TT 78: Focus Session: Spinorbitronics - From Efficient Charge/Spin Conversion Based on Spin-Orbit Coupling to Chiral Magnetic Skyrmions I (joint session MA/TT)

This session will focus on the novel direction of spintronics, often called spin-orbitronics, that exploits the Spin-Orbit Coupling (SOC) in nonmagnetic materials instead of the exchange interaction to open fascinating new roads for basic research and new line of technologies. A first aim of this symposium will be to review both fundamental and theoretical recent advances made in using spin-orbit effects for generating or detecting spin-polarized currents either through bulk contributions e.g. the Spin Hall Effect or at interfaces through Rashba effects or topological surface states in topological insulators. Spin-orbit coupling can also be used in magnetic materials to create new types of topological objects such as chiral domain walls or magnetic skyrmions, that have generated a strong interest in the last couple of years. The second objective of this focused session will be to review the most recent significant results obtained to generate and characterize strong interfacial Dzyaloshinskii-Moriya Interactions (DMI). Beyond the stabilization of Néel domain walls in perpendicular magnetic layers with great promises for a new generation of race track memories, it has been recently that this chiral interaction plays a crucial role in the observation of magnetic skyrmions at room temperature. The goal will be here also to gather the key advances on the physics of magnetic skyrmions as well as on the potential applications and concept devices that shall leverage on their fascinating topological properties.

Organized by: Vincent Cros (Université Paris-Sud), Giovanni Finocchio (University of Messina)

Time: Thursday 9:30–12:30 Location: H 1012

Invited Talk TT 78.1 Thu 9:30 H 1012

Understanding Spin-Charge Conversion in Topological Insulators — •Aurelien Manchon — King Abdullah University of Science and Technology (KAUST), Physical Science and Engineering Division (PSE), Thuwal 23955-6900, Saudi Arabia

The interface between TI and 3d transition metal ferromagnets (3d-TM) represents a powerful platform for the realization of spin-charge conversion processes such as, but not limited to, spin pumping and spin-orbit torques. Uncovering the impact of 3d-TM overlayers on the surface states of TI and evaluating the resulting interfacial spin-momentum locking will undoubtedly open promising avenues for the efficient control of spin and charge currents mediated by spin-orbit coupling.

After a short review of the experimental results available, I will first discuss the spin-charge conversion processes expected from an ideal model. I will show that the very symmetry of the spin-orbit torques expected from topological surface states is quite different from the one observed experimentally. In a second part, based on recent density functional theory calculations, I will discuss the nature of interfacial orbital hybridization in 3d-TM adsorbed on Bi2Se3. Finally, based on these considerations I will present a minimal tight-binding model that allows us to inspect the transition between surface-dominated and bulk-dominated spin-orbit torque in 3d-TM/Bi2Se3 bilayers. This last model demonstrates that spin Hall effect arising from the bulk states of the topological insulator are unlikely to contribute to the last torque observed in experiments.

TT 78.2 Thu 10:00 H 1012

Impact of disorder on interfacial DMI for skyrmionics: intermixing and dusting — •Bernd Zimmermann[1], William Legrand[2], Nicolas Reyren[2], Vincent Cros[2], Stefan Blügel[1], and Albert Fert[2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, Germany — [2]Unité Mixte de Physique, CNRS, Thales, Univ. Paris-Sud, Université Paris-Saclay, Plaiseau, France

The spin-orbit (SOC) based Dzyaloshinskii-Moriya interaction (DMI) is of utmost importance for future nanotechnological devices, e.g. for the stabilization of small magnetic skyrmions in heterostructures such as magnetic multilayers. Additionally, the problematic role of disorder in such systems, e.g. leading to pinning of skyrmions, needs to be overcome making production processes tedious and expensive.

Here, we at first reveal from *ab initio* calculations for the important example of Co-Pt bilayers a surprisingly profound robustness of the DMI against interfacial intermixing. We incorporate disorder realistically by employing the coherent-potential approximation in combination with the Korringa-Kohn-Rostoker method. The robustness of DMI is a result of compensation, which turns out to follow simple arguments. We also explore the possibility to tune the DMI by dusting the interface with various impurities, including noble and transition metals, and elements with low and high SOC (bismuth and boron).

We acknowledge funding by a postdoc fellowship from DAAD, the EU's H2020 FET-open project "MAGicSky", and computing time on JURECA of JSC and JARA-HPC of RWTH Aachen University.

