TT 92: Focus Session: Spinorbitronics - From Efficient Charge/Spin Conversion Based on Spin-Orbit Coupling to Chiral Magnetic Skyrmions II (joint session MA/TT)

Time: Thursday 15:00–18:00 Location: H 1012

Invited Talk TT 92.1 Thu 15:00 H 1012

Spin orbit fields at the Fe/GaAs(001) interface — •Christian Back — Fakultät für Physik, Universität Regensburg — Physik-Department, TU München

Interfacial spin-orbit torques (SOTs) enable the manipulation of the magnetization through an in-plane charge current. Here, we study a particularly simple single crystalline interface, Fe/GaAs(001)[1], which we use to demonstrate various effects related to interfacial SOTs. We demonstrate crystalline anisotropic magneto-resistance showing C_{2v} symmetry [2], second we show anisotropic magneto-optic response [3]. Finally, we use ferromagnetic resonance based methods to investigate interfacial SOTs and report the observation of robust SOT occuring at a single crystalline Fe/GaAs (001) interface at room temperature [4]. We find that the magnitude of the interfacial SOT, caused by the reduced symmetry at the interface, is comparably strong as in ferromagnetic metal/non-magnetic metal systems. The large spin-orbit fields at the interface also enable the spin-to-charge current conversion at the interface, known as spin-galvanic effect [4]. The results suggest that single crystalline Fe/GaAs interfaces may enable efficient electrical magnetization manipulation.

[1] M. Gmitra et al., Phys. Rev. Lett. 111, 036603 (2013) [2] T. Hupfauer et al., Nat. Commun. 6, 7374 (2015) [3] M. Buchner et al., Phys. Rev. Lett. 117, 157202 (2016) [4] L. Chen et al. Nat. Commun. 7, 13802 (2016)

TT 92.2 Thu 15:30 H 1012

Spin-charge interconversion in single crystalline Bismuth films grown on Ge(111) — •minh tuan dau[1], carlo Zucchetti[2], federico bottegoni[2], céline vergnaud[1], thomas guillet[1], alain marty[1], cyrille beigné[1], andrea picone[2], alberto calloni[2], giovanni isella[2], franco ciccacci[2], pranab kumar das[3], jun fujii[3], ivana vobornik[3], marco finazzi[2], and matthieu jamet[1] — [1]INAC-Spintec, CEA/CNRS/Grenoble-INP and Université Grenoble Alpes, 38054 Grenoble, France — [2]LNESS-Dipartimento di Fisica, Politecnico di Milano, 20133 Milano, Italy — [3]CNR-IOM Laboratorio TASC, 34149 Trieste, Italy

In this study, we have grown a bismuth wedge (0-12 nm) on Ge(111) by molecular beam epitaxy. Using structural characterization (RHEED and x-ray diffraction), we found a critical thickness of ~ 4.5 nm below which Bi exhibits an allotropic pseudocubic phase. A careful angle-resolved and spin-resolved photoemission spectroscopy study using synchrotron radiation 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 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.

TT 92.3 Thu 15:45 H 1012

Scattering of surface and interface states at skyrmionic quasiparticles interacting with defects. — •Imara L. Fernandes, Mohammed Bouhassoune, Stefan Blügel, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany

Magnetic skyrmions are promising candidates as bits of a future information technology. The precise manipulation and detection of such small magnetic nanostructures is a key ingredient for future applications in spintronics devices. Recently, we proposed the tunneling spin-mixing magnetoresistance (TXMR) to detect magnetic skyrmions by all-electrical means [1,2]. The TXMR effect originates from the non-alignment of magnetic moments and it is affected by the presence of spin-orbit interaction. We explore from a full *ab initio* approach the possibility of tuning the TXMR by inserting *3d* and *4d* transition metal defects at the vicinity of skyrmions generated in PdFe bilayer deposited on Ir(111). In the latter system, we identify surface and interface states leading to pronounced TXMR signals after scattering at skyrmionic quasi-particles. We extract the lifetimes of these confined states and draw conclusions concerning the impact of skyrmions and various atomic defects.

[1] D.M. Crum *et al.*, Nat. Commun. **6**, 8541 (2015).
[2] C. Hanneken *et al.*, Nat. Nanotech, **10**, 1039 (2015).

