Tianjin University) Li Landong (Nankai University) Wang Tuo (Tianjin University)	Energy catalysis	44
13	Metallogenic theory of collisional porphyry copper deposits	Hou Zengqian (Institute of Geology, Chinese Academy of Geological Sciences) Yang Zhiming (Institute of Geology, Chinese Academy of Geological Sciences) Gao Yongfeng (Hebei GEO University) Zheng Yuanchuan (China University of Geosciences, Beijing) Zhang Hongrui (Institute of Geology, Chinese Academy of Geological Sciences)	Environmental porphyry copper deposits in Mainland China: Geodynamic background and deposit genetic model	36

(continued)

No.	Name of Award-Winning Achievement	Main Participants	Name of Major Project Funded by NSFC	Number of Projects Funded
14	Fundamental research on catalytic purification of nitrogen oxides in combustion exhaust gas	He Hong (Research Center for Eco-Environmental Sciences, CAS) Yu Yunbo (Research Center for Eco-Environmental Sciences, CAS) Shan Wenpo (Research Center for Eco-Environmental Sciences, CAS) Liu Fudong (Research Center for Eco-Environmental Sciences, CAS) Xu Wenqing (Research Center for Eco-Environmental Sciences, CAS)	Basic research on high performance NHfSCR catalyst for diesel vehicle exhaust purification	51
15	Theory and method of thermal infrared remote sensing inversion for key parameters of surface water and heat	Li Zhaoliang (Institute of Geographic Sciences and Natural Resources Research, CAS) Tang Bohui (Institute of Geographic Sciences and Natural Resources Research, CAS) Tang Ronglin (Institute of Geographic Sciences and Natural Resources Research, CAS) Zhou Chenghu (Institute of Geographic Sciences and Natural Resources Research, CAS) Wu Hua (Institute of Geographic Sciences and Natural Resources Research, CAS)	Remote sensing information model and method	28
16	Mechanisms of new particle generation and secondary aerosol growth under composite atmospheric pollution conditions	Hu Min (Peking University) Wu Zhijun (Peking University) He Lingyan (Peking University ShenZhen Graduate School) Guo Song (Peking University) Huang Xiaofeng (Peking University ShenZhen Graduate School)	New particle generation and growth mechanism and its environmental impact under atmospheric compound pollution	25
17	Laser microzone isotope studies of complex geological processes	Yang Jinhui (Institute of Geology and Geophysics, CAS) Yang Yueheng (Institute of Geology and Geophysics, CAS) Xie Liewen (Institute of Geology and Geophysics, CAS) Wu Fuyuan (Institute of Geology and Geophysics, CAS)	Microregional isotope constraints for early earth evolution	22
18	Research on adaptive evolution and endangered mechanisms of giant pandas	Wei Fuwen (Institute of Zoology, CAS) Nie Yonggang (Institute of Zoology, CAS) Hu Yibo (Institute of Zoology, CAS) Wu Qi (Institute of Zoology, CAS) Zhan Xiangjiang (Institute of Zoology, CAS)	Giant Panda's diffusion model and its evolutionary mechanism	37

(continued)

