# MA 32: Magnetic Thin Films I

Time: Wednesday 11:00–13:00 Location: HSZ 04

MA 32.1 Wed 11:00 HSZ 04

**Remanence enhanced high-energy density in epitaxial exchange-coupled $SmCo_5$/Fe/$SmCo_5$-trilayers** — •Simon Sawatzki[1], Rene Heller[2], Christine Mickel[1], Marietta Seifert[1], Ludwig Schultz[1], and Volker Neu[1] — [1]IFW Dresden, Institute for Metallic Materials, PO Box 270116, D-01171 Germany — [2]Helmholtz-Zentrum Dresden Rossendorf, Germany

In order to enhance the energy density $(BH)_{max}$, as a key property for permanent magnet applications, exchanged-coupled trilayers of $SmCo_5$/Fe/$SmCo_5$ with fixed $SmCo_5$ layer thicknesses (25 nm) and varying soft magnetic Fe film thickness have been epitaxially grown by pulsed laser deposition on Cr buffered MgO(110) substrates. The realization of one single in-plane easy axis of the highly anisotropic $SmCo_5$ phase through the whole layer stack as well as phase formation and texture could be confirmed by Bragg-Brentano X-ray diffraction and pole figure measurements. The effect of the increasing soft layer thickness on the reversal mechanism and improved remanence due to the higher Fe-volume fraction was investigated by vibrating sample magnetometer measurements with external fields up to 9 T. As the energy density strongly depends on the volume of the samples, emphasize is put on multilayer architecture investigation and reliable thickness determination. Concerning the latter all applied analysis methods as energy dispersive X-ray analysis, Rutherford backscattering spectroscopy and transmission electron microscopy confirm energy densities with maximum values of 312 kJ/m$^3$ (39 MGOe).

MA 32.2 Wed 11:15 HSZ 04

**Growth, structure, and magnetic properties of epitaxial $Ni_xMn_{100-x}$ single layers and Co/$Ni_xMn_{100-x}$ bilayers on $Cu_3Au(100)$** — •Muhammad Yaqoob Khan[1], W. A. A. Macedo[2], P. L. Gastelois[2], J. Miguel[1], M. D. Martins[2], and W. Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, 14195 Berlin, Germany — [2]Centro de Desenvolvimento da Tecnologia Nuclear, 31270-901 Belo Horizonte, MG, Brazil

In contrast to Cu(100), on which NiMn grows with its $c$ axis in the film plane, the larger lattice constant of $Cu_3Au(100)$ should enable growth of ordered antiferromagnetic $L1_0$ NiMn epitaxial thin films with the $c$ axis perpendicular to the plane. The growth and structure of single-crystalline ultrathin $Ni_xMn_{100-x}$ films on $Cu_3Au(100)$, and also the magnetic properties of Co/$Ni_xMn_{100-x}$ bilayers have been investigated by low-energy electron diffraction (LEED), reflection high-energy electron diffraction (RHEED), and magneto-optical Kerr effect (MOKE). For the concentration range $10 \leq x \leq 77$, our results reveal good epitaxial layer-by-layer growth at a substrate temperature of 300 K. From LEED-IV and RHEED measurements, the equiatomic NiMn films were found to be in a face-centered tetragonal (fct) structure as expected for the $L1_0$ NiMn phase, with the c axis along the film normal. For Co/NiMn bilayers with $23 \leq x \leq 55$, MOKE hysteresis loops show a thickness-independent coercivity, suggesting no magnetic coupling at the interface and hence no indication of antiferromagnetism in the NiMn in contrast to earlier observations on Co/$Ni_{50}Mn_{50}$/Cu(100).

MA 32.3 Wed 11:30 HSZ 04

**FIB induced structural modifications in thin magnetic films** — •Olga Roshchupkina, Jörg Grenzer, Thomas Strache, Monika Fritzsche, Arndt Mücklich, and Jürgen Fassbender — Helmholtz-Zentrum Dresden-Rossendorf

Focused ion beam irradiation is a versatile tool that can be used for magnetic nanostructuring. In this work we compare both FIB irradiation and a standard implantation taking into account their distinctive irradiation features. A 50nm thick permalloy layer ($Ni_{80}Fe_{20}$) irradiated with different $Ga^+$ ion fluences was used for the investigations. The structure was studied via XRD and EXAFS measurements carried out on the ESRF ROBL and ID01 facilities. Additionally TEM and magneto-optic Kerr effect magnetometry were performed. Both types of irradiation demonstrate a similar behaviour: increasing the ion fluence causes a further material crystallization and a decrease of the magnetic moment. However FIB irradiation leads to a stronger crystallite growth due to the high current densities used.

MA 32.4 Wed 11:45 HSZ 04

**Magnetic anisotropy investigations in single crystalline Fe films on ripple MgO templates** — •Maciej Oskar Liedke, Michael Körner, Kilian Lenz, Thomas Strache, Jeffrey McCord, Mukesh Ranjan, Stefan Facsko, and Jürgen Fassbender — Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Institute of Ion Beam Physics and Materials Research, P.O. Box 510119, 01314 Dresden, Germany

Ion erosion of MgO substrates produces highly ordered surface patterns. The so-called ripples are not only induced along any arbitrary in-plane orientation but outstandingly, they stay crystalline upon ion irradiation. Due to the low lattice mismatch single crystalline Fe films can be grown onto these periodically modulated MgO(100) templates. Despite the intrinsic magnetic property of *bcc* Fe, i.e. cubic anisotropy, an additional ripple morphology driven uniaxial magnetic anisotropy is introduced. Thus an ensemble of twofold and fourfold symmetry is created, which is confirmed by ferromagnetic resonance and magneto-optic Kerr effect measurements. The orientation and strength of the uniaxial anisotropy, which mainly originates from shape and step-edge contributions, depends on the angle of the ripple ridges elongation with regard to the [100] direction of MgO and on the Fe film thickness, respectively. Theoretical analysis reveals anisotropy fields and orientations of both anisotropy contributions that are in agreement with the experiment.

