MA 4: Micro- and Nanostructured Materials

Time: Monday 9:30–12:00 Location: H 1012

Invited Talk MA 4.1 Mon 9:30 H 1012

Fabrication of individual nano-magnets and nano-magnet arrays by Focused Electron Beam Induced Deposition (FEBID) — •Andreas Berger — CIC nanoGUNE Consolider, Tolosa Hiribidea 76, Donostia - San Sebastian, Spain

During the past decade, FEBID has been established as a one-step technique for the fabrication of 1-, 2- and even 3-dimensional nanostructures. Specifically, there has been a growing interest in the development of FEBID processes for magnetic materials in the last few years, namely for Fe, Co and Ni, which may provide new routes for the fabrication of magnetic nano-devices as well as complex nano-magnet designs. Among these ferromagnetic metals, Co attracts the most attention because an exceptionally high purity can be obtained under the correct deposition conditions [1]. Here, we present a systematic investigation of the deposition parameters and the characterization of the structure and physical properties of our FEBID cobalt deposits, including the effect of unintended parasitic deposits as well as strategies for their removal [2]. The magnetic properties of our deposits were characterized by magneto-optical microscopy. Specifically, we investigated individual nano-scale wires down to diameter sizes of 30 nm [3], magnetic dot-arrays with periods as low as 13 nm, as well as the fabrication of non-trivial 3-dimensional magnetic nano-structures via FEBID.

References: [1] O. Idigoras et al., Nanofabrication 1, 23 (2014); [2] E. Nikulina et al., Appl. Phys. Lett. 103, 123112 (2013); [3] E. Nikulina et al., Appl. Phys. Lett. 100, 142401 (2012)

MA 4.2 Mon 10:00 H 1012

Magnetization reversal in fourfold ferromagnetic nanostructures of different dimensions — •Andrea Ehrmann[1], Tomasz Blachowicz[2], Sara Komraus[2], Marie-Kristin Nees[3], Peter-Jürgen Jakobs[3], Harald Leiste[3], Michael Mathes[4], and Marie Scharschmidt[4] — [1]Niederrhein University of Applied Sciences, Faculty of Textile and Clothing Technology, Germany — [2]Silesian University of Technology, Institute of Physics, Poland — [3]Karlsruhe Nano Micro Facility (KNMF), Karlsruhe Institute of Technology (KIT), Germany — [4]ACCESS e. V., Aachen, Germany

Ferromagnetic nanostructures with lateral dimensions between 160 nm and 400 nm have been created in a lithographic process. The fourfold particles produced from permalloy have rectangular-shaped walls around a square open area. Their magnetic properties have been measured angle-dependent using the Magneto-Optical Kerr Effect (MOKE). The oral presentation reports on the angle-dependence and the influence of the lithography radiation dose on magnetization reversal mechanisms. While the nanostructure size changes the angle-dependence of the coercivities quantitatively and qualitatively, the magnetic properties are quite stable against variations of the radiation dose, i.e. the wall width, enabling reliable creation of nanostructures with the desired properties [1].

[1] A. Ehrmann, T. Blachowicz, S. Komraus, M.-K. Nees, P.-J. Jakobs, H. Leiste, M. Mathes, M. Schaarschmidt: Directional-dependent MOKE measurements on fourfold ferromagnetic nanostructures of different dimensions, submitted

MA 4.3 Mon 10:15 H 1012

The role of vortex-antivortex pairs and cluster knots of domain walls in magnetization reversal — •Sukhvinder Singh, Haibin Gao, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, P O. Box 151150, D66041, Saarbrücken, Germany

Magnetic force microscopy was employed to investigate the role of domain wall substructures in the magnetization reversal in patterned Permalloy thin films in an in-plane magnetic field. This study reveals that the magnetic reversal mechanism proceeds through periodic subdivisions of domain walls connected between cluster knots. The magnetic flux transfer across domain walls was observed to be assisted by nucleation and annihilation of vortex-antivortex pairs in the domain wall. The nucleation of vortex-antivortex pairs creates channels to transfer the magnetic flux across the domain wall. The change in the magnetic energy landscape along the long and short axes was linked to the different evolutions of the domain wall clusters at the edges of the samples. Furthermore, the experimental findings were interpreted and evaluated by comparing and analyzing the results obtained by micromagnetic simulations. By considering the magnetic energies over the whole sweep range of the applied field, it was observed that demagnetization and exchange energies dominate the Zeeman energy only near remnant state. This restricts the transformations of the domain wall substructures to the near zero field range.

