MA 9: Spincaloric Transport (jointly with TT)

Time: Monday 15:00–18:15 Location: H31

MA 9.1 Mon 15:00 H31

Spectral characteristics of time resolved magnonic spin Seebeck effect [1] — •levan chotorlishvili, seyyed etesami, and jamal berakdar — Institut für Physik, Martin Luther University Halle-Wittenberg, 06099 Halle/Saale, Germany

Spin Seebeck effect (SSE) refers to the generation of spin current due to a temperature gradient, in analogy to the conventional Seebek effect. The current work addresses and unvocer the role of subthermal magnons contributions to the SSE in insulating ferromagnets. The finding is in line with recent experiments given in Ref. [2], and points to further interesting experiments and material composition design aiming at enhancing/exploiting SSE. Technically, the spin-current dynamics is treated based on the Landau-Lifshitz-Gilbert (LLG) equation, while the formation of the time dependent thermal gradient being described self-consistently via the heat equation coupled to the magnetization dynamics. [3]

[1] S. R. Etesami, L. Chotorlishvili, and J. Berakdar, Appl. Phys. Lett. 107, 132402 (2015). [2] S. R. Boona and J. P. Heremans, Phys. Rev. B 90, 064421 (2014). [3] N. Roschewsky, M. Schreier, A. Kamra, F. Schade, K. Ganzhorn, S. Meyer, H. Huebl, S. Geprgs, R. Gross, and S. T. B. Goennenwein, Appl. Phys. Lett. 104, 202410 (2014).

MA 9.2 Mon 15:15 H31

A novel tool to investigate anisotropic effects in spin caloric measurements — •Oliver Reimer, Michel Bovender, Jan-Oliver Dreessen, Daniel Meier, Lars Helmich, Andreas Hütten, Jan-Michael Schmalhorst, Günter Reiss und Timo Kuschel — CSMD, Physics Department, Bielefeld University, Germany

In spin caloric measurements ∇T acts as a driving force for spin currents. A ferromagnet exposed to ∇T in an external magnetic field $\vec{H}$ generates a spin current parallel to ∇T (longitudinal spin Seebeck effect [1]) which can be detected in materials with high spin orbit coupling (e.g. Pt) by the inverse spin Hall effect. In paramagnets the spin Nernst effect is expected to cause a transverse spin current which can induce a spin torque transfer at the interface to a magnetic material. Thus, ∇T could be used in combination with $\vec{H}$ to create a spin Nernst effect based magnetothermopower similar to the current driven spin Hall magnetoresistance [2,3]. We introduce a new setup which allows the rotation of ∇T in addition to varying T_{base} and ΔT. This talk gives an overview of the implementation of an infrared camera controlled rotation of ∇T which combined with the rotation of $\vec{H}$ enables the measurement of anisotropic spin caloric effects. The functionality of the setup is proven by planar Nernst effect measurements and compared to the results of D. Meier et al. [4].

[1] K. Uchida et al., Appl. Phys. Lett. 97, 172505 (2010)
[2] H. Nakayama et al., Phys. Rev. Lett. 110, 206601 (2013)
[3] M. Althammer et al., Phys. Rev. B 87, 224401 (2013)
[4] D. Meier et al., Phys. Rev. B 88, 184425 (2013)

MA 9.3 Mon 15:30 H31

Tunnel magneto-Seebeck effect in MgO tunnel junctions — •Ulrike Martens[1], Alexander Boehnke[2], Marvin von der Ehe[1], Christian Franz[3], Michael Czerner[3], Karsten Rott[2], Andy Thomas[2,4], Christian Heiliger[3], Günter Reiss[2], and Markus Münzenberg[1] — [1]Institut für Physik, Ernst-Moritz-Arndt Universität Greifswald, Germany — [2]CSMD, Physics Department, Bielefeld University, Germany — [3]Justus-Liebig-Universität Gießen, Germany — [4]IMW, IFW Dresden, Germany

In recent spincaloritronic research several groups have observed the tunnel magneto-Seebeck effect (TMS) in magnetic tunnel junctions (MTJs) incorporating CoFe electrodes and MgO tunnel barriers [1, 2]. Semiconducting materials are known to have large Seebeck coefficients. This is mainly attributed to the gap in their band structure and the asymmetric position of the Fermi-level. The tunnel magneto-Seebeck effect (TMS) is a powerful tool to investigate such spin-dependent Seebeck coefficients, because separate spin-channels can be defined in magnetic tunnel junctions (MTJs). Here, we investigate the spin-dependent Seebeck coefficients of CoFeB/MgO/CoFeB MTJs with different thicknesses of the MgO barrier. CoFeB/MgO/CoFeB MTJs with TMR ratios of 80% to 230% show TMS ratios of 5% to 50%. With a size variation of the heating laser spot we see zero crossing voltage compensation effects. Funding by DFG SPP 1538 is acknowledged.