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TT 92.4 Thu 16:00 H 1012

Orbital fingerprints of skyrmions in ferro- and antiferromagnets — •Manuel dos Santos Dias and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany

X-rays are a very powerful tool for investigating the magnetic properties of materials. The magnetic circular dichroism in ferromagnets can be combined with sum rules to separate the net spin and orbital magnetic moments, while compensated antiferromagnets have no circular dichroism. In this contribution, we explain why skyrmions in ferromagnets encode topological information in their orbital magnetic moment, that can in principle be extracted via sum-rule analysis [1]. This part of the orbital moment originates from magnetic noncoplanarity, as found in our original work and in a simple model description [2]. We then extend the analysis to a skyrmion lattice in an antiferromagnetic background. We investigate whether the topological orbital signature is present, and whether circular dichroism exists and can detect topological information.

This work was supported by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (ERC-consolidator Grant No. 681405-DYNASORE).

[1] M. dos Santos Dias *et al.*, Nat. Commun. **7**, 13613 (2016)
[2] M. dos Santos Dias and S. Lounis, Proc. SPIE **10357**, Spintronics X, 103572A (2017)

15 minutes break

TT 92.5 Thu 16:30 H 1012

Large perpendicular magnetic anisotropy and Dzyaloshinskii Moriya chiral interaction at room temperature in epitaxial graphene-based structures — Fernando Ajejas[1], Adrian Gudin[1], Ruben Guerrero[1], Leticia De Melo Costa[1], Jose Manuel Diez[1], Pablo Olleros[1], Alberto Anadon[1], Maria Varela[2], Manuel Valvidares[3], Pierluigi Gargiani[3], Jan Vogel[4], Stefania Pizzini[4], Julio Camarero[1], Rodolfo Miranda[1], and •Paolo Perna[1] — [1]IMDEA Nanociencia, Madrid, Spain — [2]ALBA SYNCHROTRON, Barcelona, Spain — [3]Universidad Complutense de Madrid, Madrid, Spain — [4]CNRS Institut Néel, Grenoble, France

A major challenge for future spintronics is to develop suitable spin transport channels with superior properties as long spin lifetime and propagation length. Graphene can meet these requirements, even at room temperature. On the other side, the use of fast motion of Néel-type chiral domain walls (and magnetic skyrmions) can satisfy the demands for high-density data storage, low power consumption and high processing speed. Here, by engineering the epitaxial growth of gr/Co/Pt(111) stacks on (111)-oriented oxide crystals, we achieve an enhanced perpendicular magnetic anisotropy (PMA), with Co thickness up to 4 nm, and left-handed Néel-type chiral domain walls (DWs) stabilized by a strong effective Dzyaloshinskii Moriya interaction (DMI).

TT 92.6 Thu 16:45 H 1012

Analysis of the Dzyaloshinskii-Moriya interaction and spin-orbit torques in Co-based trilayers — •Jan-Philipp Hanke, Frank Freimuth, Stefan Blügel, and Yuriy Mokrousov — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Originating from the interplay of spin-orbit coupling and broken inversion symmetry, the Dzyaloshinskii-Moriya interaction (DMI) attracts ever-growing attention as it mediates the formation of chiral spin textures such as magnetic skyrmions. To predict the magnitude of this chiral interaction from *ab initio*, typically, one adopts either demanding computational frameworks or limiting approximations for the spin-orbit interaction. In contrast, we present an advanced Wannier interpolation scheme that evaluates DMI in its modern theory [1] based on the ferromagnetic ground state including spin-orbit coupling self-consistently. Utilizing this technique, we identify the microscopic origin of DMI and spin-orbit torques in the trilayers $Ir_xPt_{1-x}/Co/Pt$ and $Au_xPt_{1-x}/Co/Pt$ [2]. Tuning the composition x, we find that DMI changes sign, promoting the respective systems as promising candidates for detailed experimental studies. We examine also the consequences of the obtained anisotropy of the spin-orbit torques with the magnetization direction for the dynamical properties of skyrmions.

Funding from the DFG (Grant No. MO 1731/5-1) and from the EU Horizon 2020 via the FET-Open project MAGicSky is acknowledged.

[1] F. Freimuth *et al.*, J. Phys. Condens. Matter **26**, 104202 (2014).
[2] J.-P. Hanke *et al.*, arXiv:1711.02657.

