MA 39: Magnetic Thin Films

Time: Thursday 15:00–17:00 Location: H19

Invited Talk MA 39.1 Thu 15:00 H19

Voltage control of magnetism using hydrogen — •Markus Gössler — Chemnitz University of Technology, Chemnitz, Germany

Voltage-controlled magnetic properties have entered the research spotlight as they hold great potential for future spintronic and magnetic memory devices. The use of electrochemistry in voltage-controlled magnetism, dubbed magneto-ionics,[1] promises a superior energy efficiency compared to many conventional mechanisms. Here, we present a versatile magneto-ionic concept based on the hydrogen-loading into [Co/Pd]-based bilayers and multilayer structures with perpendicular anisotropy. We show that the magnetic properties of [Co/Pd] multilayers sensitively depend on the absolute hydrogen concentration in the material and that this concentration can be set electrochemically via the applied voltage.[2] Reversibility and switching speed, as the two main limitations towards practical magneto-ionic devices, can be improved by a targeted multilayer engineering, exploiting synergies with hydrogen electrocatalysis. Funding from DFG-499361641 and ERC-101125178 is acknowledged. [1] Nichterwitz et al. APL Mater. (2021) 030903; [2] Bischoff et al., Adv. Funct. Mater. (2024) 2405323

MA 39.2 Thu 15:30 H19

Magneto-ionic control of coercivity in electrodeposited Ni_xFe_{1-x} films — •Anna Ullrich[1], Florin L. Hambeck[1], Francesca Sgarbi Stabbellini[1,2], and Karin Leistner[1,2] — [1]Institute of Chemistry, TU Chemnitz — [2]Leibniz IFW Dresden

Magneto-ionic effects provide a promising route for low-voltage, nonvolatile control of magnetic materials, essential for next-generation, energy-efficient devices. Prior research has mainly focused on iron- or cobalt-based thin films and nanostructures.[1] So far only few works mention magneto-ionic effects for Ni-based alloys,[2,3] which are promising due to their unique magnetic properties. This study systematically investigates the magneto-ionic behavior of electrodeposited Ni_xFe_{1-x} films with thicknesses of (160 ± 30) nm as a material platform to enhance magneto-ionic functionality. Coercivities range from (0.4 ± 0.3) mT in $Ni_{80}Fe_{20}$ (permalloy) to (44.6 ± 0.6) mT in pure Fe, as measured by magneto-optical Kerr effect magnetometry. Magneto-ionic control upon electrolytic gating in 1 M KOH reveals a reduction of coercivity of up to 50 % (e.g., in $Ni_{70}Fe_{30}$) at -1.18 V versus Ag/AgCl. We discuss this modification in the context of a surface oxide reduction reaction, which can modify the domain wall pinning.[4] The observed effects highlight the potential of magneto-ionic Ni-Fe alloys, especially in thicker films, for sensing and actuation applications. [1] M. Nichterwitz et al., APL Mat. 2021, 9, 030903. [2] D. Murray et al., ACS Appl. Mater. Interf. 2021, 13, 38916. [3] De h-Ora et al., Zenodo 2021, doi:10.5281/zenodo.5769775. [4] J. Zehner et al., Adv. Electron. Mater. 2020, 6, 2000406.

MA 39.3 Thu 15:45 H19

Structural, magnetic and electrical properties of oxygen-deficient $La_{0.6}Sr_{0.4}CoO_{3-\delta}$ thin films — Suqin He[1,2,3], •Oleg Petracic[1], Valeria Lauter[4], Lei Cao[1,5], Yunxia Zhou[5], Moritz Weber[2,3], Jürgen Schubert[6], Omar Concepción[6], Regina Dittmann[2,3], Rainer Waser[2,3], Thomas Brückel[1,3], and Felix Gunkel[2,3] — [1]JCNS-2, Forschungszentrum Juelich GmbH, 52425 Juelich, Germany — [2]PGI-7, Forschungszentrum Juelich GmbH, 52425 Juelich, Germany — [3]JARA-FIT, RWTH Aachen University, 52056 Aachen, Germany — [4]Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA — [5]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany — [6]PGI-9, Forschungszentrum Juelich GmbH, 52425 Juelich, Germany

In $La_{0.6}Sr_{0.4}CoO_{3-\delta}$ (LSCO) the gradual oxygen release triggers a phase transition from the initial ferromagnetic perovskite to an oxygen vacancy layered antiferromagnetic brownmillerite structure. We have studied LSCO thin films fabricated by pulsed laser deposition. In situ x-ray diffraction and polarized neutron diffraction reveals the topotactic phase transition of the LSCO thin films, which can be attributed to the release of oxygen and ultimately the transition to a coherently ordered BM phase. By comparing the magnetic and electronic properties of the sample at different oxygen deficient states, we demonstrate that the magnetic and electronic transitions are apart from the structural phase transition. S. He, O. Petracic, V. Lauter, L. Cao, Y. Zhou, M. L. Weber, J. Schubert, O. Concepción, R. Dittmann, R. Waser, T. Brückel, F. Gunkel, Adv. Funct. Mater. 2024, 34, 2313208.

