Chemical synthesis of two-dimensional electronic devices

With the support by the National Natural Science Foundation of China, a collaborative study by research team led by Prof. Jiao LiYing (焦丽颖) from the Department of Chemistry, Tsinghua University and Prof. Ren TianLing (任天令) from the Institute of Microelectronics, Tsinghua University, proposed a non-destructive strategy for building integrated circuits based on two-dimensional (2D) materials, which was published in *Nature Electronics* (2019, 2: 164—170).

As the dimension of transistors is approaching the thermal and quantum limits, further scaling of the devices is becoming increasingly difficult and costly. As a result, considerable effort has been exerted in exploring the potential of 2D electronic materials which are promising for constructing ultra-short channel devices. However, as there are only a few atoms in the vertical direction of these ultrathin materials, it is very easy to introduce defects and impurities into them when using conventional device fabrication processes, which leads to degradation in device performance. Therefore, developing new device manufacturing strategies that are specifically designed for 2D semiconductors is essential.

To address this challenge, their group presented a new device manufacturing strategy in which 2D electronic components can be chemically synthesized and integrated simultaneously in a single step, creating 2D devices in which each component in the active layer is connected via covalent bonds instead of physical interfaces. The as-synthesized devices can be worked immediately without any further fabrication process. The approach involves the phase-patterned growth of atomic layers and using 2D $MoTe_2$ as the active material. This strategy not only significantly reduced the contact resistance and structural damages in ultrathin semiconductors but also greatly facilitated the design and optimizations of circuits. As a proof of the concept, they synthesized arrays of field-effect transistors (FETs) with buried local gates, logic devices and radio frequency devices. The obtained devices exhibited high performance.

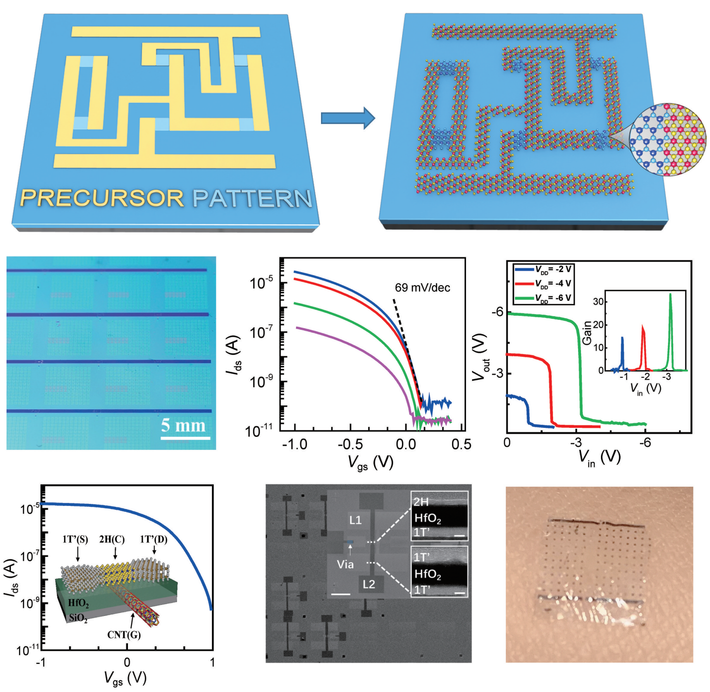

Figure Chemical synthesis and integration of 2D devices and circuits.

The approach is based on ultrathin materials, and thus ultrashort channels can be created through the introduction of nanoscale gates. The density of integration can also be significantly increased through 3D integration via repeated growths at different levels, providing new possibilities for extending Moore's law. The demonstrated combination of chemically synthesized 2D devices and soft polymers also provides new insight into the construction of flexible and wearable electronic devices. Therefore, this approach provides an alternative design architecture for future integrated circuits and opens a direction for building high-performance electronic devices based on ultrathin materials. Moreover, this work also demonstrates the power of chemistry in the further scaling of electronic devices.