[1] Walter, M., et al. Nature Mater. 10, 742 (2011)
[2] Liebing, N., et al. Phys. Rev. Lett. 107, 177201 (2011)
[3] A. Boehnke et al. Rev.Sci. Instrum 84 (2013)

MA 9.4 Mon 15:45 H31

Spincaloric properties of epitaxial $Co_2MnSi/MgO/Co_2MnSi$ magnetic tunnel junctions — •Benjamin Geisler[1,2] and Peter Kratzer[2] — [1]FRM II, Technische Universität München, 85748 Garching, Germany — [2]Fakultät für Physik, Universität Duisburg-Essen, 47048 Duisburg, Germany

Magnetic tunnel junctions (MTJs) with ferromagnetic, half-metallic electrodes are interesting spintronics devices due to their high tunnel magnetoresistance ratio. If a thermal gradient is applied to such a MTJ, the relative electrode magnetization can be detected by measuring the induced voltage, i.e., by exploiting the magneto-Seebeck effect.

Here we present an *ab initio* viewpoint on transport and spincaloric properties of epitaxial $Co_2MnSi/MgO(001)/Co_2MnSi$ MTJs [Phys. Rev. B 92, 144418 (2015)]. We compare results calculated with the conventional Sivan-Imry approach to results obtained from solving the Landauer-Büttiker equation directly. The latter procedure circumvents the linear response approximation inherent in the Seebeck coefficient and provides the response of the system (current or voltage) to arbitrary thermal gradients. Moreover, thermal variations of the chemical potential in the leads and finite-bias effects can be readily included in this method. Especially the former are found to be important here for obtaining qualitatively correct results. We show how the spincaloric properties of the MTJs depend on the interface atomic structure and that they can be tailored by a targeted growth control. Finally, we shortly comment on the influence of thermally activated electrode phonons and interface magnons.

MA 9.5 Mon 16:00 H31

Current progress of the tunnel magneto-Seebeck effect in Heusler based MTJs — •Alexander Boehnke[1], Torsten Huebner[1], Ulrike Martens[2], Marvin von der Ehe[2], Christian Sterwerf[1], Christian Franz[3], Timo Kuschel[1], Andy Thomas[1,4], Christian Heiliger[3], Markus Münzenberg[2], and Günter Reiss[1] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]University of Greifswald, Germany — [3]University of Giessen, Germany — [4]IMW, IFW Dresden, Germany

The tunnel magneto-Seebeck effect (TMS) [1,2] describes the difference of the Seebeck coefficients S_p and S_{ap} of a magnetic tunnel junction (MTJ) in the parallel and antiparallel magnetization alignment. Obviously, increasing the difference between S_p and S_{ap} as well as their magnitude is desirable to reduce the signal-to-noise ratio, e.g. for determining the magnetic state of the MTJ in memory applications.

Here, we suggest MTJs with an MgO barrier and Heusler compound electrodes (e.g. Co_2FeAl, Co_2FeSi) as good candidates for fulfilling both goals, because of their half-metallic density of states [3]. We will present current results on TMS measurements performed on these MTJs and discuss how to optimize the choice of materials for future devices.

[1] Walter et al., Nature Mater. 10, 742 (2011).
[2] Boehnke et al. Rev. Sci. Instrum. 84, 063905 (2013).
[3] Geisler et al., Phys. Rev. B. 92, 144418 (2015).

MA 9.6 Mon 16:15 H31

Comparison of laser induced and intrinsic tunnel magneto-Seebeck effect in $CoFeB/MgAl_2O_4/CoFeB$ magnetic tunnel junctions — •Torsten Huebner[1], Alexander Boehnke[1], Ulrike Martens[2], Markus Münzenberg[2], Andy Thomas[3], Timo Kuschel[1], and Günter Reiss[1] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]IFP, Greifswald University, Germany — [3]IMW, IFW Dresden, Germany

The Seebeck coefficient of a Magnetic Tunnel Junction (MTJ) depends on its magnetic state known as the tunnel magneto-Seebeck (TMS) effect [1]. It has been extensively studied with indirect Joule and laser induced heating [2,3]. Zhang, Teixeira et al. [4,5] proposed a third method using the intrinsic Joule heating by the tunneling current without any external temperature gradient. Here, we prepared $CoFeB/MgAl_2O_4/CoFeB$ MTJs and obtained a maximum tunnel magneto-resistance (TMR) ratio of 34 % at room temperature for a nominal barrier thickness of 1.8 nm. We used a modulated diode laser ($P_{\max}$=150 mW, λ=637 nm, f=177 Hz) to generate a temperature gradient across the junctions and recorded IU-characteristics to compare the laser induced TMS with the intrinsic TMS.

