Spin Pumping in Topological Insulator-Ferromagnet Heterostructures Studied by Ferromagnetic Resonance Techniques

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Topological insulators (TIs) provide challenging prospects for the future of spintronics due to their large spin-orbit coupling and dissipationless, counter-propagating conduction channels in the surface state, however, a means to interact with and exploit the topological surface state (TSS) remains elusive. Spin-valves are composed of two ferromagnetic layers, separated by a non-magnetic spacer layer, permitting indirect communication through either static exchange between the ferromagnetic layers, or a dynamic exchange mechanism via spin pumping. Using a TI as a non-magnetic spacer is particularly intriguing as the carriers in the topological surface state are spin-polarized, pointing towards a route of exploiting TIs in a spintronics device.

In this talk, we present a study of spin pumping at the TI-ferromagnet interface in a pseudo-spin valve heterostructure. Using ferromagnetic resonance (FMR), we show that the Gilbert damping increases approximately linearly with increasing TI thickness, demonstrating a high capacity to absorb angular momentum, and – if the process is reversed – to generate a significant spin transfer torque [1]. By combining the element-specific x-ray magnetic circular dichroism (XMCD) technique with FMR, time-resolved (TR) XMCD gives access to the magnetodynamics of the different ferromagnetic layers in a spin-valve structure [2]. Using this synchrotron-radiation based technique, we performed layer-resolved measurements which show dynamic exchange coupling up to a TI thickness of 8 nm [1]. This effect is virtually temperature-independent [3].

These results shed new light on the spin dynamics of this novel material class, and suggest great potential for TIs in spintronic devices, through their novel magnetodynamics. As these effects can be observed at room temperature and low magnetic fields, TIs are particularly well suited to future device applications, as well as being a fertile ground for investigation of fundamental physical phenomena.

References:

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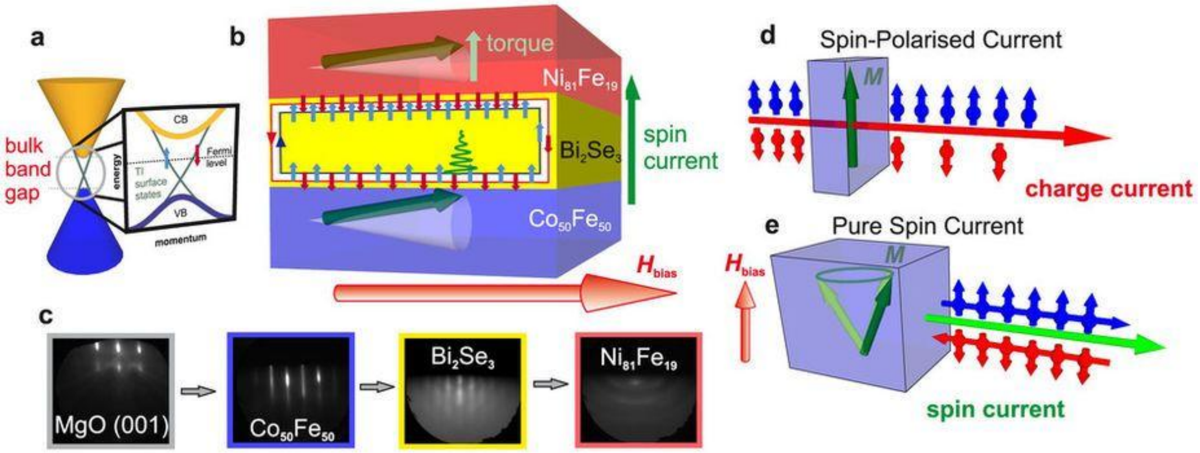

Figure 1: (a) Bandstructure of a TI, showing the valence (below) and conduction (above) bands, with the spin-locked surface state crossing the bulk bandgap. (b) Schematic of the device structure, showing the TI (Bi_2Se_3) placed between two ferromagnetic layers ($Co_{50}Fe_{50}$ and $Ni_{81}Fe_{19}$). The surface state is indicated by up- and down-arrows, representing counter-propagating spin-momentum locked conduction. The precession of magnetization excited around the static bias field drives a pure spin current from the $Co_{50}Fe_{50}$ through the Bi_2Se_3 into the $Ni_{81}Fe_{19}$, exerting a spin transfer torque. (c), Reflection high-energy electron diffraction (RHEED) images of the growth of each layer. (d,e) Illustration of the difference between a spin polarized current and a pure spin current. Note the similarity between counter-propagation of spins in a pure spin current and the counter propagating conduction channels in the TSS. From Ref. [1].