MA 28: Thin Films: Magnetic Anisotropy

Time: Wednesday 15:00–17:00 Location: EB 107

MA 28.1 Wed 15:00 EB 107

Surface Anisotropy in (110) Epitaxial Complex Oxide Thin Films — •Katharina Lasinger[1,2], Yixuan Song[1], Geoffrey S. D. Beach[1], and Caroline A. Ross[1] — [1]Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts, 02139, USA — [2]Department of Materials, ETH Zurich, CH-8093 Zurich, Switzerland

The demand for ever increasing density, and hence reduced dimensions, leads to a dominance of surface properties over their bulk counterparts in nano-scale magnetic devices. Spatial inversion symmetry is naturally broken at surfaces and interfaces. Surfaces on low symmetry planes, such as (110), can lead to a further in-plane anisotropic contribution. Using spin-Hall magnetoresistance measurements, we determine the in-plane and out-of-plane uniaxial anisotropy energies for a thickness series (5 - 50 nm) of europium iron garnet and thulium iron garnet epitaxially grown on a (110) gadolinium gallium substrate. We observe a large thickness dependence of the in-plane anisotropy energy, where the surface anisotropy energy is of the same sign and comparable in magnitude to the bulk value. Complex anisotropy landscapes can be tuned to act as a platform for enabling rich spin textures and dynamics [1,2] by taking advantage of the thickness and temperature dependence demonstrated in this work.

(Our Work: "Sizable In-Plane Surface Anisotropy in a (110) Epitaxial Complex Oxide Thin Film", about to be submitted.)

[1] O. R. Sulymenko, et al., Phys. Rev. Appl., 8(6), 064007, 2017.

[2] Y. Zhou, et al., Phys. Rev. Appl., 13(6), 064051, 2020.

MA 28.2 Wed 15:15 EB 107

Tuning perpendicular magnetic anisotropy via hydrogen concentration — Madeleine Bischoff[1], Olav Hellwig[2,3], Karin Leistner[1], and •Markus Gössler[1] — [1]Institute of Chemistry, Chemnitz University of Technology — [2]Institute of Physics, Chemnitz University of Technology — [3]HZDR Dresden-Rossendorf

A strong perpendicular anisotropy is crucial for modern magnetic data storage devices, providing two stable magnetization directions on a bit scale. Post deposition control of this anisotropy via voltage, promises a drastic improvement of the energy-efficiency for the writing process in such devices. Here, we investigate electrochemical hydrogen-loading in aqueous electrolytes as a voltage-controlled magneto-ionic method[1] for the modulation of anisotropy in perpendicularly magnetized Co/Pd multilayers. Using both in situ electrochemical Kerr microscopy and flow-cell coulometry, we can measure coercivity directly as a function of hydrogen concentration. We find a continuous increase of coercivity up to 20% at a concentration smaller than 0.3 hydrogen atoms per metal atom, which we attribute to hydrogen-induced changes in the anisotropy. Our findings agree with recent DFT predictions of hydrogen in Co/Pd[2]. We argue that the degree of intermixing between Co and Pd atoms during sputter deposition determines the maximum attainable hydrogen concentration in our films and therefore the maximum anisotropy change. Our work highlights the importance of the concentration in ionic devices, which has previously been neglected in the magneto-ionic literature. [1] M. Gößler et al., Small 15, 1904523 (2019) [2] K. Klyukin et al., Phys. Rev. Mater. 4, 104416 (2020)

MA 28.3 Wed 15:30 EB 107

Tailoring the Magnetoionic Effect in Magnetic Thin Films through Defect Engineering — •Arne Vereijken[1], Ben Billinger[2], Dimitri Sharikow[1], Markus Gössler[2], Christian Janzen[1], Karin Leistner[2], and Arno Ehresmann[1] — [1]Institute of Physics and CINSaT, University of Kassel, Germany — [2]Institute of Chemistry, University of Technology Chemnitz, Germany

