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Controlling Nanomagnetism via Coupled Degrees of Freedom

Controlling magnetic order and dynamics at the nanoscale is central to the development of next-generation spintronic devices. An increasingly important direction is to exploit the coupling and interconversion between magnetism and other degrees of freedom. Physical entities such as spin/orbital angular momentum, lattice motion, interfacial charge, and light can exchange energy and angular momentum with magnetic systems, providing new routes toward fast and energy-efficient control of nanomagnetism [1]. Such coupled interactions have become an important framework for understanding and engineering nanoscale magnetization dynamics.

In this talk, I will present several examples of controlling nanomagnetism via coupled degrees of freedom. The first part focuses on the ultrafast current-driven domain-wall motion in the noncollinear antiferromagnets Mn_3Sn/Ge [2] and ferrimagnetic spinel oxide $NiCo_2O_4$ [3]. Based on the *s*-*d* exchange coupling, I will explain the mechanism underlying magnetic octupole domain wall dynamics and the role of nonadiabatic spin-transfer torque in antiferromagnetic sublattices. In addition, the magneto-optical and transport characterizations of the spin Hall effect and magnetic spin Hall effect in Mn_3Sn/Ge will also be discussed [4]. In the second part, I will report the acoustic orbital Hall effect driven by surface acoustic waves (SAWs) in light-metal/ferromagnet heterostructures. Here, the phonon–orbital coupling induces an oscillating orbital accumulation that diffuses from the light metal to the ferromagnet. At the same time, SAWs modulate the magnetization dynamics through magnetoelastic coupling, with both the orbital current and the magnetization precession oscillating at the same SAW frequency. Their coupled dynamics enable the rectification of the ac orbital current into a dc charge current. Finally, I will discuss ferroelectric control of charge transport in ultrathin metals and ferroelectric modulation of exchange coupling in multiferroic/ferromagnetic heterostructures through magnetoelectric coupling. Taken together, these examples demonstrate how coupling magnetization to spin/orbital currents, acoustic phonons, and ferroelectric polarization enables versatile control of nanomagnetism.

References

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