Chin. Phys. Lett. **39**, 070101 (2022) **Viewpoint**

Orbit-Transfer Torque Switching

Yeliang Wang(王业亮)*

School of Integrated Circuits and Electronics, MIIT Key Laboratory for Low-Dimensional Quantum Structure and Devices, Beijing Institute of Technology, Beijing 100081, China

(Received 2 June 2022; accepted manuscript online 9 June 2022)

DOI: 10.1088/0256-307X/39/7/070101

In the post-Moore era, memory devices with smaller sizes, lower energy consumption, and higher reliability are desired. As a classic type of non-volatile memory, magnetic random-access memory (MRAM) is outstanding, since it keeps data storage by magnetic states (electron spin) instead of electron charges. Specifically, in MRAM, the data is stored in the magnetic tunnel junction unit, and the logical 0 and 1 are determined by the parallel and antiparallel magnetic states of the two ferromagnetic layers, respectively.

In the past, spin-torque, including spin-transfer torque (STT) and spin-orbit torque (SOT), is exploited to realize the switching of magnetic states. STT-MRAM is implemented in a two-terminal device,[1,2] where the "writing" current and "reading" current are applied along the same channel. The "writing" current, which is exploited to realize magnetization switching, is usually large, leading to the severe heating problem and poor endurance.

Different from two-terminal STT-MRAM, SOT-MRAM has a three-terminal configuration, which is favorable to achieve magnetization switching by polarized spin current with spin-torque, based on spin Hall effect or spin Rashba–Edelstein effect.[3,4] Unfortunately, conventional SOT-MRAM is incompatible with perpendicular magnetization switching that is necessary for device scaling down and high integration density. To realize perpendicular magnetization switching in SOT, either an external in-plane magnetic field or structure asymmetry of the device is needed.

A recent work[5] published in Chinese Physics Letters reports a new route to realize perpendicular magnetization switching in the absence of an external magnetic field, that is, so-called orbit-transfer torque (OTT). The OTT exploits the orbital magnetic moment instead of the spin of the Bloch electrons. The key point is that the orbital magnetic moment generates the torque effect. Intriguingly, in some two-dimensional materials, the orbital magnetic moment is forced to be out of plane due to dimension constraint, facilitating the field-free perpendicular magnetization switching of the adjacent ferromagnetism.

In that work, Ye and his colleagues proposed the concept of OTT and successfully demonstrated the OTT-driven perpendicular magnetization switching in WTe_2/Fe_3GeTe_2 heterostructure devices.[5] The authors show that the magnetization of Fe_3GeTe_2 is switched by applying an electrical current in the adjacent WTe_2 layer. The WTe_2 layer holds a nonzero Berry curvature dipole, which is defined as the dipole moment of Berry curvature in momentum space.[6] Thus the polarization of orbital magnetism in such heterostructures is generated by an electric current rather than an external magnetic field [Fig. 1].

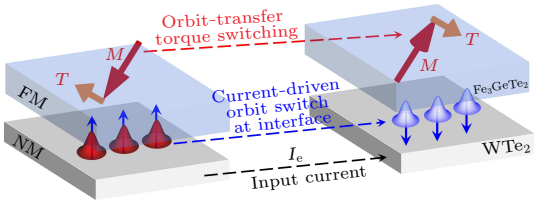

Fig. 1. Illustration of orbit-transfer torque switching. In a heterostructure consisting of ferromagnetic Fe_3GeTe_2 and non-magnetic WTe_2, the nonzero Berry curvature dipole at the interface results in the polarization of orbital magnetic moment, thus yielding magnetization switching in Fe_3GeTe_2. Such upward and downward magnetization states can be reversibly switched by injecting opposite directions of current.

The discovery of OTT is significant for both fundamental scientific research and technology application in future. Firstly, the OTT is a new mechanism for magnetization reversal after STT and SOT. Secondly, the OTT surpasses the previous STT and SOT for field-free perpendicular magnetization switching and has more realistic application prospects for the up-

*Corresponding author. Email: yeliang.wang@bit.edu.cn
© 2022 Chinese Physical Society and IOP Publishing Ltd

coming OTT-MRAM. Moreover, the OTT exploits the current-induced polarized orbital magnetic moment of Bloch electrons, extending the concept from spintronics to orbitronics and even their hybrid. OTT also enables three-terminal MRAM devices, and thus combines the advantages of high speed, high density, and low energy consumption.

References

[1] Slonczewski J C 1996 *J. Magn. Magn. Mater.* **159** L1
[2] Sankey J C, Cui Y T, Sun J Z, Slonczewski J C, Buhrman R A and Ralph D C 2008 *Nat. Phys.* **4** 67
[3] Liu L, Pai C F, Li Y, Tseng H W, Ralph D C and Buhrman R A 2012 *Science* **336** 555
[4] Liu L, Lee O J, Gudmundsen T J, Ralph D C and Buhrman R A 2012 *Phys. Rev. Lett.* **109** 096602
[5] Ye X G, Zhu P F, Xu W Z, Shang N Z, Liu K H and Liao Z M 2022 *Chin. Phys. Lett.* **39** 037303
[6] Sodemann I and Fu L 2015 *Phys. Rev. Lett.* **115** 216806