9th JEMS Conference 2018
Joint European Magnetic Symposia
3rd – 7th September 2018 • Mainz • Germany
General Chair: Prof. Dr. Jairo Sinova
Co-General Chair: Prof. Dr. Mathias Kläui
www.jems2018.org

SP 18 Magnetism and spin transport in topological materials

SP18 - Parallel Session 1

SP18 - Parallel Session 1

SP18.1.02

Electronic properties in chiral spin textures from non-commutative quantum mechanics

F. R. Lux, F. Freimuth, S. Blügel, Y. Mokrousov

Text Non-collinear magnetism has a profound impact on the electron transport. Its hallmarks are the large anomalous Hall effect in strongly frustrated non-collinear antiferromagnets and the topological Hall effect in magnetic skyrmions. While these effects are readily studied from ab initio for atomic scale structures, they are notoriously difficult to treat theoretically when the scale of the problem exceeds beyond the nanometer scale.

Here, we pursue a different approach which is based on a semiclassical expansion of the single-particle’s Green’s function in the Keldysh formalism. It allows us to treat the deviations from the collinear magnetic state diagrammatically – order by order – in the gradients of the texture. This systematic formalism is especially suited to analyze transport and magnetic properties of the electronic system.

The developed framework can find important applications in the field of spin-orbitronics, where the orbital physics of electrons plays a central role and orbital magnetization represents a key concept. By employing the above procedure, we demonstrate how the orbital magnetization in extended chiral magnetic systems can be understood as the electronic response to emergent electromagnetic fields. We also discover that in such systems the spin-orbit interaction can be used to great advantage in that it promotes a complex interplay of real-space and k-space topology resulting in enhanced response to external fields in interfacial chiral magnets.

SP 18 Magnetism and spin transport in topological materials

SP18 - Parallel Session 1

SP18.1.03

Chemical, structural and magnetic properties of the Fe/Sb2Te3 interface

E. Longo, C. Wiemer, R. Cecchini, M. Longo, A. Zenkevich, M. Fanciulli, R. Mantovan

Text Interfacing Topological Insulators (TI) with ferromagnetic (FM) layers is a promising path towards next generation of ultra-low power spintronic devices based on charge-to-spin current conversion. In this contribution we study the structure, chemical composition and magnetism of the yet poorly investigated Fe/Sb_2Te_3 heterostructure interface. Polycrystalline Sb_2Te_3 thin films (30 nm), displaying weak antilocalization effects, were synthesized on large-scale (4'') Si/SiO_2 substrates by Metal Organic Chemical Vapor Deposition (MOCVD) at room temperature, then capped with a ^{57}Fe(1 nm)/^{54}Fe(10 nm) bilayer by Pulsed Laser Deposition (PLD) to allow interface-sensitive Conversion Electron Mössbauer Spectroscopy (CEMS). CEMS evidences that about half of the 1 nm ^{57}Fe coordinates ferromagnetically, whereas the remaining ^{57}Fe atoms closer to Sb_2Te_3 preferentially bonds with Te in a “FeTe” paramagnetic alloy. X-ray diffraction (XRD) shows the polycrystalline nature of both Fe and Sb2Te_3 layers and X-ray reflectivity (XRR) confirms the presence of an intermixed layer at the interface. Our results show that the use of the Fe/Sb_2Te_3 system for exploiting interface charge-to-spin conversion may not be trivial. On the other hand, the possibility to engineer ultrathin FeTe layers in contact with the TI Sb_2Te_3 might be interesting for observing the elusive Majorana fermion. We will also present the evolution of the interface structure and magnetism following rapid thermal annealing processes.

SP 18 Magnetism and spin transport in topological materials

SP18 - Parallel Session 1

SP18.1.04

Spin-charge interconversion in Bismuth films grown on Ge(111)

A. Marty, C. Zucchetti, M. T. Dau, F. Bottegoni, C. Vergnaud, T. Guillet, C. Beigné, A. Picone, A. Calloni, G. Bussetti, A. Brambilla, L. Duo, G. Isella, F. Ciccacci, P. Das, J. Fujii, I. Vobornik, M. Finazzi, M. Jamet