15 min. break

MA 9.7 Mon 16:45 H31

Influence of laser heating on switching fields in magnetic tunnel junctions — •Hangfu Yang, Niklas Liebing, Xiukun Hu, Sibylle Sievers, Mark Bieler, and Hans W. Schumacher — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

The field of spin caloritronics focuses on the interplay between heat, charge and spin currents in magnetic systems and gained a lot of interest due to new phenomena such as the tunnel magneto-Seebeck effect [1] and the thermal spin transfer torque [2]. Here, we study the influence of temperature and temperature gradients on magnetic switching of the free layer of CoFeB/MgO/CoFeB magnetic tunnel junctions (MTJs). Thermal gradients across the MTJs are generated locally by femtosecond laser pulses. The switching of the free layer is determined by magnetostatic measurements of the critical switching curve as a function of the laser power. We find that the entire critical curve shifts up to 4 mT along the easy axis at a laser power of 110 mW. We show that the shift in the critical curve is caused by an increase of the overall temperature due to heat accumulation rather than by a temperature gradient. Future studies will focus on reducing the stationary temperature increase, allowing for the generation of larger temperature gradients in our samples.

[1] N. Liebing et al., Phys. Rev. Lett. 107, 177201 (2011); M. Walter et al., Nature Mater. 10, 742-746 (2011).

[2] M. Hatami et al., Phys. Rev. Lett. 99, 066603 (2007); G.M. Choi et al., Nature Phys. 11, 576-581 (2015).

MA 9.8 Mon 17:00 H31

Thickness-dependent low-temperature enhancement of the spin Seebeck effect in YIG films — •Joel Cramer[1], Er-Jia Guo[1,2], Andreas Kehlberger[1], Christoph Schneider[1], Gerhard Jakob[1], and Mathias Kläui[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Quantum Condensed Materials Division, Oak Ridge National Laboratory, TN 37830, Oak Ridge, USA

In ferromagnetic insulator (FMI)/normal metal (NM) bilayers the temperature dependence of the spin Seebeck effect (SSE) has been probed as a function of FMI thickness, different interfaces and detection materials [1, 2]. At low temperatures, an enhancement of the SSE signal is observed, including the appearance of a peak in the amplitude. This enhancement is more pronounced for thicker films and vanishes for film thicknesses below 600 nm. Furthermore, the temperature of the signal maximum strongly depends on the FMI thickness as well as on the FMI/NM interface. The thickness dependence can be well explained by considering a model of a magnon-driven SSE, which takes into account the frequency dependent propagation length of thermally excited magnons inside the bulk material. The NM dependence, however, indicates that previously neglected interface effects play a major role in the observed signal. In order to obtain a better understanding of the influence of the FMI/NM interface, transmission electron microscopy (TEM) measurements combined with elemental analysis (EELS) are performed. [1] A. Kehlberger et al. Phys. Rev. Lett. 115, 096602 (2015) [2] Er-Jia Guo et al. arXiv: 1506.06037

MA 9.9 Mon 17:15 H31

Static magnetic proximity effect in Pt layers on sputter deposited NiFe$_2$O$_4$ and on Fe of various thicknesses investigated by x-ray resonant magnetic reflectivity — •Panagiota Bougiatioti[1], Christoph Klewe[1], Olga Kuschel[2], Joachim Wollschläger[2], Laurence Bouchenoire[3,4], Simon D. Brown[3,4], Jan-Michael Schmalhorst[1], Daniel Meier[1], Günter Reiss[1], and Timo Kuschel[1] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]Fachbereich Physik, Universität Osnabrück, Germany — [3]XMaS, ESRF, Grenoble, France — [4]University of Liverpool, UK

In this project we implemented x-ray resonant magnetic reflectivity (XRMR) to investigate magnetic proximity effects (MPE) in Pt films on sputter deposited NiFe$_2$O$_4$(260 nm) (NFO) and in Pt/Fe(x nm) samples with x from 1.1 nm to 18.2 nm. We did not observe a magnetic response down to a limit of 0.04 μ_B per Pt atom regarding the sputter deposited NFO bilayer, in agreement to previously investigated chemical vapor deposited NFO samples [1]. We performed longitudinal spin Seebeck effect measurements on this bilayer system and exclude an anomalous Nernst effect induced by the MPE in Pt down to a certain limit. Furthermore, we confirm the independence of the MPE from the thickness of the magnetic layer (Fe), unveiling its sensitivity to the interface properties of the magnetic material [2].

