Robust memristors based on layered two-dimensional materials

With the support by the National Natural Science Foundation of China and Nanjing University, the research team led by Prof. Miao Feng (缪峰) at the National Laboratory of Solid State Microstructures, School of Physics, Collaborative Innovation Center of Advanced Microstructures, Nanjing University, developed a robust memristor with excellent thermal stability and flexibility, with results published in *Nature Electronics* (2018, 1: 130—136).

Many industrial fields require electronic devices operating in harsh environments of temperature over 200 ℃. For example, the electronic components and sensors, used for monitoring the operating status of turbo engine in aerospace industry and assisting drilling operations in the oil and gas industry, are operated in ultra-high temperature environments. Usually, special cooling systems integrated with conventional devices can ensure the normal operation of the electronic devices at high temperatures. Considering the long-term stability of the system and the cost reduction, it is more desirable that electronic devices without any auxiliary equipment are able to operate under high temperature conditions. However, choices of electronic devices operating at high temperatures are very limited.

Memristor is considered to be one of the most noteworthy emerging storage technologies in the post Moore Era. However, memristors also face the robustness issues, which pose a challenge to multi-domain applications in the future. Van der Waals heterostructure based on layered two-dimensional (2D) materials offers an unprecedented opportunity to create materials with atomic precision by design. By combining superior properties of each component, such heterostructure also provides possible solutions to address various challenges associated with the electronic devices, especially those with vertical multilayered structures.

In this study, Miao's team developed a robust memristor based on van der Waals heterostructure of fully layered 2D materials (graphene/$MoS_{2-x}O_x$/graphene) which demonstrates excellent thermal stability lacking in traditional memristors. The devices have shown the excellent switching performance with endurance up to 10^7 and high-temperature operation of up to 340℃, which is record-high for memristors. The team performed *in situ* high-resolution transmission electron microscopy (HRTEM) studies on the $MoS_{2-x}O_x$ membranes at high temperatures. They observed that $MoS_{2-x}O_x$ membrane has excellent thermal stability at temperatures up to 800 ℃, suggesting that the layered crystal structure of $MoS_{2-x}O_x$ is responsible for the high thermal stability of the devices. Furthermore, the team performed *in situ* investigations of scanning transmission electron microscopy (STEM) on the cross section of the device to reveal the robust nature. Based on the experimental observation, a switching mechanism was proposed to be the migration of oxygen ions. The devices fabricated on flexible Polyimide (PI) substrate also show excellent endurance against mechanical bending of over 1000 times. This new type of memristor highlights the significant potential of using two dimensional layered materials to create reliable and thermally stable electronic devices.

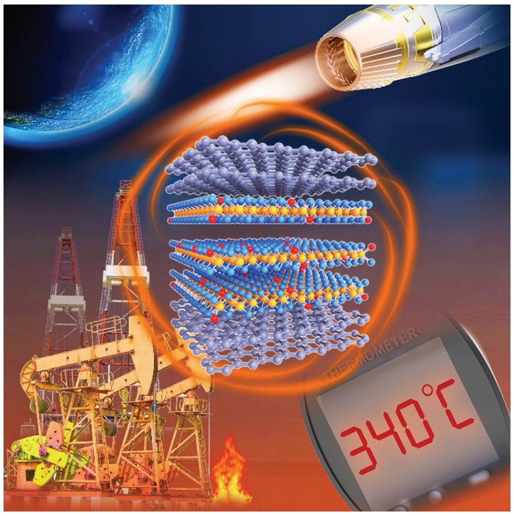

Figure Crystal structure of the robust memristor (center) and related applications.