Text Bismuth exhibits electronic peculiarities that made it the subject of experimental and theoretical interest for decades. With a structure close to that of graphene and a very large spin-orbit coupling, it has the potential to be a topological semimetal or semiconductor. To explore this possibility, we have grown very thin films of Bi on Ge(111) by molecular beam epitaxy. Indeed, this technique gives the opportunity to grow metastable allotropic phases of Bi or to induce strain into bulk Bi which may give topological properties. We have grown bismuth with various thicknesses (0-12 nm) on Ge(111). Electron and x-ray diffraction reveal a critical thickness of ≈ 4.5 nm below which Bi exhibits a pseudocubic phase. A careful angle-resolved and spin-resolved photoemission spectroscopy study using synchrotron radiation (ELETTRA) showed that the pseudocubic phase exhibits surface states with linear band dispersion and a characteristic helical spin texture. We have then investigated the spin-charge interconversion at these surface states using different techniques: magneto-optical Kerr effect to probe the spin Hall effect (SHE), inverse SHE using optical spin orientation in the Ge film beneath and finally ferromagnetic resonance–driven spin pumping from a ferromagnetic layer grown on top of Bi separated by an Al spacer. We found a significant signature of the spin-charge interconversion in these surface states and a clear Bi-thickness dependence of the conversion signals.

SP 18 Magnetism and spin transport in topological materials

SP18 - Parallel Session 1

SP18.1.05

Spin-orbit torque-ferromagnetic resonance with topological insulators

F. Bonell, M. Goto, S. Miwa, J. F. Sierra, M. V. Costache, Y. Suzuki, S. O. Valenzuela

Text The large spin-orbit interaction in topological insulators (TIs) makes them efficient charge-to-spin converters, able to exert large current-induced spin-orbit torques (SOTs) on an adjacent ferromagnet (FM). The technique of SOT-induced ferromagnetic resonance (SOT-FMR) gives access to the nature and magnitude of the torques. Only few studies have focused on SOT-FMR in TI/FM multilayers and large SOTs have been reported. However, their exact origin remains unclear because intermixing, magnetic dead layers and charge transfer are known to occur at TI/metal interfaces. In order to understand how these interfaces influence the SOTs, we performed systematic SOT-FMR on TI/NM/Py multilayers with different normal metal (NM) spacers.
The multilayers were fully grown by molecular beam epitaxy. $(Bi_{0.4}Sb_{0.6})_2Te_3$ was used as the TI layer, designed to show a low density of crystal defects, a low carrier density and bulk insulating behavior. Al, Ag and Te with various thicknesses were used as NM spacers. We systematically complemented transport measurements by a characterization of TI/NM interfaces with x-ray photoelectron spectroscopy. A clear correlation was found between the SOTs direction/magnitude and the chemical interactions occuring at interfaces. This result turns to be inconsistent with a bulk spin Hall mechanism and is well explained by a model of spin depolarization at interfaces applied to charge-spin conversion through the surface Rashba-Edelstein effect.

SP 18 Magnetism and spin transport in topological materials

SP18 - Parallel Session 1

SP18.1.06

First-principles method of calculating spin-orbit torque (SOT) in Co/heavy metal and Co/ topological insulator heterostructures

M. F. Islam, M. Stamenova, C. Holmqvist, N. Pournaghavi, M. Paulsson, S. Sanvito, C. M. Canali

Text Efficient manipulation of magnetization by charge currents is crucial for developing next generation non-volatile magnetic memory technology. In recent years, materials with strong spin-orbit coupling (SOC) have been found to generate spin currents from charge currents via SOT. When coupled with a neighboring magnetic metal or magnetic insulator, non-equilibrium spins induced by the SOC at the interface can exert torques onto the magnetic moments and can switch the magnetization. While heavy metals with strong SOC such as platinum (Pt) are known to be suitable material for spin current generation, in recent years topological insulators such as Bi2Se3 have drawn much attention because of their naturally spin-polarized surface states [1]. In this work, we investigate SOTs in the Co/Pt and Co/ Bi2Se3 heterostructures using first-principles non-equilibrium Green's function methods as implemented in the Smeagol code. We also discuss/compare the switching efficiency of these two heterostructures.

[1] J. Han et. al., Phys. Rev. Lett. 119, 077702 (2017).