The field of magnetoionics presents a promising approach for energy-efficient and reversible switching behavior in magnetic thin film systems, including but not limited to exchange bias samples and ferromagnetic thin films[1]. Harnessing the magnetoionic effect locally holds potential for structuring artificial domain landscapes, with applications including, among others, domain-wall logic[2,3] and magnet-based lab-on-a-chip technologies[2]. In a systematic study, various defect introduction strategies are explored to understand their influence on magnetoionic modification in magnetic thin film systems. The focus is on adjusting the growth parameters to control the distribution of grain sizes and, consequently, grain boundaries, anticipating enhanced effective, reactive surface area of a ferromagnetic thin film and increased magnetoionic effect. Similarily, we investigate how defects, induced by keV light ion bombardment, impact the magnetoionic effect. This dual microstructural approach aims to advance our understanding of mechanisms and parameters driving the magnetoionic effect.[1] J. Zehner et al., Adv. Electron. Mater. 5, (2019), 5, 1900296 [2] N. Leo et al., Nature 560, (2018), 466*470 [3] D. Holzinger et al., ACS Nano 9, (2015), 7, 7323*7331

MA 28.4 Wed 15:45 EB 107

Spin Wave Modes in YIG Thin Films with Perpendicular Magnetic Anisotropy — •Zeynep Reyhan Öztürk[1] and Fikret Yildiz[2] — [1]SESAME, Amman, Jordan — [2]Gebze Technical University, Kocaeli, Türkiye

This study investigates the importance of magnetic anisotropy in advancing magnetic memory and logic applications, particularly focusing on achieving perpendicular magnetic anisotropy (PMA) in thick ferrimagnetic films using Yttrium Iron Garnet (YIG).

YIG, known for its unique properties in spintronics and magnonics, was utilized to deposit textured crystalline thin films on Si (100) substrates through Pulsed Laser Deposition. Successful realization of PMA, especially in films around 100 nm thick, was attributed to compressive strain at the Si/YIG interface induced by lattice mismatch. The study's in-depth analysis revealed multiple spin wave modes, with the estimated exchange stiffness constant for YIG films. Noteworthy is the rare coexistence of spin wave modes with PMA in YIG thin films up to 120 nm.

These findings contribute significantly to advanced magnonics and insulating spintronics. Importantly, the study achieved PMA without additional layering or doping on silicon substrates, offering a cost-effective and compatible fabrication process. Ongoing experiments, such as XMCD measurements, aim to explore strain-induced anisotropy and the spatial distribution of spin-polarized electrons in YIG films for faster spin wave computing devices and advanced magnonic logic applications.

MA 28.5 Wed 16:00 EB 107

Influence of cap layer material and deposition pressure on the perpendicular magnetic anisotropy in Co/Pt and CoFeB/Pt multilayers — •Raphael Kohlstedt[1], Rico Ehrler[1], Peter Heinig[1,2], and Olav Hellwig[1,2] — [1]Chemnitz University of Technology, D-09107 Chemnitz, Germany — [2]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, D-01328 Dresden, Germany

Co/Pt magnetic multilayers (MLs) often serve as perpendicular magnetic anisotropy (PMA) model systems for magnetic data storage. Concerning dynamic applications CoFeB based MLs received much interest because of their smooth growth and because of the low intrinsic magnetic damping in magnetically soft CoFeB in-plane single layers, which opened up possibilities for new applications [1, 2]. Often PMA ML systems are protected from oxidation by a cap layer, which usually does not attract much attention. Nevertheless, if the CL makes up a significant part of the whole film thickness or is in direct contact with the magnetic material there are a few important things to consider when choosing the material and the deposition pressure. In this study, the influence of the CL on $[Co/Pt]_X$ and $[CoFeB/Pt]_X$ (X. . . repetition number) by varying the material and the deposition pressure is investigated. The effect of interdiffusion of the cap layer material in highly out-of-plane textured (Co/Pt) and polycrystalline towards amorphous (CoFeB/Pt) MLs is presented using XRD, XRR, and magnetometry.

[1] D. Wang et al. IEEE Trans. Magn., 40(4), 2004

[2] von Korff Schmising et al. Phys. rev. res., 5(1), 2023

MA 28.6 Wed 16:15 EB 107

Understanding the collective out-of-plane magnetization reversal in tilted stripe domain systems via a single point of irreversibility — •Peter Heinig[1,2], Ruslan Salikhov[1], Fabian Samad[1,2], Lorenzo Fallarino[1,3], Gauravkumar Patel[1], Attila Kákay[1], Nikolai S. Kiselev[4], and Olav Hellwig[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Chemnitz University of Technology — [3]CIC energiGUNE — [4]Forschungszentrum Jülich

