MA 15: Magnetic Thin Films II

Time: Tuesday 9:30–12:00 Location: H33

MA 15.1 Tue 9:30 H33

Compositional tuning of boundary magnetization properties in epitaxial $Cr_{2-x}Al_xO_3$ (0001) films — •Lorenzo Fallarino[1], Christian Binek[2], and Andreas Berger[1] — [1]CIC nanoGUNE, Donostia - San Sebastian, Spain — [2]University of Nebraska, Lincoln, Nebraska, USA

The magnetoelectric antiferromagnet Cr_2O_3 (Chromia) is known to exhibit an equilibrium net magnetization at its (0001) surface [1]. This boundary magnetization (BM) can be exploited to switch the associated bulk antiferromagnetic order parameter solely by magnetic means in (0001) oriented thin Chromia films [2,3]. In order to investigate whether these BM properties can be extended to alloys containing different oxide materials, we investigated the effect of Al_2O_3 doping onto the structural and magnetic properties of Cr_2O_3. We fabricated a sample series of 100 nm thick epitaxial $Cr_{2-x}Al_xO_3$ (0001) films in the concentration range x = 0 - 0.6. Using SQUID magnetometry, we demonstrated that the critical temperature T_N of such alloy films can be tuned by using the BM as a probe to study the magnetic transition. Moreover, we evaluated the critical exponent and the absolute BM values for all the samples, which both corroborate the BM nature of the observed magnetic signals [4].

[1] K. D. Belashchenko, Phys. Rev. Lett. **105**, 147204 (2010);
[2] L. Fallarino et al., Appl. Phys. Lett. **104**, 022403 (2014);
[3] L. Fallarino et al., Phys. Rev. B **91**, 054414 (2015);
[4] L. Fallarino et al., Phys. Rev. B **91**, 214403 (2015);

MA 15.2 Tue 9:45 H33

The influence of low-energy proton irradiation on the magnetic properties of undoped TiO_2 anatase thin films — •Markus Stiller[1], José Barzola-Quiquia[1], Pablo Esquinazi[1], Daniel Spemann[2], Jan Meijer[2], Michael Lorenz[3], and Marius Grundmann[3] — [1]Abteilung für Supraleitung und Magnetismus, Fakultät für Physik und Geowissenschaften, Universität Leipzig, Linnestr. 5, D-04103, Germany — [2]Abteilung Nukleare Festkörperphysik, Fakultät für Physik und Geowissenschaften, Universität Leipzig, Linnestr. 5, D-04103, Germany — [3]Abteilung Halbleiterphysik, Fakultät für Physik und Geowissenschaften, Universität Leipzig, Linnestr. 5, D-04103, Germany

The temperature and field dependence of the magnetization of epitaxial, undoped TiO_2 anatase thin films on sapphire substrates was investigated. Field hysteresis as well as zero-field cooled and field cooled curves were measured for the as-prepared thin films as well as after irradiation of low-energy protons. The anatase thin films exhibit ferromagnetism after proton irradiation, which strength does not increase linearly with the amount of irradiated protons. A clear magnetic anisotropy, opposite to the expected one, was observed after the first irradiation. The presence of impurities (with ppm resolution) was investigated by means of particle-induced X-ray emission. The experimental results indicate that Ti vacancies are the origin for the observed magnetic order.

MA 15.3 Tue 10:00 H33

Magnetic properties of YCo_5 epitaxial thin films. — •Shalini Sharma, Erwin Hildebrandt, and Lambert Alff — Institute of Materials Science, Technische Universität Darmstadt, Germany

Rare earth-cobalt (R-Co) intermetallic compounds are of high interest for application as high-temperature permanent magnets. YCo_5 is predicted to exhibit high anisotropy at and above room temperature with a large magnetocrystalline anisotropy constant, K_1, of about 10^7 erg/cm^3. In this work, molecular beam epitaxy was used to synthesize epitaxial thin films of YCo_5 on (0001)-oriented Al_2O_3 substrates. X-ray diffraction revealed the growth window for phase pure YCo_5 thin films. The magnetic properties of the films were investigated using a SQUID magnetometer. In phase pure thin films, the (so far) highest coercivity was measured to be 3 kOe, and the highest saturation magnetization was 472 emu/cc at 300 K. It is well known, that these values depend strongly on the exact stoichiometry of the sample. We expect that further optimization will come closer to the values reported for single crystals.