SP 18 Magnetism and spin transport in topological materials

SP18 - Parallel Session 1

SP18.1.07

Highly efficient spin-to-charge current conversion in strained HgTe surface states protected by a HgCdTe layer

P. Noël, C. Thomas, Y. Fu, L. Vila, P.-H. Jouneau, S. Gambarelli, T. Meunier, P. Ballet, J.-P. Attané

Text We report the observation of spin-to-charge current conversion in strained mercury telluride at room temperature using spin pumping experiments. We show that a HgCdTe barrier can be used to protect the HgTe from direct contact with the ferromagnet, leading to very high conversion rates, with inverse Edelstein lengths up to 2.0 □ 0.5 nm. The
to differ strongly from what is expected in spin Hall effect systems. These measurements, associated to the temperature dependence of the resistivity, suggest that these high conversion rates are due to the spin momentum locking property of HgTe surface states.

SP 18 Magnetism and spin transport in topological materials

SP18 - Parallel Session 2

SP18 - Parallel Session 2

SP18.2.02

Spin-split Landau levels of quasi 2D Dirac fermions dependent on antiferromagnetic order in EuMnBi2

H. Sakai, H. Masuda, M. Tokunaga, M. Ochi, H. Takahashi, K. Akiba, A. Miyake, K. Kuroki, Y. Tokura, S. Ishiwata

Text Dirac and Weyl magnets have been of current interest for topological spintronic applications, due to their unusual magneto-transport phenomena. Among them, a layered antiferromagnet EuMnBi2, where the Bi layer hosting quasi 2D Dirac fermions and the magnetic blocking layer (Eu-Mn-Bi layer) stack alternatively, have attracted attention as a novel Dirac magnet, since the antiferromagnetic order of Eu sublattice markedly influences the Dirac fermion transport; the interlayer resistivity increases by about one order of magnitude, when the Eu moments flop in the ab plane. In this state, plateau-like structures in Hall resistivity were observed, signifying the multilayer half-integer quantum Hall effect [H. Masuda et al., Sci. Adv. (2016)]. So far, however, detailed impacts of magnetism on the Dirac-like band have been elusive.
In this presentation, to reveal the variation of electronic structure upon the magnetic order in EuMnBi2, we have studied the Landau level splitting in a tilted magnetic field. The amplitude of SdH oscillations is strongly modulated by changing the field angle, i.e., the Zeeman-to-cyclotron energy ratio, indicating a large spin splitting. Intriguingly, the effective g factor estimated from the field angle dependence of the SdH oscillations differs by ~50% between two antiferromagnetic phases. First-principles calculations suggests that such a marked impact on the Dirac fermion state originates from strong exchange coupling with the local Eu moments.

SP 18 Magnetism and spin transport in topological materials

SP18 - Parallel Session 2

SP18.2.03

First-principles studies of transition-metal magnetic impurities in topological Dirac materials

C. Holmqvist, F. Islam, N. Pournaghavi, A. Pertsova, C. M. Canali

Text Three-dimensional (3D) topological insulators (TIs) and Weyl and Dirac semimetals (WSMs and DSMs) are remarkable materials that provide a platform for realizing novel quantum phenomena such as the QAHE, the axion electrodynamics and the quantum topological magnetoelectric effect, which depend crucially on the presence or absence of time reversal symmetry. Particular interest has been devoted to the study of magnetically doped TIs, WSMs and DSMs, where several outstanding issues are still under debate. In this work we report on extended and systematic first-principles calculations based on density functional theory carried out on transition-metal (TM) doped 3D TIs, WSMs and DSMs. Specifically, we have investigated the electronic structure and the magnetic properties of TM-doped Bi2Se3 [1, 2] and Sb2Te3 [3], paying particular attention to the interplay between the magnetic impurity states and the topologically protected Dirac surface states. Our study of TM-doped Sb2Te3 [3], done in collaboration with experimental groups, provides general guidelines for the realization of a robust QAHE in the ferromagnetic state of this TI. We will also report on ongoing work on several topological semimetals, aimed at elucidating the possibility of inducing a topological phase transition from the DSM to the WSM by symmetry breaking.

[1] M.R. Mahani et al., PRB 90, 195441 (2014).
[2] M.F. Islam et al., to be submitted to PRB (2018).
[3] M.F. Islam et al., arxiv:1802.05302 (submitted to PRB).