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## Spin Orbit Interaction Engineering for beyond Spin Transfer Torque memory

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Spin transfer torque memory uses electron current to transfer the spin torque of electrons to switch a magnetic free layer. This talk will address an alternative approach to energy efficient non-volatile spintronics through engineering of spin orbit interaction (SOC) and the use of spin orbit torque (SOT) by the use of electric field to improve further the energy efficiency of switching. I will first discuss the engineering of interface SOC, which results in the electric field control of magnetic moment or magneto-electric (ME) effect. Magnetic memory bits based on this ME effect, referred to as magnetoelectric RAM (MeRAM), is shown to have orders of magnitude lower energy dissipation compared with spin transfer torque memory (STTRAM). Likewise, interests in spin Hall as a result of SOC have led to many advances. Recent demonstrations of magnetization switching induced by in-plane current in heavy metal/ferromagnetic heterostructures have been shown to arise from the large SOC. The large SOC is also shown to give rise to the large SOT. Due to the presence of an intrinsic extraordinarily strong SOC and spin-momentum lock, topological insulators (TIs) are expected to be promising candidates for exploring spin-orbit torque (SOT)-related physics. In particular, we will show the magnetization switching in a chromium-doped magnetic TI bilayer heterostructure by charge current. A giant SOT of more than three orders of magnitude larger than those reported in heavy metals is also obtained. This large SOT is shown to come from the spin-momentum locked surface states of TI, which may further lead to innovative low power applications. I will also describe other related physics of SOC at the interface of anti-ferromagnetism/ferromagnetic structure and show the control exchange bias by electric field for high speed memory switching.

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