中央大學物理學系

Department of Physics, National Central University

Colloquium

Effective Shaping and Probing of Antiferromagnetic Order: Route Toward Energy-Efficient Spintronics

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Abstract :

Antiferromagnetic (AFM) materials offer compelling opportunities for next-generation spintronic technologies, yet their practical implementation has long been limited by the difficulty of controlling and probing the Néel order, particularly in polycrystalline systems. In this talk, I will present our recent progress in understanding and engineering spin transport through AFMs by establishing deterministic control and sensitive electrical readout of the Néel order. Using NiO-based heterostructures as model platforms, we demonstrate that spin–orbit torque (SOT) can drive a transition from a randomly oriented local Néel texture to a globally aligned Néel order once a threshold spin current is exceeded [1]. This facilitated long-range Néel order suppresses spin absorption within the AFM and dramatically enhances spin transmission, resulting in more than a fourfold increase in both damping-like and field-like SOT efficiencies in W/NiO/CoFeB trilayers. Complementary to current-driven control, we further show that spin Hall magnetoresistance (SHMR) provides a powerful, device-compatible probe of AFM order, capable of detecting the Néel temperature, spin-flop transitions, and field-induced reorientation even in polycrystalline films. Importantly, we demonstrate a spin-current-free, non-volatile control of the Néel order via field cooling from a soft AFM phase, enabling robust AFM state initialization without relying on adjacent heavy metals [2]. Together, these results establish a unified framework in which global Néel order engineering—enabled by SOT, thermal pathways, and SHMR readout—governs spin transport in antiferromagnets, opening new routes toward scalable, energy-efficient AFM spintronic and computing devices.