MA 4.4 Mon 10:30 H 1012

Magnetic hardening of FeCo nanowires — Sara Liébana-Viñas[1], •Ruslan Salikhov[1], Cristina Bran[2], Marina Spasova[1], Ulf Wiedwald[1], Manuel Vazquez[2], and Michael Farle[1] — [1]University Duisburg-Essen, Duisburg and CENIDE, Germany — [2]Institute of Material Science of Madrid (CSIC), Madrid, Spain

We report on the magnetic hardening of FeCo nanowires (NW) by forming few nm thick oxides at both NW tips. FeCo NWs with 20 and 40 nm diameter were synthesized in porous alumina templates. We found that the formation of a 3 nm thick FeCo oxide layer at the NW tips results in an increase of the coercive field by 20% at T = 10 K. Our finding experimentally confirms that magnetic NWs even with large aspect ratios (up to 300) are demagnetized via nucleation of domain walls (DWs) at the NW tips. The magnetic hardening suggests the possibility to improve the performance of FeCo NWs for applications in magnetic field sensors, recording heads and rare-earth free permanent magnets. The importance of DW pinning at both ends of magnetic NWs will be discussed. We acknowledge funding of EU through FP7-REFREEPERMAG.

MA 4.5 Mon 10:45 H 1012

Surface crystallization and magnetic properties of FeCuSiBP soft magnetic ribbons — •Elena Lopatina[1,2], Ivan Soldatov[1,2], Christian Becker[1,2], Viktoria Budinsky[3], Mie Marsilius[3], Ludwig Schultz[1,2], Giselher Herzer[3], and Rudolf Schaefer[1,2] — [1]IFW Dresden, Dresden, Germany — [2]Institute for Materials Science, TU Dresden, Dresden, Germany — [3]VACUUMSCHMELZE GmbH & Co. KG, Hanau, Germany

Surface crystallization in soft magnetic alloys has been the subject of many studies that were mainly performed by Mossbauer spectroscopy, atomic force microscopy, transmission- and scanning electron microscopy. However, there are only few studies of surface crystallization by means of magneto-optical Kerr microscopy, which allows a direct visualization of the changes in magnetic microstructure that arise from surface crystallization. In this work we report on the influence of surface crystallization on the magnetic properties and magnetic microstructures of FeCuSiBP ribbons by Kerr imaging. The as cast ribbon has been annealed at temperatures in the interval of 370-550 °C, by pulling the ribbon through a furnace, thus applying some tensile stress along the ribbon axis that causes a creep-induced transverse anisotropy into the ribbon. Furthermore, since the vast majority of applications of soft magnetic materials operate under AC conditions, we show by time-resolved Kerr microscopy how the surface domain structure react to ac magnetic fields up to the kHz regime and how the dynamic surface hysteresis loops compare to the inductively measured bulk loops with rising frequency, both on original and etched ribbons.

MA 4.6 Mon 11:00 H 1012

Magnetic nanostructure patterns via hierarchical self-assembly: An in-situ study combining GISAXS and NRS — •Denise Erb, Kai Schlage, Hans-Christian Wille, and Ralf Röhlsberger — Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, D-22607 Hamburg, Germany

Nanopatterning via self-assembly has gained considerable interest as an alternative to lithography-based techniques for nanostructure fabrication. We propose a routine for preparing highly ordered metallic nanostructure arrays based exclusively on self-assembly processes: crystal surface reconstruction, copolymer microphase separation, metal diffusion on heterogeneous surfaces. The versatile routine allows fabricating nanostructures in a variety of shapes and sizes. We present results of in-situ structural and magnetic investigations of Fe nanodot arrays during formation by Grazing Incidence Small Angle X-ray Scattering (GISAXS)[1] and Nuclear Resonant Scattering of synchrotron radiation (NRS) [2], examining the dependence of nanodot morphology on deposition conditions and the evolution of magnetic moment dynamics during nanodot growth [3].