MA 15.4 Tue 10:15 H33

Ferromagnetic resonance study of equiatomic FeRh thin films — •Anna Semisalova[1,2], Sven Stienen[1], Craig W. Barton[3], Roman Boettger[1], Rantej Bali[1], Thomas Thomson[3], Michael Farle[4], Jürgen Fassbender[1], Kay Potzger[1], and Jürgen Lindner[1] — [1]HZDR, Institute of Ion Beam Physics and Materials Research, Dresden, Germany — [2]Lomonosov MSU, Faculty of Physics, Moscow, Russia — [3]University of Manchester, School of Computer Science, Manchester, UK — [4]University of Duisburg-Essen, Faculty of Physics and Center for Nanointegration, Duisburg, Germany

Chemically ordered FeRh alloy with nearly equiatomic composition is antiferromagnetic at room temperature and exhibits a first-order phase transition to the ferromagnetic (FM) state at 370 K. Here, we present the study of FM resonance (FMR) in non-capped and Pt-capped magnetron sputtered 40 nm FeRh films on a MgO(100) substrate and analyse the influence of ion irradiation and chemical disordering on their magnetic properties. The temperature dependent FMR study between 200-500 K allowed us to observe the hysteretic temperature behavior, accompanied by a clear transformation of the FMR line, and explore the complex magnetic structure of films. We distinguished and characterized the contribution of anomalous FM interfacial layers induced by atomic intermixing and lattice strain. Finally, we have revealed the formation of a magnetic phase with an out-of-plane easy axis of magnetization caused by low-fluence irradiation with Ne^+ ions.

MA 15.5 Tue 10:30 H33

Exchange driven spin spiral in Rh/Fe/Ir(111) — •Niklas Romming[1], Markus Hoffmann[2,3], Bertrand Dupé[2], André Kubetzka[1], Kirsten von Bergmann[1], Stefan Heinze[2], and Roland Wiesendanger[1] — [1]Department of Physics, University of Hamburg, 20355 Hamburg, Germany — [2]Institute of Theoretical Physics and Astrophysics, University of Kiel, 24098 Kiel, Germany — [3]PGI-1/IAS-1, FZ Jülich and JARA, D-52424 Jülich, Germany

Magnetism in ultra-thin films can substantially differ from commonly known magnetic configurations e.g. due to hybridization at the interface, stacking faults, and broken inversion symmetry [1]. Spin spiral and skyrmion states were found in mono- and double layers of 3*d* on 5*d* transition-metal surfaces due to the competition between various magnetic interactions [1]. It was recently shown that the magnetic interactions of Fe/Ir(111) can be altered with a non-magnetic adlayer of Pd, changing its magnetic state from a nanoskyrmion lattice with 1 nm period to a spin spiral with 6-7 nm period [2].

Here, we combine spin-polarised STM with first-principles calculations to investigate the influence of a Rh adlayer on Fe/Ir(111). We show that the magnetic ground state of Rh/Fe/Ir(111) is a spin spiral with a period of 1-2 nm, which is driven by the exchange interaction. Its propagation direction depends on the Rh stacking and can deviate from the high-symmetry directions.

[1] K. von Bergmann *et al.*, JPCM **26**, 394002 (2014)
[2] N. Romming *et al.*, Science **341**, 636 (2013); B. Dupé *et al.*, Nature Commun. **5**, 4030 (2014)

15 min. break

MA 15.6 Tue 11:00 H33

Electric field switching of individual magnetic skyrmions — •Pin-Jui Hsu, Andre' Kubetzka, Aurore Finco, Niklas Romming, Kirsten von Bergmann, and Roland Wiesendanger — Department of Physics, University of Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany

Using electric fields offers an energy-efficient route toward tailoring the magnetic properties of materials. In particular, the capability of switching magnetic states by employing electric fields provides a great potential to future magnetic information technology. In the present work, we report on the electric field switching of individual skyrmionic objects. A spin spiral ground state with a periodicity of about 3.8 nm has been identified for Fe triple-layers (Fe-TL) grown on Ir(111) by using spin-polarized scanning tunneling microscopy (SP-STM). Field dependent SP-STM measurements reveal a magnetic phase transition from a spin spiral to a skyrmionic state and then to a saturated ferromagnetic state. According to SP-STM measurements with in-plane spin sensitivity on three different rotational domains, the skyrmionic objects exhibit a unique rotational sense suggesting a sizable Dzyaloshinskii-Moriya (DM) interaction from the Fe-Ir interface as the driving force for their stability. Local writing and deleting of single magnetic skyrmions, i.e., switching between skyrmionic and ferromagnetic states of Fe-TL, have been demonstrated with a pronounced bias-polarity dependence. Based on the observed linear dependence of the threshold voltage Ut on the tip-sample distance, the electric field has been found to play the decisive role for the switching mechanism.

