Magnetic Interfaces and Nanostructures Division
Room 330 - Session MI-TuA

Topological Insulator Heterostructures

Moderators: Axel Enders, University of Nebraska-Lincoln, Germany, **Valeria Lauter**, Oak Ridge National Laboratory

2:20pm **MI-TuA-1 Evidence of Antiferromagnetic Coupling between Topological and Magnetic Insulators***, **Leonid Rokhinson**,* Purdue University **INVITED**

Exchange interaction between topological and magnetic insulators enables local control of topologically protected surface states by lithographically shaping magnetic materials. In previous works ferromagnetic exchange has been successfully realized. We report an experimental evidence of antiferromagnetic exchange between a topological insulator Bi2Se3 and a magnetic insulator EuSe. Spin-polarized neutron reflectometry reveals reduction of in-plane magnetic susceptibility up to 25K, well above the Neel temperature of the bulk EuSe. A combination of SQUID magnetometry and transport measurements indicates an antiferromagnetic interfacial exchange coupling that opens an energy gap in topological surface states. High temperature local control of topological surface states with zero net magnetization opens new opportunities for the design of electronic, spintronic and quantum computation devices, ranging from quantization of Hall conductance at zero fields to spatial localization of non-Abelian excitations in superconducting topological qubits.

3:00pm **MI-TuA-3 Infrared Magnetospectroscopy of Magnetic Topological Insulator Heterostructures***, **Badih Assaf**,* University of Notre Dame **INVITED**

Topological insulator (TI)-magnetic insulator(MI) heterostructures are employed to achieve efficient electrical switching of magnetization, owing to the spin-charge coupling enabled by the helical Dirac surface states of the TI. These surface states are however prone to the breaking of time-reversal symmetry by magnetism. A magnetic insulator deposited on the surface of a TI is thus hypothesized to induce a gapping of the Dirac surface states. This energy gap is challenging to measure using common surface spectroscopies since the surface is buried under the magnetic insulator. We develop TI-MI heterostructures based on the topological crystalline insulator $Pb_{1-x}Sn_xSe$ (x>0.2) and a magnetic insulator EuSe. The high mobility achieved in PbSnSe (>10000cm^2/Vs) allows us to measure the magnetic proximity induced gap using magnetooptical Landau level spectroscopy up to 17.5T at 4.5K. We find the upper bound of this gap to be close to 20meV. We confirm the coexistence of this gapped Dirac state with magnetism using neutron reflectometry. This result has important implications on the potential of TCIs for devices that rely on proximity between a magnet and a topological material, such as spintronic switching devices, since it is evident that the gap remains smaller than the Fermi energy and likely should not influence the spin-charge coupling characteristics of the TI.

4:20pm **MI-TuA-7 Topological States in the van der Waals Magnet $MnBi_2Te_4$: from 3D to 2D***, **Hendrik Bentmann**,* Wuerzburg University, Germany **INVITED**

The interplay of topology and magnetism is a route to spintronic applications based on dissipationless charge and spin transport. The van der Waals material MnBi2Te4 naturally combines strong spin-orbit interaction and local magnetic moments, opening a playground for the study of magnetic topological phenomena. In its 3D bulk phase, MnBi2Te4 forms an antiferromagnetic topological insulator [1]. Related topological states are also realized in the modular modular (Bi2Te3)n(MnBi2Te4) series, where the insertion of non-magnetic spacer layers yields modified magnetic properties [2,3]. In the main part of the talk, I will present more recent efforts to achieve 2D MnBi2Te4 layers using molecular beam epitaxy [4]. A particular focus will be on the realization of a single MnBi2Te4 monolayer, which shows robust 2D ferromagnetism below Tc = 14 K. As demonstrated by angle-resolved photoemission (ARPES), a monolayer MnBi2Te4 placed on Bi2Te3 induces a large magnetic gap in the topological surface state, promising realization of a robust quantum anomalous Hall state.

[1] M. M. Otrokov, I. I. Klimovskikh, HB, et al., Nature 576, 416 (2019).
[2] R. C. Vidal,..., HB, A. Isaeva, et int., Phys. Rev. X 9, 041065 (2019).
[3] R. C. Vidal, HB, et al., Phys. Rev. Lett. 126, 176403 (2021).
[4] P. Kagerer, C. Fornari,..., HB, F. Reinert et int., J. Appl. Phys. 128, 135303 (2020).