TT 78.3 Thu 10:15 H 1012

Control of the skyrmion Hall angle by combining spin-Hall effect, breathing mode and in-plane field — •Riccardo Tomasello[1], Anna Giordano[2], Roberto Zivieri[2], Vito Puliafito[3], Stefano Chiappini[4], Bruno Azzerboni[3], Mario Carpentieri[5], and Giovanni Finocchio[2] — [1]Dept. Engineering, Polo Scientifico e Didattico di Terni, University of Perugia, Terni, Italy — [2]Dept. Mathematical and Computer Sciences, Physical Sciences and Earth Sciences, University of Messina, Messina, Italy — [3]Dept. Engineering, University of Messina, Messina, Italy — [4]Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy — [5]Dept. Electrical and Information Engineering, Politecnico di Bari, Bari, Italy

The spin-Hall effect(SHE)-driven skyrmion motion is characterized by an in-plane angle, i.e. the skyrmion Hall angle (SHA)[1].

Here, we micromagnetically report, for the first time, the SHE-driven dynamics of a breathing skyrmion. In particular, we can excite the breathing mode by applying an ac perpendicular-polarized current[2] and we can control the SHA by an in-plane external field Hy. Our results show that the SHA depends on the SHE current only under the simultaneous presence of Hy and breathing mode. Our achievements can be important for understanding the origin of the SHA current dependence when the field-like torque comes from the SHE and the breathing mode is due to temperature and/or disordered parameters[3].

[1]G. Chen, Nat. Phys. 13, 112 (2017). [2]G. Finocchio et al., Appl. Phys. Lett. 107, 262401 (2015). [3]J.-V. Kim and M.-W. Yoo, Appl. Phys. Lett. 110, 132404 (2017).

TT 78.4 Thu 10:30 H 1012

Electric-field-induced and magneto-optic response properties of chiral magnetic solids — •Sebastian Wimmer, Sergiy Mankovsky, Svitlana Polesya, and Hubert Ebert — Dept. Chemie, LMU, München, Deutschland

Chiral magnetism and its manifestation in response properties such as Hall effects are one of the most attractive topics in current solid state science owing to their fascinating fundamentals as well as promising potential for application. This talk will report on the space-time symmetry restrictions on the tensor shapes of charge and spin conductivity, spin-orbit torque and (Rashba-)Edelstein effect and accompanying first-principles calculations of the respective response coefficients in Mn-based compounds experimentally known to exhibit large chirality-induced Hall effects. The numerical work has been performed using the spin-polarized relativistic Korringa-Kohn-Rostoker (SPR-KKR) multiple-scattering-based band structure method and Kubo's linear response formalism. The focus will be on chirality-driven or topological contributions arising due to a nonvanishing scalar spin chirality. Discussions will be based on computational studies of a spin texture smoothly varying between the collinear and noncollinear coplanar limits and manipulation of the spin-orbit coupling strength. Complementary results for orbital moments and current distributions as well as X-ray magnetic dichroism will be presented in addition.

30 minutes break

Invited Talk TT 78.5 Thu 11:15 H 1012

Interfacial spin-orbitronic: Rashba interfaces and topological insulators as efficient spin-charge current converters — •Juan-Carlos Rojas-Sanchez — Insitut Jean Lamour, Univ. Lorraine -CNRS, Nancy, France

New materials with large efficiency of spin-charge current interconversion are highly desirable to study new physical phenomena as well as for spintronics applications. The spin-orbit coupling (SOC) in the 2DEG states at Topological Insulator (TI) or Rashba Interfaces (RI) is predicted to be more efficient than their 3D counterparts for such interconversion. We have found the highest efficiency at room temperature using the topological insulator α-Sn [1]. The spin-to-charge current conversion in such 2D systems is called Inverse Edelstein Effect (IEE), or spin galvanic effect. I will show results of spin-to-charge conversion by spin pumping experiments and their analysis in term of inverse Edelstein Length in RI TI [1-3]. Experimental results based on ARPES and spin pumping indicate that direct contact of metallic ferromagnetic layer is detrimental for the surfaces states of topological insulators but we can keep the surfaces states of α-Sn using Ag spacer [1]. I will use the conversion parameter obtained at room temperature with α-Sn to demonstrate the very large advantage of the SOC effects in 2D interface states with respect to the Spin Hall Effect (SHE) of 3D metals and the resulting perspective for low power spintronic devices.

[1]J.-C. R-S et al. PRL 116, 096602 (2016). [2]J.-C. R-S et al. Nat. Comm 4, 2943 (2013). [3]E. Lesne, J.-C. R-S et al. Nat. Mat. 15, 1261 (2016).