No.	Name of Award-Winning Achievement	Main Participants	Name of Major Project Funded by NSFC	Number of Projects Funded
19	Mechanism of histone methylation and small RNA regulation of plant growth and development and transposon activity	Cao Xiaofeng (Institute of Genetics and Developmental Biology, CAS) Liu Chunyan (Institute of Genetics and Developmental Biology, CAS) Song Xianwei (Institute of Genetics and Developmental Biology, CAS) Lu Falong (Institute of Genetics and Developmental Biology, CAS) Liu Bin (Institute of Genetics and Developmental Biology, CAS)	Research on molecular mechanism of ribosomal RNA processing and modification to regulate plant growth and development	25
20	Molecular mechanisms of autophagy in multicellular organisms and its relation to neurodegenerative diseases	Zhang Hong (Institute of Biophysics, CAS) Zhao Yan (Institute of Biophysics, CAS) Tian Ye (National Institute of Biological Sciences, Beijing) Zhao Hongyu (National Institute of Biological Sciences, Beijing) Li Sihui (Institute of Biophysics, CAS)	Tissue-specific autophagy molecular mechanism and activity regulation mechanism during the development of multicellular organisms	12
21	Study of cross-species infection and transmission capacity of animal influenza viruses	Chen Hualan (Harbin Veterinary Research Institute, Chinese Academy of Agricultural Sciences) Shi Jianzhong (Harbin Veterinary Research Institute, Chinese Academy of Agricultural Sciences) Deng Guohua (Harbin Veterinary Research Institute, Chinese Academy of Agricultural Sciences) Yang Huanliang (Harbin Veterinary Research Institute, Chinese Academy of Agricultural Sciences) Li Yanbing (Harbin Veterinary Research Institute, Chinese Academy of Agricultural Sciences)	Genetic variation mechanism of Chinese H5N1 subtype avian influenza virus infection and pathogenicity in mammals	6
22	A fine localization study of key genes in mental illness based on chain imbalance and long haplotype analysis	Shi Yongyong (Shanghai Jiao Tong University) He Lin (Shanghai Jiao Tong University) Li Zhiqiang (Shanghai Jiao Tong University) He Guang (Shanghai Jiao Tong University) Zhao Xinzhi (Shanghai Jiao Tong University)	Study on genetic susceptibility and pathogenesis of schizophrenia	28
23	Discovery and traceability studies of several emerging natural epidemic diseases (former name: Discovery and traceability studies of emerging natural epidemic diseases)	Cao Wuchun (Academy of Military Medical Sciences) Jiang Jiafu (Academy of Military Medical Sciences) Jia Na (Academy of Military Medical Sciences) Fang Liqun (Academy of Military Medical Sciences) Li Hao (Academy of Military Medical Sciences)	Study on the spatiotemporal spread and epidemic law of infectious diseases based on modern information technology	22

(continued)

No.	Name of Award-Winning Achievement	Main Participants	Name of Major Project Funded by NSFC	Number of Projects Funded
24	Research on new pathogenesis of depression and new targets of anti-depression (former name: Research on pathogenesis of depression and new targets of anti-depression)	Gao Tianming (Southern Medical University) Zhu Dongya (Nanjing Medical University) Cao Peng (Institute of Biophysics, CAS) Zhu Xinhong (Southern Medical University) Cao Xiong (Southern Medical University)	Nuclear membrane BKCa channel discovery and its role in ischemic brain neuron death	35
25	Mechanism of activation, regulation and effects of inflammatory macrophages (former name: Mechanism of activation, regulation and effects of macrophages in inflammatory diseases)	Zhou Rongbin (University of Science and Technology of China) Jiang Wei (University of Science and Technology of China) Peng Hui (University of Science and Technology of China) Wang Xiaqiong (University of Science and Technology of China) Tian Zhigang (University of Science and Technology of China)	Innate immune recognition and regulation	33
26	New mechanisms of hepatitis B virus variation and immunogenetic inheritance in the development of hepatocellular carcinogenesis (former name: Hepatitis B virus evolution and immunogenetic inheritance in the development of hepatocellular carcinogenesis)	Cao Guangwen (The Second Military Medical University) Yin Jianhua (The Second Military Medical University) Jiang Deke (Fudan University) Tu Hong (Shanghai Cancer Institute) Yu Long (Fudan University)	Molecular epidemiology for the association of hepatitis B with hepatocellular carcinoma	31
27	High-throughput computing theory and methods for internet video streaming	Zhang Yongdong (Institute of Computing Technology, CAS) Yan Chenggang (Institute of Computing Technology, CAS) Xie Hongtao (Institute of Computing Technology, CAS) Tang Jinhui (Nanjing University of science and Technology) Tang Sheng (Institute of Computing Technology, CAS)	Large-scale video content analysis and processing in internet environment	18
28	High-power microwave breakdown mechanism and suppression method	Chang Chao (Northwest Institute of Nuclear Technology) Chen changhua (Northwest Institute of Nuclear Technology) Chen Huaibi (Tsinghua University) Tang Chuanxiang (Tsinghua University) Liu Guozhi (Northwest Institute of Nuclear Technology)	High-power microwave plasma discharge physics	13