[1] G. Renaud, R. Lazzari, and F. Leroy, Surface Science Reports 64 (2009) 255

[2] R. Röhlsberger, Nuclear Condensed Matter Physics with Synchrotron Radiation, Springer Tracts in Modern Physics 208 (2004)

[3] D. Erb, Ph.D. thesis, University of Hamburg, submitted (2014)

MA 4.7 Mon 11:15 H 1012

Building Blocks of Artificial Square Spin Ice: Stray-Field Studies of Thermal Dynamics and Tuned Interactions. — •Merlin Pohlit, Fabrizio Porrati, Michael Huth, and Jens Müller — Physikalisches Institut Goethe-University, Frankfurt a. M., Germany

Over the last decade, spin ice systems with their intricate interplay between disorder, frustration and degeneracy giving rise to fundamentally new phenomena like the occurrence of monopole excitations, came to the fore of intensive research interest. Due to the ability to tune the geometric shape and the possibility to access spatially-resolved magnetic properties, artificial spin ice systems, i.e. nanostructured arrays of macroscopic spins, were succesfully employed as 2D model systems for their 3D equivalent. Here we present magnetic measurements performed on individual building blocks of artificial square spin ice. For this purpose a thermally-active cobalt-based spin ice structure was grown by focused electron beam induced deposition (FEBID) onto the surface of a lithographically defined μm-sized Hall-sensor based on a two-dimensional electron gas of an AlGaAs/GaAs heterostructure. This setup provides continuous access to the array's stray field during magnetization reversal. Using relatively simple temperature and magnetic field protocols, individual microstates were prepared and thermally-activated switching was observed. We demonstrate the feasibility of tuning the inter-macrospin interactions in artificial spin ice systems by additional deposition steps and electron irradiation at the lattice nodes.

MA 4.8 Mon 11:30 H 1012

Diffracted vectorial magneto-optical magnetometry of ferromagnetic dolmen-like structures — •Lisa Willig[1,2], Junjia Ding[3], Adekunle Adeyeye[3], Ivan Maksymov[2], Peter Metaxas[2], and Mikhail Koystylev[2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany — [2]School of Physics, University of Western Australia, Crawley, WA, Australia — [3]Electrical and Computer Engineering, National University of Singapore, Singapore, Singapore

Vector and Diffracted magneto-optical Kerr effect measurements were combined to study the magnetisation dynamics during magnetic reversal ferromagnetic dolmen-like structure. The unit cells of the two-dimensional Permalloy (NiFe) array consists of three elements in the submicrometer range (2μm $\times$ 0.8μm). This is the first investigation on a system with strongly dipole-dipole coupled unit cells, as the inter-element spacing is just 50nm. The periodicity of the structure leads to a diffraction pattern besides specular reflection. The hysteresis loops of the visible diffracted order beams as well as the specular reflected beam were obtained. In combination with micromagnetic simulations this enables a detailed analysis of the magnetisation reversal in each unit cell. The different diffraction orders correspond to a magnetic order with wavelengths smaller or equal to the length of the unit cell. Additionally measurements of more than one magnetisation component allow the reconstruction of the magnetisation vector during the reversal process.

MA 4.9 Mon 11:45 H 1012

Domain wall dynamics in asymmetric ferromagnetic rings — •Kornel Richter[1], Mohammad-A. Mawass[1], Andrea Krone[1], Benjamin Kruger[1], Markus Weigand[2], Hermann Stoll[2], Gisela Schutz[2], and Mathias Klaeui[1] — [1]Johannes Gutenberg Universität-Mainz, Institut of Physics, Staudinger Weg 7, 55128 Mainz, Germany — [2]Max-Planck-Institute for Intelligent Systems, Heisenbergstr. 3, Stuttgart 70569, Germany

Domain wall (DW) propagation in ferromagnetic nanorings is characterized by a non-constant DW velocity even if it is driven by rotating field of constant amplitude and frequency. Here, we examine ferromagnetic rings, in which the domain wall velocity can be additionally controlled on a local scale using variations of DW potential landscape that has been introduced to the sample via geometrical variations, such as a non-constant ring-width. Time-resolved observations of domain wall motion in asymmetric rings reveal that the phase shift between the direction of magnetic field and domain wall position is strongly related to the asymmetric shape of the sample, namely, the varying ring width. Such relative change of the phase shift result in variations of DW velocity profile, thus allowing one to control the DW velocity locally. In addition, the asymmetric shape of the sample give rise to the presence of DW motion that occurs even without the presence of external magnetic field (i.e. automotion). Such effects can be understood in terms of the minimization of the total energy.