MA 22: Thin Films: Magnetic Coupling Phenomena / Exchange Bias / Magnetic Anisotropy

Time: Wednesday 9:30–11:45 Location: H47

MA 22.1 Wed 9:30 H47

Spin dynamics in coupled ferrimagnetic heterostructures — •Felix Fuhrmann[1], Sven Becker[1], Akashdeep Akashdeep[1], Zengyao Ren[1,2], Mathias Weiler[3], Gerhard Jakob[1,2], and Mathias Kläui[1,2,4] — [1]Institute of Physics, University of Mainz, Germany — [2]Graduate School of Excellence "Materials Science in Mainz" (MAINZ), Germany — [3]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Germany — [4]Center for Quantum Spintronics, Norwegian University of Science and Technology, Trondheim, Norway

With growing demand for more energy efficient information technology, the utilization of magnons as information carriers entails potential advantages [1]. To successfully develop magnon-based devices, there are several requirements for the applied materials to meet. The insulating ferrimagnet Yttrium Iron Garnet ($Y_3Fe_5O_{12}$, YIG) and related garnets are good candidates with an outstanding low damping and large magnon propagation lengths [1]. Our heterostructures of YIG and Gadolinium Iron Garnet ($Gd_3Fe_5O_{12}$, GIG) were grown by pulsed laser deposition. We observe a ferromagnetic coupling between the Fe sublattices of the two layers, leading to complex magnetic response to external magnetic fields and a nontrivial temperature dependence [2]. We investigate the spin dynamics by broadband ferromagnetic resonance (FMR) experiments. Our observations are corroborated by measurements of SQUID magnetometry, spin Hall magnetoresistance and spin Seebeck effect [2]. [1] A. Chumak et al., Nat. Phys, 11, 453 (2015). [2] S. Becker et al., Phys. Rev. Appl., 16, 014047(2021).

MA 22.2 Wed 9:45 H47

Optical detection of magnon-phonon coupling using μFR-MOKE technique — •Manuel Müller[1,2], Lukas Liensberger[1,2], Mathias Weiler[3], Matthias Althammer[1,2], Rudolf Gross[1,2,4], and Hans Huebl[1,2,4] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Technische Universität Kaiserslautern, Kaiserslautern, Germany — [4]Munich Center for Quantum Science and Technology (MCQST), München, Germany

Magnetoelastic coupling between wave-like excitations of the spin system (spin waves) and the lattice (elastic waves) can result in a hybridization of both modes. This coupling can reach the strong-coupling regime, which is of interest for future (quantum) applications, such as microwave-to-optics transducers and phononic spin valve devices.

We here present an experimental approach to investigate magnon-phonon coupling for the YIG layers in a YIG/GGG/YIG trilayer on an individual basis using the microfocused frequency-resolved magneto-optic Kerr effect(μFR-MOKE) technique [1]. We discuss the magnetization dynamics recorded individually for the top and bottom YIG layer with those acquired using broadband ferromagnetic resonance. This data gives further insight to the involved modes as well as their coupling. As a longterm perspective, we expect that this technique will allow the investigation of microstructures with enhanced coupling rates via their optimized geometry.

[1] L. Liensberger et al., IEEE Magn. Lett. **10**, 5503905 (2019).

MA 22.3 Wed 10:00 H47

Experimental tests of the accuracy of the reflection matrix description in linear magneto-optics — •Carmen Martín Valderrama, Mikel Quintana, and Andreas Berger — CIC nanoGUNE BRTA, E-20018 Donostia-San Sebastián, Spain

Magneto-Optical (MO) Kerr Effect (MOKE) techniques are frequently utilized to monitor magnetization M reversal, and even its vector information, in a non-destructive way [1]. The assumption is hereby that the Jones-formalism reflection matrix R, including 1^{st} order MOKE, is given as $R = \begin{pmatrix} r_s & \alpha(m_x)+\gamma(m_z) \\ -\alpha(m_x)+\gamma(m_z) & r_p+\beta(m_y) \end{pmatrix}$, with $m_{x,y,z}$ being the M components in Cartesian coordinates, r_s and r_p as Fresnel coefficients and α, β and γ being MOKE coefficients for longitudinal, transverse and polar effects. Recently, however, there have been reports of linear MOKE that is independent of a sample's magnetization [2]. Thus, it is important to verify the above R expression experimentally, which to our knowledge has not been done rigorously. For this, we utilized a sample with uniform M, which can be precisely rotated by an applied field, thus systematically varying the MOKE coefficients, while monitoring all of them simultaneously by means of General MO Ellipsometry. For the pure in-plane magnetization case, for instance, the α vs. β relation will lead to an ellipse equation, $\alpha^2/\alpha_0^2+\beta^2/\beta_0^2=1$, if R is correct. We have confirmed this behavior experimentally with a very high degree of precision. However, we also discovered deviations from it in cases where samples exhibit MO anisotropy. [1] Appl. Phys. Lett. 71, 965 (1997), [2] Phys. Rev. B 102, 140408(R) (2020)