[1] T. Kuschel et al., Phys. Rev. Lett. 115, 097401 (2015)

[2] T. Kuschel et al., submitted to IEEE Trans. Magn. (2015)

MA 9.10 Mon 17:30 H31

Temperature dependence of the domain wall magneto-Seebeck effect — •Alexander Fernández Scarioni, Patryk Krzysteczko, Xiukun Hu, Niklas Liebing, Sibylle Sievers, and Hans W. Schumacher — Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116, Braunschweig, Germany

We study the thermopower response of a magnetic domain wall in a nanowire under the influence of a thermal gradient and compare it with corresponding magnetoresistance measurements. The nanowire used is an L-shape permalloy (Ni80Fe20) nanowire. A single domain wall can be nucleated and pinned at a notch between two electrical contacts. We observe a clear thermopower signature of the domain wall pinned at the notch.

The thermal gradient is generated by an electrical microheater placed in the vicinity of the magnetic nanowire. We study the local heat distribution experimentally by microscopic resistance thermometers and numerically by finite element calculations.

By combination of thermal gradient and magnetothermopower measurements at various temperatures we can describe the system based on the anisotropic magneto-Seebeck effect.

MA 9.11 Mon 17:45 H31

Thermally excited magnon accumulation in complex magnetic materials — •Ulrike Ritzmann, Denise Hinzke, and Ulrich Nowak — Universität Konstanz, Konstanz, Germany

It was shown experimentally that in a magnetic insulator spin currents can be created by applying temperature gradients [1]. Using atomistic spin model simulations, we study magnonic spin currents and their characteristic length scales in ferromagnetic materials with different temperature profiles [2,3,4]. Furthermore, we explore thermally excited spin currents in antiferromagnetic materials and study the magnon accumulation in the vicinity of a temperature step and its characteristic length scale. We determine the different antiferromagnetic modes that are excited and discuss their propagation length using an one-dimensional analytical model.

These methods can be extended for ferrimagnetic materials. In a two-sublattice ferrimagnet, we determine the thermally excited magnon accumulation due to a temperature step. We study the temperature dependence of the magnon accumulation in ferrimagnets and investigate under which condition the magnon accumulation in such systems vanishes.

We acknowledge financial support by the DFG through SFB 767 and through SPP "Spin Caloric Transport".

[1] K. Uchida et al, Appl. Phys. Lett. **97**, 172505 (2010)

[2] U. Ritzmann et al., Phys. Rev. B **89**, 024409 (2014)

[3] A. Kehlberger et al.,Phys. Rev. Lett. **115**, 096602 (2015)

[4] U. Ritzmann et al., Phys. Rev. B **92**, 174411(2015)

MA 9.12 Mon 18:00 H31

Spin wave scattering and localization effects due to defects in magnetic materials — •Martin Evers, Cord A. Müller, and Ulrich Nowak — University of Konstanz, 78457 Konstanz, Germany

From earlier studies of transport of particles and waves it is known that there are different transport regimes. E.g. in a perfect crystal transport will be ballistic, but one usually has to deal with some kind of imperfections that induce disorder in the system. As Anderson has shown in 1958 in case of phase coherent transport disorder can also lead to completely suppressed transport, known as Anderson localization [1]. For the case of spin waves this will lead to a vanishing magnon propagation length, even without any damping mechanism [2,3].

Within a classical spin model utilizing the Landau-Lifshitz-Gilbert equation we study coherent backscattering (CBS), which is a weak localization phenomena and therefore a precursor for Anderson localization, in 2D. Especially the influence of non-linearities, damping and the Dzyaloshinskii-Moriya interaction is investigated. We also find evidence for coherent forward scattering [4] of magnons in a quasi one-dimensional setting, providing a direct signal of Anderson localization and absence of thermalization.

[1] P. W. Anderson, Phys. Rev. **109**, 1492 (1958)
[2] U. Ritzmann et al., Phys. Rev. B **89**, 024409 (2014)
[3] M. Evers et al., Phys. Rev. B **92**, 014411 (2015)
[4] T. Micklitz et al., Phys. Rev. Lett. **112**, 110602 (2014)