MA 32.5 Wed 12:00 HSZ 04

**Magnetic properties of Permalloy elements fabricated by focused-ion-beam-based methods** — •Saleh Getlawi, Nikolas Becker, Haibin Gao, Michael Koblischka, and Uwe Hartmann — Inst. of Experimental Physics, Saarland University, P.O. Box 151150, 66041 Saarbrücken

Focused-ion-beam (FIB) irradiation and milling are very versatile and rapid laboratory techniques for structuring small elements from thin films. The purpose of this work is a systematic comparison of the magnetic properties of Permalloy(Py,Ni81FE19) thin elements prepared by conventional electron beam lithography (EBL) and by FIB-based methods. In particular effects of Ga+ ion irradiation on structural and magnetic properties were investigated. A variety of Py nanowires of 20nm thickness and 200nm width were prepared. The wires have notches for domain wall pinning and pads of different geometry for domain wall nucleation. Atomic and magnetic force microscopy were used for structural and magnetic characterization. The influence of Ga+ irradiation was found to be significant.

MA 32.6 Wed 12:15 HSZ 04

**Different Methods for the Investigation of a Substrate Induced Uniaxial Anisotropy** — •Stefan Rössler, Sebastian Hankemeier, Robert Frömter, and Hans Peter Oepen — Institute of Applied Physics, Hamburg, Germany

As a result of the polishing process polishing lines remain on the surface of a diamond substrate. The lateral distance of these lines is about 100-200 nm and the height about 1-2 nm, respectively. We have investigated the impact of these lines on the magnetic properties of a 20 nm Permalloy film. The surface texture of the substrate is replicated in the thin film. The magnetic properties have been investigated by means of magneto optical Kerr effect (MOKE) measurements. These measurements reveal a morphology induced anisotropy with an easy axis of magnetization parallel to the polishing lines. A model has been developed to evaluate the strength of this anisotropy from the surface configuration. From Atomic Force Microscopy (AFM) analysis we obtain the surface morphology, which is used for the calculation of the uniaxial anisotropy constant. The effect of the anisotropy on the domain pattern in 5 $\mu$m × 5 $\mu$m × 10 nm Permalloy squares has been investigated by means of SEMPA. From the size of the four domains of a Landau state the local anisotropy in the nanostructure can be calculated utilizing OOMMF simulations. Magnetotransport measurements have been performed with Permalloy squares as a function of the direction of an externally applied magnetic field. The transport results can also be used to determine the strength of the local anisotropy.

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MA 32.7 Wed 12:30 HSZ 04

**Nanoengineered iron oxide** — •Mehrdad Baghaie Yazdi[1], David Bierwagen[1], Marie-Laure Goyallon[1], Heinz

Wanzenböck[2], Wolfgang Donner[1], and Lambert Alff[1] — [1]Institute of Materials Science, Technische Universität Darmstadt — [2]Institute for Solid State Electronics, Technische Universität Wien

$Fe_3O_4$ is clearly an interesting candidate as material for spintronics. Here we show that $Fe_3O_4$ can perform as transparent magnetic oxides (TMO) and that Fe nanoclusters can be used to tune the resistivity of magnetite layers. We have successfully grown multilayer thin films of magntite/aluminum doped zinc oxide (ZAO) on glass, by a combination of rf and dc-sputtering, yielding average transmittance in the visible spectrum (400-800 nm) ranging from 40 to above 80% , while maintaining a magnetic moment per area of 0.05 A. Further multilayers of $\alpha-$Fe and $Fe_3O_4$ have been grown in one single step using a kinetically controlled process of reactive rf-sputtering. These films show a decrease in resistivity by one order of magnitude compared to single layer magnetite. The $Fe_3O_4$ in both, TMO and the iron-iron oxide composite, shows a sharp Verwey transitions around 120 K, confirming the high quality of the magnetite layers.

MA 32.8 Wed 12:45 HSZ 04

**Magnetic Properties of $(CoFe)_x(MgO)_{100-x}$ nanogranular thin films investigated by FMR spectroscopic tool** — •Olga Meshcheriakova[1], Yuri Kudryavtsev[2], Volodymyr Yermolenko[2], Benjamin Balke[1], Gerhard Fecher[1], and Claudia Felser[1] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg-University Mainz, D-55099 Mainz, Germany — [2]Institute of Metal Physics, National Academy of Sciences of Ukraine, 252680 Kiev-142, Ukraine

The ferromagnetic and magneto-transport properties of $(CoFe)_x(MgO)_{100-x}$ nanogranular films were investigated. Tunneling magnetoresistance (TMR) of magnetic nanogranular films has been measured by four-probe DC conductivity measurements depending on the concentration of $(CoFe)_x$ ferromagnetic granules and the thermal treatment. The maximum TMR effect of 1.5% at H=6500 Oe occurs at x=50 in the as-deposited films. Annealing process leads to drastic reduction of TMR due to the ferromagnetic granules coalescent into magnetic clusters, thus the conductance changes from tunneling to metal type. FMR spectra are experimentally obtained for the samples in the initial and annealed states in a range of concentrations x=90, 73, 60, 50, 35, and 23. The annealing of $(CoFe)_x(MgO)_{100-x}$ nanogranular films at 350°C during 1 hour causes significant changes of magnetic properties of the films: effective and saturation magnetizations significantly increase and initially paramagnetic films become ferromagnetic due to the slight size increasing of ferromagnetic clusters. Further research requires more detailed structural analysis.