MA 22.4 Wed 10:15 H47

XMCD investigation on Sm-Co magnetic thin films: strong orbital pinning on Co and the role of Sm — •Damian Günzing[1], Georgia Gkouzia[2], Ruiwen Xie[2], Teresa Wessels[1], Hongbin Zhang[2], Lambert Alff[2], Alpha T. N'Diaye[3], Heiko Wende[1], and Katharina Ollefs[1] — [1]Faculty of Physics, University of Duisburg-Essen — [2]Institute of Materials Science, Technical University of Darmstadt — [3]Advanced Light Source, Lawrence Berkeley National Lab Berkeley

We present the investigation of crystalline Sm-Co thin films manufactured via MBE on an Al_2O_3 substrate without additional buffer layers [1] by soft X-ray magnetic circular dichroism (XMCD). We use XMCD to investigate the element-specific spin and orbital moments of the individual elements, here Sm and Co. Often, with soft X-rays only the first few nm are probed via electron yield detection, leading to significant surface effects. In contrast, here, we use the luminescence of the substrate and are able to study the entire sample over the whole film thickness. We see a surprisingly strong orbital pinning on the Co sites in applied fields up to 2T. From element-specific hysteresis curves we find that the Sm atoms are coupled to Co, but with spectroscopic features saturating different in high fields. We compare the experimental results obtained by XMCD with multiplet calculations using Quanty, which suggest an exchange field present at the Sm site. (Financially supported by the DFG Project-ID 405553726*CRC 270). [1] S. Sharma et al., *ACS Appl. Mater. Interfaces* (2021) 13, 27, 32415-32423

MA 22.5 Wed 10:30 H47

Temperature independent coercivity by means of nanoscale materials design — •Mikel Quintana[1], Adrián Meléndez[1,2], Carmen Martín Valderrama[1], Lorenzo Fallarino[1], and Andreas Berger[1] — [1]CIC nanoGUNE BRTA, E-20018 Donostia-San Sebastián, Spain — [2]UPV/EHU, E-48940 Bizkaia, Spain

Thin film materials, in which the exchange coupling strength is designed to be depth-dependent, behave at each depth as if their properties were controlled by a "local" Curie temperature T_c^{loc}, down to the 1-2 nm length-scale [1]. This phenomenon enables the control and design of ferromagnetic (FM) magnetization profiles as a function of temperature T. For instance, it allows one to engineer films exhibiting FM exchange-coupling everywhere, but which can split into separate multilayers exhibiting seemingly isolated FM states in certain T-ranges. Here, we present a multilayer system composed by two CoRu films separated by a graded $Co_{1-x(z)}Ru_{x(z)}$ spacer layer with varying Ru concentration x along the depth z of the film. The spacer layer is such that an effective-PM-state thickness dividing two FM films decreases when reducing T. This specific materials design allows us to obtain a coercive field H_c plateau in an extended temperature range, in which H_c changes less than 2% between 150 K and 225 K, while conventional films exhibit a change of 20% in the same T-range. The stable coercivity plateau can be designed at any temperature by means of an adapted $T_c^{loc}(z)$ design, enabling T-independent operation points for technological applications. [1] L. Fallarino et. al., Materials **11**, 251 (2018).

MA 22.6 Wed 10:45 H47

Influence of adhesion layer and sputter gas pressure on structural and magnetic properties of Co/Pt multilayers — •Rico Ehrler[1], Tino Uhlig[1], and Olav Hellwig[1,2] — [1]Chemnitz University of Technology, D-09107 Chemnitz, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, D-01328 Dresden, Germany

Co/Pt multilayers (MLs) are standard systems for perpendicular anisotropy layered thin films. The use of a specific underlayer, sometimes in combination with additional, very thin adhesion layers, is a common practice to define a crystalline texture for the ML on amorphous substrates. In addition, the sputter gas pressure during deposition can be used to tune the lateral heterogeneity and laminate order, which strongly affect the magnetic behavior of the system. However, the precise interplay between adhesion and sputter gas pressure, especially for the seed layer, is often neglected.

In this context, we will discuss the impact of the underlayers on the structural and magnetic properties of the Co/Pt ML system. We will emphasize the influence of an adhesion layer on the whole system and combine this with a systematic and separate variation of the sputter deposition pressure of Pt seed and Co/Pt ML. Carefully tuning these parameters enables us to exert a high degree of control on the structure of these systems, with characteristics ranging from continuous thin films to isolated grain structures.