5:00pm **MI-TuA-9 Rashba-Type Splitting of the Au(110) Surface State: A Combined Inverse and Direct Photoemission Study***, **Markus Donath**, K. Ritter,* University of Münster, Germany*; K. Miyamoto, T. Okuda,* Hiroshima University, Japan

The Shockley surface state located at Y on the (1×2)-reconstructed Au(110) surface is predicted to exhibit a Rashba-type spin splitting. Previous photoemission experiments searched for this splitting but it could not be resolved yet. In order to uncover a possible splitting, the unoccupied surface state on Au(110) is examined with spin- and angle-resolved inverse photoemission, whereas Na-covered Au(110) allows for investigation of the now occupied surface state by means of spin- and angle-resolved direct photoemission [1]. Our data show clear spin splittings in the order of 100 meV with a sign reversal at Y in the surface state's in-plane spin components which is characteristic for a Rashba-type behavior. Furthermore, we deduce an effective mass of $m^* = (0.27 \pm 0.02)m_e$ and a Rashba parameter of $\alpha_R = (0.46 \pm 0.04)$ eVÅ from direct photoemission measurements.

[1] K.T. Ritter, K. Miyamoto, T. Okuda, and M. Donath, Phys. Rev. B **104**, L161101 (2021).

5:20pm **MI-TuA-10 Spin-Polarized Resonant Tunneling - a New Tool for Sensing and Manipulating Magnetism on the Atomic Scale***, **Anika Schlenhoff**,* Department of Physics, University of Hamburg, Germany **INVITED**

Atomic-scale magnetism as found in ultrathin films with non-collinear spin textures or in moiré structures of 2D-hybrid materials raise expectations for potential spintronic applications, demanding for atomic-scale, spin-sensitive, but yet robust techniques for sensing and manipulation. Spin-polarized image-potential states (sp-IPS) are unoccupied electronic states in the vacuum gap between a probe tip and a magnetic sample. They exhibit the same local spin quantization axis as the surface, even when it rotates on the atomic scale [1]. In a spin-polarized scanning tunneling microscopy (SP-STM) setup, spin-polarized electrons can tunnel resonantly from the magnetic tip via the sp-IPS into the surface, resulting in a magnetic image contrast mediated by these states.

Our SP-STM experiments on non-collinear spin textures in ultra-thin films demonstrate that the spin-polarized resonant electron tunneling via sp-IPS allows for atomic-scale spin-sensitive imaging in real space at tip-sample distances of up to 8 nm, providing a loophole from the hitherto existing dilemma of losing spatial resolution when increasing the tip-sample distance in a scanning probe setup [2]. Technically applicable to a variety of material systems, our spin-polarized resonant tunneling studies on iron- and cobalt-intercalated graphene show that the IPS's sensitivity to the interlayer coupling of graphene to the metallic substrate and the resulting local IPS spin-polarization can be used for probing the graphene magnetism in the moiré unit cell [3].

When the electrons relax from the sp-IPS into the surface, a spin-transfer torque (STT) is exerted on the sample that can be exploited for thermally-assisted magnetization switching [4]. On ferromagnetic nano-islands, we observe IPS that are bound to the rim of the islands, causing a spatial modulation of the IPS electron spin-polarization above the uniformly magnetized nanoislands. As I will show, tunneling locally through the sp-IPS can be used to tune the spin-polarization of the resonant tunneling current and thus the STT for current-induced magnetization switching, using the sp-IPS as a spin-filter [5].

Utilizing the local spin-polarization of IPS via spin-polarized resonant tunneling, our approach qualifies for a spin-sensitive read-write technique with ultimate lateral resolution, potentially opening a pathway towards future technical applications.

[1] A. Schlenhoff *et al.*, Phys. Rev. Lett. **123**, 087202 (2019).

[2] A. Schlenhoff *et al.*, Appl. Phys. Lett. **116**, 122406 (2020).

[3] A. Schlenhoff *et al.*, in preparation.

[4] A. Schlenhoff *et al.*, Phys. Rev. Lett. **109**, 097602 (2012).

[5] A. Schlenhoff *et al.*, in preparation.

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