(continued)

No.	Name of Award-Winning Achievement	Main Participants	Name of Major Project Funded by NSFC	Number of Projects Funded
29	Robust control theory and methods for time delay systems	Xu Shengyuan (Nanjing University of Science And Technology) Zhang Baoyong (Nanjing University of Science And Technology) Ma Qian (Nanjing University of Science And Technology) Lin Cen (The University of Hong Kong) Zhang Zhengqiang (Qufu Normal University)	Anti-windup design for delayed stochastic systems	15
30	A study of multimode image structured sparse representation and fusion theory method	Li Shutao (Hunan University) Fang Leyuan (Hunan University) Kang Xudong (Hunan University) Yang Bin (Hunan University)	Researches on sparse representation and its applications for image recognition	11
31	Theory and methods of operational security evaluation of dynamic systems	Zhou Donghua (Tsinghua University) Hu Changhua (Rocket Force University of Engineering) Si Xiaosheng (Rocket Force University of Engineering) Xu Zhengguo (Tsinghua University) Li Gang (Tsinghua University)	Control system reliability theory	23
32	Research on several key basic theories of neural network	Zhang Yi (Sichuan University) Zhou Jiliu (Sichuan University) Lv Jiancheng (University of Electronic Science and Technology of China) Zhang Lei (University of Electronic Science and Technology of China) Peng Dezhong (University of Electronic Science and Technology of China)	Dynamic behavior of neural networks	24
33	Theory and application of multi-objective dynamic optimization decision-making and control integration in the whole production process	Chai Tianyou (Northeastern University) Tang Lixin (Northeastern University) Liu Tengfei (Northeastern University) Yang Guanghong (Northeastern University) Wang Liangyong (Northeastern University)	Basic theory and key technologies of major energy-consuming equipment with intelligent systems	37
34	Magnetic nanomaterial construction and multifunctional control	Hou Yanglong (Peking University) Gao Song (Peking University) Yu Liang (Peking University) Ma Ding (Peking University) Yang Ce (Peking University)	Magnetically functional materials	40
35	Preparation science and transport control mechanism of high-performance nanowire energy storage materials and devices	Mai Liqiang (Wuhan University of Technology) Xu Lin (Wuhan University of Technology) Zhao Yunlong (Wuhan University of Technology) He Liang (Wuhan University of Technology) Niu Chaojiang (Wuhan University of Technology)	Nanowire materials and devices for energy storage	7

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No.	Name of Award-Winning Achievement	Main Participants	Name of Major Project Funded by NSFC	Number of Projects Funded
36	Energy band structure of low-dimensional semiconductor materials and photon characteristics control (former name: Energy band structure of low-dimensional semiconductors and photonic characteristics control)	Pan Anlian (Hunan University) Zou Bingsuo (Hunan University) Duan Xidong (Hunan University) Li Honglai (Hunan University) Zhuang Xiujuan (Hunan University)	New information photonics materials and devices	16
37	Discovery of a new dynamic model and its application in the development of plastic amorphous alloy materials	Bai Haiyang (Institute of Physics, CAS) Wen Ping (Institute of Physics, CAS) Sun Baoan (Institute of Physicsv CAS) Liu Yanhui (Institute of Physics, CAS) Wang Weihua (Institute of Physics, CAS)	Metal amorphous, quasicrystalline and nanocrystalline materials and preparation bases	25
38	Construction and mechanism of high-efficiency condensed phase flame retardant system for polymer materials that are not easy to form carbon	Wang Yuzhong (Sichuan University) Zhao Haibo (Sichuan University) Deng Cong (Sichuan University) Hu Xiaoping (Sichuan University) Shao Zhubao (Sichuan University)	Principles and methods of construction of high fire safety polymer materials in confined spaces	33
39	Basic research on the construction and application of low-dimensional oxide semiconductor homogeneous/heterogeneous interface	Liu Yichun (Northeast Normal University) Xu Haiyang (Northeast Normal University) Zhang Xintong (Northeast Normal University) Shao Changlu (Northeast Normal University) Wang Zhongqiang (Northeast Normal University)	Research on basic issues in three dimensional heterojunction solar cells based on oxide nanowire array	30
40	Carbon nanotube composite fiber lithium ion battery (former name: New fibrous lithium ion battery)	Peng Huisheng (Fudan University) Wang Yonggang (Fudan University) Ren Jing (Fudan University) Sun Xuemei (Fudan University) Chen Peining (Fudan University)	Aligned carbon nanotube/polymer composite materials for the application in energy	13
41	Theory and regulation method of decomposition and evolution of marine natural gas hydrate	Song Yongchen (Dalian University of Technology) Fan Shuanshi (South China University of Technology) Zhao Jiafei (Dalian University of Technology) Yang Mingjun (Dalian University of Technology) Kong Xianjing (Dalian University of Technology)	Study on the key and basic scientific issues of natural gas hydrate exploitation	34
42	Special welding metallurgy mechanism and microstructure performance control	Feng Jicai (Harbin Institute of Technology) Cao Jian (Harbin Institute of Technology) He Peng (Harbin Institute of Technology) Zhang Hongtao (Harbin Institute of Technology) Lin Tiesong (Harbin Institute of Technology)	Welding processes and equipment	16