MA 22.7 Wed 11:00 H47

Evidence for perpendicular anisotropy gradients in Co thin films on Pt seeds — •Gauravkumar Patel[1], Sven Stienen[1], Ruslan Salikhov[1], Rodolfo Gallardo[2], Lorenzo Fallarino[1,3], Kilian Lenz[1], Jürgen Lindner[1], and Olav Hellwig[1,4] — [1]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden — [2]Universidad Tecnica Federico Santa Maria, Valparíso, Chile — [3]CIC energiGUNE BRTA, 01510 Vitoria-Gasteiz, Spain — [4]Chemnitz University of Technology, 09107 Chemnitz

Tailoring the magnetization dynamics and anisotropy in ferromagnetic thin films by different seed layers is of great fundamental and practical importance, e.g., different seed layer materials lead to different microstructure and magnetocrystalline anisotropy energy. We have used Ta and Pt as seed layers for thin Co films and studied their broadband ferromagnetic resonance (FMR) in out-of-plane saturation as a function of Co thickness and determined the respective perpendicular magnetic anisotropy. For Ta seeds, the magnetic anisotropy decreases and shows an inverse thickness dependence. In contrast for Pt seeds the magnetic anisotropy is no longer monotonous with thickness, but shows an initial thickness dependent decrease with a distinct minimum and subsequently a steady increase again. XRD measurements show that for Pt seeds, the Co develops a well-defined hcp texture with a thickness dependent strain relaxation. As a result of this structural evolution for Co on Pt seeds our FMR measurements reveal a strong anisotropy gradient in growth direction for this system.

MA 22.8 Wed 11:15 H47

Magnetization reversal of Co/Pt multilayer systems with weak perpendicular magnetic anisotropy — •Peter Heinig[1,2], Ruslan Salikhov[1], Fabian Samad[1,2], Lorenzo Fallarino[1,3], Attila Kakay[1], and Olav Hellwig[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Chemnitz University of Technology — [3]CIC energiGUNE

Perpendicular anisotropy thin film systems are well known for their highly periodic magnetic stripe domains. Here we study $[Co(3.0\ nm)/Pt(0.6\ nm)]_X$ multilayers in the regime of transitional in-plane to out-of-plane anisotropy. For this we vary the number of repeats X in order to tune the remanent state from purely in-plane (IP) via tilted stripe domains (tilted), i.e. with significant out-of plane as well as in-plane magnetization component, to fully out-of-plane stripe domains (OOP). Vibrating Sample Magnetometry and Magnetic Force Microscopy are used to investigate three characteristic samples with $X = 6, 11$ and 22, which represent the three above mentioned remanent states, respectively. In contrast to fully in-plane or fully out-of-plane systems experimental data and corresponding micromagnetic simulation of the tilted magnetization regime ($X = 11$) reveals fully reversible field regions as well as distinct points of irreversibility during an external field sweep. This collective reversal behavior seems at first sight somewhat counter intuitive for a macroscopic system and has qualitative similarities with microscopic systems, such as the Stoner Wohlfarth particle and the vortex reversal in an in-plane magnetized disk, which both show as well distinct points of irreversibility.

MA 22.9 Wed 11:30 H47

Magnetic anisotropy and magnetic ordering of transition-metal phosphorus trisulfides — •Tae Yun Kim[1,2] and Cheol-Hwan Park[1,2] — [1]Center for Correlated Electron Systems, Institute for Basic Science, Seoul, Korea — [2]Department of Physics and Astronomy, Seoul National University, Seoul, Korea

Transition-metal phosphorus trisulfides ($TMPS_3$'s) — a family of antiferromagnetic materials to which $FePS_3$, the first discovered two-dimensional magnetic material [1], belongs — have been regarded as an ideal testbed for studying the strong influence of low dimensionality on the existence of magnetic order. We developed anisotropic magnetic models for $TMPS_3$'s from first-principles calculations; the bulk magnetic properties, including the critical temperatures (T_N's), reported from previous experiments were explained very well [2]. Remarkably, it was predicted by applying our magnetic models to the few-layer cases that monolayer $NiPS_3$ exhibits a fairly high T_N, which is in contrast with the conclusion from a recent Raman study that the T_N is largely suppressed in monolayer $NiPS_3$ [3]. We discuss how the degeneracy in the magnetic ground state of monolayer $NiPS_3$ changes significantly its polarized Raman spectra, which provides a reconciliation between our theoretical predictions and the previous experimental results as to the existence of magnetic order in monolayer $NiPS_3$.

[1] J.-U. Lee et al., Nano Lett. 16, 7433 (2016)
[2] T. Y. Kim and C.-H. Park, Nano Lett. 21, 10114 (2021)
[3] K. Kim et al., Nat. Commun. 10, 345 (2019)