The third kind electronic memory: Fill gap between volatile and non-volatile

With support by the National Natural Science Foundation of China and Fudan university, the research team led by Prof. Zhou Peng (周鹏) at the State Key Laboratory of ASIC and System, School of Microelectronics, Fudan University, Shanghai, China, bring forward a quasi-non-volatile memory technology with fast writing speed and long refresh time, which was published in *Nature Nanotechnology* (2018, 13: 404—410).

So far the memory technologies based on charge storage are divided into the volatile technology and non-volatile technology, both with strengths and weaknesses. For the volatile technology, the low integration density and volatile characteristics of the ultrafast static random access memory (SRAM) technology have restricted its use to cache memory applications, whereas dynamic random access memory (DRAM) has limited data retention ability (on the time scale of ms) and requires frequent refresh (written back) operations, and, therefore, increased power consumption. Nonvolatile memory can store data for as long as 10 years without a power supply, but its accessing speed is inferior to the volatile memory technology, such as the flash technology in which the writing operation time is approximately 100 μs. Considering the large gap between volatile and nonvolatile memory technologies, a new quasi-nonvolatile memory technology that possesses ultrahigh writing speed and long refresh time is required for high-speed and low-power RAM.

According to the international technology roadmap for semiconductors (ITRS 2.0), novel device structures and materials with high mobility and controlled interface states are needed for next generation electronics. Two-dimensional (2D) materials have favourable electrical and optoelectronic properties even at the atomic thickness scale, which is impossible to achieve using bulk semiconductors due to surface roughness scattering. 2D materials are characterised by rich electronic band structures and their van der Waals heterostructures are not affected by the lattice mismatch. Thus far, memory devices based on 2D materials have exhibited slow speeds with the effective write time of 10 ms, which is much slower than that of the current commercial silicon memory technologies, such as DRAM (approximately 10 ns) and flash (approximately 100 μs) technologies.

Zhou's group had developed a quasi-nonvolatile RAM technology that fills the gap between volatile and nonvolatile memory technologies. Using a semi-floating gate (SFG) architecture, the charges of the 2D SFG memory can flow into the floating gate using voltage control with an ultrahigh-speed writing operation (approximately 15 ns) that is comparable to commercial DRAM. In addition, the band-engineered van der Waals heterostructures significantly enhance the refresh time to 10 s, which is approximately 156 times longer than the standard time for DRAM (64 ms). Because of the unique quasi-nonvolatile characteristics of 2D SFG memory, considerable power consumption caused by frequent refresh operations can be saved.

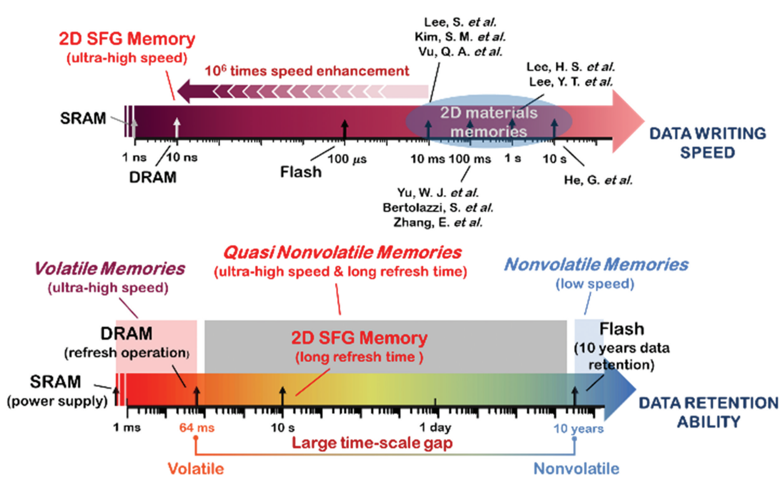

Figure Representation of the quasi-non-volatile characteristics. Due to the ultrahigh speed and long refresh time of the 2D SFG memory, the gap between volatile and non-volatile memory technologies is filled.