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No.	Name of Award-Winning Achievement	Main Participants	Name of Major Project Funded by NSFC	Number of Projects Funded
43	Damage mechanism and analysis theory of concrete-filled steel tube structures based on full life cycle	Han Linhai (Tsinghua University) Yang Youfu (Fuzhou University) Yang Hua (Harbin Institute of Technology) Li Wei (Tsinghua University)	Study on the seismic performance and design methods of recycled-aggregate concrete-filled high-strength steel tubular (RCFHST) structures subjected to the coupling effects of multi-hazards	16
44	Research on theory and method of structural optimization design under complex constraints	Guo Xu (Dalian University of Technology) Cheng Gengdong (Dalian University of Technology) Yan Jun (Dalian University of Technology) Zhang Weisheng (Dalian University of Technology)	Structural optimization	33
45	Research on surface instability mechanics of soft materials and biological soft tissues	Feng Xiqiao (Tsinghua University) Cao Yanping (Tsinghua University) Li Bo (Tsinghua University) Wang Jianshan (Tsinghua University) Huang Shiqing (Tsinghua University)	Theoretical and experimental studies on deformation and failure of surfaces and interfaces of natural biological materials	27

Table A-4-3 First Prize of National Award for Technological Invention Recipients Supported by NSFC

No.	Name of Award-Winning Achievement	Main Participants	Name of Major Project Funded by NSFC	Number of Projects Funded
1	High-precision flight calibration technology and equipment for complex airports	Zhang Jun (Beihang University) Shi Xiaofeng (Beihang University) Su Wei (Flight Inspection Center of CAAC) He Feng (Beihang University) Li Xiaoqiang (Beijing Tianhua Hangyu Technology Co.)	A theoretical study on the integrity of an integrated model of avionics partitioning for fault closure	2

Table A-4-4 First Prize of National Scientific and Technological Progress Award recipients Supports by NSFC