MA 15.7 Tue 11:15 H33

Ion-beam-induced magnetic and structural phase transformation of fcc Fe thin films on different substrates — •Jonas Gloss[1], Michal Horký[2,3], Michael Schmid[1], Michal Urbánek[2,3], and Peter Varga[1,3] — [1]Institute of Applied Physics, Vienna University of Technology, 1040 Vienna, Austria — [2]Institute of Physical Engineering, Brno University of Technology, 616 69 Brno, Czech Republic — [3]CEITEC BUT, Brno University of Technology, 616 00 Brno, Czech Republic

Ultrathin fcc Fe films on Cu(100) have been studied extensively in the past for their unique capability of magnetic (non-magnetic to ferromagnetic) and structural (fcc to bcc) transformation upon ion beam irradiation [1,2]. Replacing Fe by $Fe_{78}Ni_{22}$ allows for growing metastable films up to 25 nm [3]. To facilitate applications, in the current work we use Si(100) and $SrTiO_3$(100) substrates with a Cu buffer layer. Cu on both substrates grows epitaxially, although not layer-by-layer. On these substrates the as-grown 8-nm $Fe_{78}Ni_{22}$ films are non-magnetic and transformable. We also present magnetic nanostructures in these films written by a focused ion beam.

[1] W. Rupp, et al., Appl. Phys. Lett. **93**, 063102 (2008).
[2] S. Shah Zaman, et al. J. Appl. Phys. **110**, 024309 (2011).
[3] J. Gloss, et al., Appl. Phys. Lett. **103**, 262405 (2013).

MA 15.8 Tue 11:30 H33

Competition between complex magnetic states of Fe/Re(0001) — •Alexandra Palacio Morales, Kirsten von Bergmann, André Kubetzka, and Roland Wiesendanger — Department of Physics, University of Hamburg, D-20355 Hamburg, Germany

Scanning tunneling microscopy on Fe/Re(0001) recently revealed the growth of an epitaxial Fe monolayer (ML) [1] as well as the Fe ML spin texture [2]. A transition from pseudomorphic to reconstructed areas was found with increasing coverage. In the pseudomorphic regions, a frustrated antiferromagnetic triangular spin structure, called Néel state, was observed.

Here, we focus on the reconstructed areas of Fe on Re(0001). We found isolated and dense packed reconstruction lines together with a spin spiral having a period of 4 atomic lattice constants along the reconstruction lines. Moreover, the Néel state is observed in the vicinity of the spin spiral.

[1] S. Ouazi, et al., Surf. Sci. **630**, 280 (2014).
[2] S. Ouazi, et al., Phys. Rev. Lett. **112**, 076102 (2014).

MA 15.9 Tue 11:45 H33

Dzyaloshinskii-Moriya interaction and magnetic texture in thin Fe films deposited on transition-metal dichalcogenides — •Daniel Schröder[1], Svitlana Polesya[1], Sergiy Mankovsky[1], Hubert Ebert[1], and Wolfgang Bensch[2] — [1]Dept. Chemie, Universität München, D-81377 München, Germany — [2]Institute of Inorganic Chemistry, Christian-Albrechts-Universität zu Kiel, Kiel, Germany

The magnetic properties of Fe monolayers deposited on top of different types of transition-metal dichalcogenides (TMDC) have been investigated by means of first-principles DFT calculations. Changing the structure and the composition of the substrate results in a considerable variation of magnetic properties of the Fe overlayer, in particular - of the magnetocrystalline anisotropy and interatomic exchange interactions. The calculated Dzyaloshinskii-Moriya(DM) interaction parameters have been used for a subsequent investigation of the magnetic structure of Fe overlayers using Monte Carlo simulations. Rather strong DM interactions have been obtained for some of the systems under investigation, which can lead to the formation of skyrmionic structures varying with the strength of an applied external magnetic field.