Perpendicular anisotropy thin film systems are well known for their

periodic magnetic stripe domain structures. In this study, we focus on investigating the behavior of [Co(3.0 nm)/Pt(0.6 nm)]$_X$ multilayers within the transitional regime from preferred in-plane (IP) to out-of-plane (OOP) magnetization orientation, particularly, we examine the sample with $X = 11$ repetitions, which exhibits a remanent state characterized by a significant presence of both OOP and IP magnetization components, here referred to as the "tilted" stripe domain state*. Using vibrating sample magnetometry, magnetic force microscopy and micromagnetic simulations we investigate this specific sample and find an unusual OOP field reversal behavior via a remanent parallel stripe domain state and a single point of irreversibility. While the reversal via distinct points of irreversibility is qualitatively similar to that of a nano-sized Stoner Wohlfarth particle or a vortex reversal in a micron-sized IP magnetized disk, our system is macroscopic. Finally, we show that this characteristic behavior is a rather general feature of transitional IP to OOP systems.
*[L. Fallarino et al., Phys. Rev. B 99, 024431 (2019)]

MA 28.7 Wed 16:30 EB 107

Disclosing the hidden properties of thin cobalt films with mixed hcp and fcc phases — •G. Patel[1,2], F. Ganss[1], R. Salikhov[1], S. Stienen[1], L. Fallarino[3], R. Ehrler[4], R. Gallardo[5], O. Hellwig[1,4], K. Lenz[1], and J. Lindner[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]Dresden University of Technology, Germany — [3]CIC energiGUNE, Spain — [4]Chemnitz University of Technology, Germany — [5]Universidad Tecnica Federico Santa Maria, Chile

Cobalt is a magnetic material that finds extensive use in various applications, ranging from magnetic storage to ultrafast spintronics. Usually, it exists in two phases with hexagonal close-packed (hcp) or face-centered cubic (fcc) crystal structure. The crystal structure of Co films significantly influences their magnetic and spintronic properties. The ratio of the two Co phases has a significant influence on their magnetic properties, indicating that a seemingly simple material can be rather complex in real samples. We report on the thickness dependence of the structural and magnetic properties of sputter-deposited Co on a Pt seed layer. It grows in an hcp lattice at low thicknesses, while for thicker films, it becomes a mixed hcp-fcc phase due to a stacking fault progression. The reciprocal space map technique confirms the presence of both phases. Moreover, the precise determination of the Landé g-factor provides valuable insights into the structural properties. This careful study reveals the fundamental physics, but also provides important insight for potential applications of thin Co films with perpendicular magnetic anisotropy.

MA 28.8 Wed 16:45 EB 107

Thickness-dependent magneto-ionic effects in Fe thin films — •Ben Billinger[1], Arne Vereijken[2], Arno Ehresmann[2], Karin Leistner[1,3], and Markus Gössler[1] — [1]Institute of Chemistry, Chemnitz University of Technology — [2]Institute of Physics and CINSaT, University of Kassel — [3]Leibniz IFW Dresden

Magneto-ionics promises the reconfiguration of magnetic materials in a reversible and non-volatile manner.[1] Magnetic thin films, owing to their large surface-to-volume ratio, are particularly promising. In this study, we investigate the influence of film thickness on the magneto-ionic effect caused by the oxidation/reduction of sputtered iron thin films in aqueous electrolytes. Our iron films (10-100 nm) are covered by a native magnetite layer, which can be electrochemically reduced to ferromagnetic iron and re-oxidized reversibly, providing the basis for our magneto-ionic response.[2] We measure smaller coercivities in the reduced state, compared to the oxidized and pristine states, utilizing our in situ electrochemical Kerr microscopy setup.[2] The magnitude of the magneto-ionic effect, measured by relative changes in coercivity, can be enhanced to over 50% at small film thicknesses. For the smallest Fe thicknesses, the initial four-fold in-plane anisotropy of Fe levels out after magneto-ionic cycling, revealing a significantly increased coercivity compared to the pristine samples. We discuss our findings in terms of an increased surface roughness during reoxidation and highlight the importance of surface structure for future magneto-ionic devices. [1] M. Nichterwitz et al., APL Mater. 9, 030903 (2021), [2] J. Zehner et al., Adv. Electron. Mater. 6, 2000406 (2020)