TT 78.6 Thu 11:45 H 1012

Dynamical spin-orbitronic effects in exchange-bias bilayers from first-principles — •Filipe Souza Mendes Guimarães, Manuel dos Santos Dias, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The interplay between charge and spin has been extensively studied in ferromagnetic systems. Recently, the focus has shifted to antiferromagnets, which are insensitive to external magnetic fields and offer much faster dynamics. When ferromagnets and antiferromagnets are coupled through the exchange bias, we can combine the best of both worlds [1]. For a deep understanding of such complex structures, a microscopic material-specific dynamical theory, such as the one we developed, is crucial [2,3]. In this work, we apply our theory to an idealized FePt/PtMn bilayer, to identify how the ferromagnet/antiferromagnet interface contributes to the dynamical magnetization and transport properties. We demonstrate how the resonances, reaching the THz range, may enhance the currents flowing through the system. The layer-resolved magnetic interactions and spin-orbit torques can also be used to understand switching processes of this type of heterostructures.

[1] S. Fukami *et al.*, Nature Materials **15**, 535–541 (2016)
[2] F. S. M. Guimarães *et al.*, Phys. Rev. B **92**, 220410(R) (2015)
[3] F. S. M. Guimarães *et al.*, Sci. Rep. **7**, 3686 (2017)

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TT 78.7 Thu 12:00 H 1012

Determination of the Dzyaloshinskii-Moriya interaction in epitaxial asymmetric trilayers — •Fernando Ajejas[1], Adrian Gudin[1], Ruben Guerrero[1], Diane Chaves[2], Viola Křižáková[2], Jan Vogel[2], Stefania Pizzini[2], Paolo Perna[1], and Julio Camarero[1] — [1]IMDEA Nanociencia, Campus Universidad Autónoma de Madrid, Spain — [2]CNRS, Institut Néel, Université Grenoble Alpes, 38042 Grenoble, France

We will address the issue of domain wall velocity limitations in ultrathin magnetic films in symmetric and non-symmetric stacks. The DW wall speed is in general limited by the breakdown. This limitation is overcome in asymmetric trilayer systems in which Co is deposited on a heavy metal: in this case the Dzyaloshinskii-Moriya interaction (DMI) favours chiral Néel walls that are more stable against precession. It has been shown that in asymmetric thin layer systems the domain wall speed saturates above the Walker field, which is in general not the case for symmetric samples. Using magneto-optical Kerr magnetometry and microscopy, we measured domain wall velocities driven by magnetic field pulses in Pt/Co/Pt and Pt/Co/M (M=Al, Cu, Ir,) Typical Co thicknesses is 0.6 nm. The main result is that the saturation velocity of the DWs in the Pt/Co/M trilayers is strongly dependent on the nature of the top interface. We attribute this variation to the different contribution of the Co/M interfaces to the total DMI strength. The largest saturation velocities (typically 300m/s) are obtained for the samples covered by Al, Cu, or an oxyde, while much smaller velocities (typicaly 100m/s) are obtained for Ir or Ta top layers.

TT 78.8 Thu 12:15 H 1012

The spin-Hall stationarity conditions in the light of the second law of thermodynamics — •Jean-Eric Wegrowe[1], Rober Benda[1], Jean-Michel Dejardin[2], and Miguel Rubi[3] — [1]LSI, Ecole polytechnique, Palaiseau, France — [2]Laboratoire de Mathématique et Physique, Université de Perpignan, France — [3]Facultat de Fisica, Universitat de Barcelona, Spain

The determination of the stationary states for the bulk spin-Hall effect are discussed in the context of the two spin-channel model. It is shown that the usual stationarity condition (namely no explicit time-dependence) leads to an indeterminacy: different stationary states can equally be defined [1]. A first state S1 is characterized by a transverse pure spin current and no electric field while a second stationary state S2 is characterized by spin-dependent electric fields and no transverse current. The two states have the same properties with respect to spin-accumulation and spin-Hall angle, but not with respect to the total power dissipated.

The application of the second law of thermodynamics allows a reformulation of the problem in the form of a variational principle under constraints (Kirchhoff-Helmholtz principle). The constraints include charge accumulation and spin-flip scattering. The stationary state is then defined univocally: the first state S1 is found for the Corbino disk while the second state S2 is found for the Hall bar [2].

[1] J.-E. Wegrowe, J. Phys.: Cond Matter 29, 485801 (2017). [2] J.-E. Wegrowe, R. Benda, M. J. Rubì, Europhys. Lett. 18, 67005 (2017).