No.	Name of Award-Winning Achievement	Main Participants	Main Institutes	Name of Major Project Funded by NSFC	Number of Projects Funded
1	Theoretical technologies and major discoveries in the exploration of large-scale, fully-condensed gas fields in the Bohai Bay Basin	Xie Yuhong, Xue Yongan, Deng Jianming, Xu Changgui, Shi Hesheng, Zhou Donghong, Niu Chengmin, Deng Yunhua, Tian Lixin, Li Huiyong, Liu Xiaogang, Lju Dingyou, Wang Xin, Shang Suogui, Zhang Gongcheng	China National Offshore Oil Corporation China University of Petroleum Chengdu University of Technology China University of Geosciences, Wuhan Jilin University Yangtze University Beijing Shi Da Kesheng Petroleum Technology Co.	Control of the formation of large oil and gas systems by the neotectonic movements and deep dynamic processes in the central Bohai Sea	3
2	Key technology and industrialization of high-efficiency and long-life semiconductor lighting	Li Jinmin, Lin Kechuang, Wang Junxi, Yi Xiaoyan, Liu Zhiqiang, Fan Yubo, Lin Mingfeng, Zhu Xiaodong, Li Guoping, Yuan Yikai, Ruan Jun, Liang Yi, Wu Ximin, Cai Wenbi, Liu Naixin	Institute of Semiconductors, CAS Sanan Optoelectronics Co., ltd Xiamen Hualian Electronics Co. Ltd. Shenzhen Chau Ming Technology Co. Hebei Lide Electronics Co. Beijing Liangye Environmental Technology Co. Hongli Smart Group Co.Foshan NationStar Optoelectronics Co., Ltd. Beijing Semiconductor Lighting Technology Promotion Center Xiamen Guangpu Electronics Co.	Research on new micro-nano technology for improving external quantum efficiency of vertical structure LED	2
3	FT-1500A high performance general 64-bit microprocessor and its application	Dou Qiang, Zhao Zhenyu, Wang Yongwen, Deng Rangyu, Gao Jun, Zhou Hongwei, Deng Yu, Pan Guoteng, Zhang Chengyi, Gong Rui, Deng Lin, Ou Guodong, Guo Yufeng, Ma Zhuo, Sui Bingcai	National University of Defense Technology China Electronics and Information Industry Group Co. Tianjin Feiteng Information Technology Co.	Research on key technologies of heterogeneous multi-stream architecture for scientific computing	3
4	Key technologies and industrialization of clean production of pulp and paper and the whole process control of water pollution	Chen Kefu, Ying Guangdong, Xu Jun, Zhang Fengshan, Li Jun, Cao Yanjun, Qiao Jun, Li Xiaoliang, Mo Lihuan, An Qingchen, Feng Yucheng, Zeng Jingsong, Zhou Jingpeng, Zhang Wei, Han Wenjia	South China University of Technology Shandong Sun Paper Co.	Study on stabilization mechanism of colloidal lignin in poplar hydrolysate and pectinase treatment to improve lignin removal selectivity	2

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No.	Name of Award-Winning Achievement	Main Participants	Main Institutes	Name of Major Project Funded by NSFC	Number of Projects Funded
5	Theory, technology and engineering application of high-rise steel-concrete hybrid structure	Zhou Xuhong, Liu Jiepeng, Fu Xueyi, Zhang Sumei, Yang Xiangbing, Xu Kun, Xu Guojun, Yang Bo, Tong Genshu, Zhou Qishi, Lin Xuchuan, Zhang Xiaodong, Li Jiang, Wang Yuhang, Liu Xiaogang	Chongqing University Sydi International Design Consultants (Shenzhen) Co. China Construction Steel Construction Co. Zhejiang Green Building Integrated Technology Co. China Metallurgical Construction Research Institute Co. Harbin Institute Of Technology Hunan University Zhejiang University Institute of Engineering Mechanics, China Earthquake Administration Central South University	Research on new type steel-concrete composite structure	2
6	Construction of Chinese medicine vein theory and its guidance for prevention and treatment of microvascular disease	Wu Yiling, Yang Yuejin, Jia Zhenhua, Li Xinli, Huang Congxin, Yang Minghui, Cao Kejiang, Dong Qiang, Wu Weikang, Zeng Dingyin, Wen Jinkun, Gao Yanbin, Zhou Jingmin, Wei Cong, Zheng Qingshan	Hebei Yi Ling Medical Research Institute Co. Chinese Academy of Medical Sciences Fawai Hospital Jiangsu Province Hospital Wuhan University People's Hospital Chinese PCA General Hospital Fudan University Huashan Hospital Sun Yat-sen University Hebei Medical University Capital Medical University Fudan University Zhongshan Hospital	Discussion on quantitative evaluation method of combined effect of drugs	1
7	High-performance precision manufacturing innovation team of Dalian University of Technology	Guo Dongming, Jia Zhenyuan, Gao Hang, Wang Yongqing, Sun Yuwen, Wang Fuji, Lei Mingkai, Liu Wei, Sheng Xianjun, Zhang Zhenyu, Wu Dongjiang, Zhang Jun, Jin Xiji, Yang Rui, Zhou Ping	Dalian University of Technology	Basic research on precision manufacturing theory and technology	80