MA 39.4 Thu 16:00 H19

Double Exchange Bias (EB) Effects in IrMn/CoFe/IrMn Systems — •Arne Vereijken, Varun Vanakalapu, Rico Huhnstock, and Arno Ehresmann — Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Kassel, Germany

The EB effect, characterized as an unidirectional anisotropy in a ferromagnet (FM) coupled to an antiferromagnet (AFM) through a shared interface[1], is utilized in Lab-on-Chip (LOC) systems[2], among other technologies. In LOC systems, it is combined with ion bombardment induced magnetic patterning (IBMP) to engineer magnetic stray field landscapes (MFLs)[2]. This work demonstrates that adding a second EB interface to the same FM adds a degree of freedom for tailoring MFLs, achieving stronger and steeper stray field gradients beneficial for LOC applications. Whether the two EBs are independent of each other, particularly when aligned parallel or at an angle, poses an intriguing question. Investigations using vibrating sample magnetometry and magneto-optical Kerr effect measurements and comparisons with advanced EB models tailored for polycrystalline systems and the specific measurement conditions[3], reveal that the EB strength in the employed Ir17Mn83/Co70Fe30/Ir17Mn83 systems slightly exceeds twice that of single EB systems. This is attributed to additive, mostly independent EBs, making the second EB a great candidate for refining MFL engineering. [1] Meiklejohn, W. H. et al. (1956). Phys. Rev. 102, 1413 [2] Holzinger, D. et al. (2015). ACS Nano 9 (7), 7323-7331 [3] Merkel, M. et al. (2022). Phys. Rev. B 106, 014403

MA 39.5 Thu 16:15 H19

Layer-resolved Vector Magnetometry using Generalized Magneto-optical Ellipsometry — •Carmen Martín Valderrama, Irene Prieto, Mikel Quintana, and Andreas Berger — CIC nanoGUNE BRTA, E-20018 Donostia-San Sebastián, Spain

For a detailed and quantitatively precise understanding of magnetic multilayers it is crucially important to determine their spatial magnetization configurations, particularly along the depth of their structures. Here, we demonstrate that it is possible to achieve layer-resolved vector magnetometry in nanoscale magnetic multilayer films by means of a single magneto-optical reflection experiment. We designed, fabricated, and measured a set of epitaxial ferromagnetic/nonmagnetic/ferromagnetic multilayer samples that exhibit in-plane uniaxial anisotropy and a tunable ferromagnetic interlayer coupling strength through the non-magnetic interlayer. By means of Generalized Magneto-optical Ellipsometry measurements, we obtain the entire optical reflection matrix R of a given sample for each applied field value, which allows us to monitor the field evolution of the magnetization vector for the two ferromagnetic layers independently. Hereby, we observe that the magnetization switching of one layer can trigger a discontinuous change of the magnetization in the second layer even for weak ferromagnetic interlayer coupling. Moreover, we reproduce the obtained behavior using a model of two coupled macrospins, which corroborates even the unexpected aspects of our experimental results and thus reinforces the sensitivity and reliability of our experimental layer-resolved vector magnetometry.

MA 39.6 Thu 16:30 H19

Ferrimagnetic moment arrangement in the Ti-doped Barium hexaferrite revealed by EMCD — •Hitoshi Makino[1], Devendra Singh Negi[2], Ján Rusz[3], Bernd Rellinghaus[1], and Darius Pohl[1] — [1]DCN, TUD Dresden University of Technology — [2]Indian Institute of Technology Jodhpur — [3]Uppsala University

Barium hexaferrite is a well-known ferrimagnetic complex oxide with good durability at high temperatures and in erosive environments. Previous research has indicated that Titanium substitutions can enhance the coercivity at elevated temperatures. Our efforts aim at elucidating the underlying mechanism through measurements of electron energy loss magnetic chiral dichroism (EMCD) in the transmission electron microscope (TEM). We conducted EMCD experiments on three samples with different Titanium concentration ($BaFe_{12-x}Ti_xO_{19}$, x=0, 0.6, 1.0). We have deconvoluted the Fe L-edges as obtained from classical EMCD measurements into different oxidation states of iron

($Fe^{3+} \rightarrow Fe^{2+}$ generated by Titanium-substitution) to observe the changing of magnetic moment arrangement. High resolution EELS mapping revealed, that Ti^{4+} ion substitute mainly for the $4f_2$ site, an atomic site with parallel magnetic Fe moment. The EMCD signal of the Ti-rich sample ($BaFe_{12-x}Ti_xO_{19}$, x=1.0) indicate an antiparallel Fe^{2+} magnetic moment arrangement. This discrepancy will be discussed by using inelastic scattering simulations as well as DFT calculations. A detailed analysis of the underlying measurement errors and the involved limitations of the method will be presented.

MA 39.7 Thu 16:45 H19

Imaging Local Magnetic Moments with Atomic-Scale Electron Vortex Beams via EMCD in $BaFe_{11}TiO_{19}$ — •Darius Pohl[1], Hitoshi Makino[1], Bernd Rellinghaus[1], Rolf Erni[3], Devendra Singh Negi[5], Arthur Ernst[4], and Ján Rusz[2] — [1]DCN, TUD Dresden University of Technology, Dresden, Germany — [2]Uppsala University, Uppsala, Sweden — [3]Empa, Dübendorf, Switzerland — [4]JKU, Lenz, Austria — [5]Indian Institute of Technology Jodhpur

Electron magnetic circular dichroism (EMCD), the electron wave counterpart of X-ray magnetic circular dichroism (XMCD), enables element-specific measurement of spin and orbital magnetic moments with nanometer-scale resolution in transmission electron microscopy. Electron vortex beams (EVBs), recently discovered to carry quantized orbital angular momentum (OAM), are emerging as a promising tool for EMCD measurements, facilitating the analysis of magnetic properties in materials. Since EVBs can be tightly focused to sub-nanometer scales, this approach offers unprecedented potential for quantifying spin and orbital magnetic moments with exceptional spatial resolution. We employ specially designed condenser apertures to produce isolated, atomic-scale EVBs with user-defined OAM. As a proof-of-concept, we demonstrate vortex EMCD measurements on ferrimagnetic barium hexaferrite samples. For the first time, EVB-EMCD achieves the resolution necessary to resolve local ferrimagnetic order. The experimental findings are further corroborated by inelastic scattering simulations and density functional theory (DFT) calculations.