TT 92.7 Thu 17:00 H 1012

Electrically and thermally-induced spin polarization in semiconductor heterostructures and at perovskite oxides interfaces — •Anna Dyrdał[1,2], Łukasz Karwacki[3], Józef Barnaś[2,3], Vitalii Dugaev[4], and Jamal Berakdar[1] — [1]Institut für Physik, Martin-Luther Universität Halle-Wittenberg, Halle, Germany — [2]Faculty of Physics, A. Mickiewicz University, Poznan, Poland — [3]Institute of Molecular Physics, Polish Academy of Sciences, Poznan, Poland — [4]Department of Physics and Medical Engineering, Rzeszow University of Technology, Rzeszow, Poland

Spin-orbit interaction leads to a variety of spin and transport phenomena that enable control of single spins in a pure electrical manner. The physics that stands behind such effects is very rich and depends on the nature of spin-orbit coupling in the host material. We will discuss and summarize our recent results on electrically and thermally induced nonequilibrium spin polarization obtained within effective models describing 2DEG in semiconductor heterostructures and perovskite oxide interfaces [1-3]. In principle, we will focus on analytical and numerical results describing temperature dependences and show that impurities vertex correction plays important role in thermally-induced spin polarization. We will comment relations between spin polarization and Berry curvature. The influence of spin-orbit torque induced due to non-equilibrium spin-polarization in magnetic systems on spin dynamics will be also discussed.

[1] A. Dyrdał, et al., arXiv:1711.07707; [2] Ł. Karwacki, et al., arXiv:1711.07702; [3] A. Dyrdał, et al., PRB 95, 245302 (2017).

TT 92.8 Thu 17:15 H 1012

Engineering Chiral and Topological Orbital Magnetism of Domain Walls and Skyrmions
— •Fabian R. Lux, Frank Freimuth, Stefan Blügel, and Yuriy Mokrousov —
Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

In the field of spin-orbitronics, the orbital physics of electrons plays a central role, with the orbital magnetization representing a key concept. While the orbital magnetism in ferromagnets is relatively well understood, very little is known about it for non-collinear structures such as magnetic skyrmions and domain walls. By employing a semiclassical Green's function formalism, we demonstrate how the orbital magnetization in extended chiral magnetic systems can be understood as the electronic response to emergent electromagnetic fields [1]. We discovered that in such systems the spin-orbit interaction can be used to a great advantage in that it promotes a complex interplay of real-space and k-space topology leading to enhanced orbital responses in interfacial chiral magnets. Besides discussing possible applications of the emergent orbital magnetism in chiral spin systems we also suggest new perspectives for the field of chiral orbitronics.

[1] F. R. Lux *et al.*, arXiv:1706.06068 (2017)

TT 92.9 Thu 17:30 H 1012

Current-induced remagnetization in epitaxial Au/Fe/MgO(001) heterostructures — •Pika Gospodaric[1], Ewa Mlynczak[1], Daniel E. Bürgler[1], Lukasz Plucinski[1], Yuriy Mokrousov[2], and Claus M. Schneider[1] — [1]Peter Grünberg Institut PGI-6, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

In the emerging field of the spintronics devices the focus shifts towards the three-terminal cell structure. In this geometry, the magnetization of the recording magnetic layer is switched with an in-plane electric current. Presently, the spin-orbit torque is considered as one of the most promising ways of current-induced switching of ferromagnets and antiferromagnets. Here, we study an epitaxial Fe(001) ultra-thin film, with in-plane remanent magnetization, sandwiched between the MgO substrate and an epitaxal Au thin film. This system has well-defined interfaces between the layers and a good crystalline quality, which gives rise to the typical four-fold in-plane magneto-crystalline anisotropy of Fe(001) layers. In a Hall bar geometry we observed reproducible switching of the magnetization of the Fe(001) thin film after applying a current density beyond $2 \cdot 10^7$ A/cm^2. The magnetic state was read-out by measuring the planar Hall voltage in the transversal channel. By varying the current density we were able to induce intermediate magnetization states, which could be explained with changes in the magnetic domain structure. These results give the prospect to apply Fe/Au heterostructures in neuromorphic architectures.

TT 92.10 Thu 17:45 H 1012

Dynamics of interacting Skyrmions in densely populated Skyrmion lattices — •Martin Stier and Michael Thorwart — University of Hamburg, Hamburg, Germany

We address issues which may arise in densely populated Skyrmion lattices which are possibly used in future high-capacity memory devices. A manipulation of the information-carrying Skyrmions is typically achieved by electrical currents - either in terms of spin-transfer or spin-orbit torques. However, Skyrmions themselves distort these torques in their surrounding area. This can actually result in the creation of new Skyrmions under certain conditions. Furthermore, an interaction between Skyrmions in different layers, e.g. in an artificial antiferromagnet, will change the dynamics of the according Skyrmions. This can even have beneficial effects, such as the prevention of the drift due to the Skyrmion Hall effect and an increase of the velocity.