MA 23: Micro- and Nanostructured Magnetic Materials I

Time: Thursday 10:15–12:45 Location: H22

MA 23.1 Thu 10:15 H22

Sub 20nm structures with perpendicular magnetization — •Holger Stillrich[1], Sabine Pütter[1], Andreas Frömsdorf[2], and Hans Peter Oepen[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany — [2]Institut für Physikalische Chemie, Universität Hamburg, Grindelallee 117, 20146 Hamburg, Germany

Magnetic nanostructures with perpendicular magnetic anisotropy are fabricated using SiO_2 nanoparticles. SiO_2 filled diblock copolymer micelles are deposited as a single layer on a Co/Pt multilayer film with perpendicular easy axis of magnetization. The polymer shell is removed in an oxygen plasma which yields a SiO_2 particle array that is used as mask for ion milling. Two kinds of diblock copolymers with different polymer length are used. The mean particle diameter is 12 and 20nm and the mean particle distance is 30 and 80nm, respectively, which was determined via AFM and SEM investigations. After sputtering a replica in the Co/Pt film is produced with slightly reduced dot size.

The magnetic properties of both films and magnetic dot arrays are investigated via the magneto-optical Kerr effect.

We find that the 20nm dots are ferromagnetic at room temperature and the perpendicular easy axis of the Co/Pt multilayer is preserved. The 12nm dots are superparamagnetic at room temperature. The influence of ion energy, number of Co/Pt-bilayers and size distribution of magnetic dots on the average magnetic properties is discussed.

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MA 23.2 Thu 10:30 H22

TEM investigations of the magnetization patterns of sagged Permalloy microstructures — •Christian Dietrich[1], Michael Huber[1], Dieter Weiss[1], Josef Zweck[1], and Riccardo Hertel[2] — [1]Institut für Experimentelle und Angewandte Physik der Universität Regensburg, Germany — [2]Forschungszentrum Jülich, Germany

For Lorentz transmission electron microscopic investigations of patterned magnetic specimens, the electron beam has to transmit the sample. Therefore the specimens are usually grown onto thin Si_3N_4 membranes. Due to mechanical tension the magnetic layers are not perfectly flat but sagged. Performing AFM measurements we found that the topography of the specimens is in a good approximation paraboloidally sagged with the center about 20-30 nm below the edges (for a micron sized specimen). When only in-plane magnetic fields are applied, the magnetization pattern behaves as expected for flat specimens. However, when an out-of-plane magnetic field is applied, the magnetization patterns change remarkably. For Permalloy squares with Landau domain structure the domain walls bend while for disks the vortex displacement due to an applied in-plane field deviates from the usual behaviour. The results can be explained by energy considerations and are of importance in the investigation of vortex motion, when perpendicular magnetic fields are present. Once more, the sensitive reaction of micromagnetic patterns on the specimen's geometry is confirmed.

MA 23.3 Thu 10:45 H22

Magnetization Reversal of Microstructured Kagomé Lattices — •Andreas Westphalen[1], Alexandra Schumann[1], Arndt Remhof[1], Thorsten Last[2], Ulrich Kunze[2], Thomas Eimüller[3], and Hartmut Zabel[1] — [1]Institut für Experimentalphysik/Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany — [2]Institut für Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, 44780 Bochum, Germany — [3]Nachwuchsgruppe, Institut für Experimentalphysik/Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany

We report on magneto-optical Kerr effect (MOKE) investigations of microstructured rectangular islands (thickness: 20 nm, lateral size: 4.7 $\times$ 0.3 μm^2 to 2.7 $\times$ 0.15 μm^2) arranged as Kagomé lattices. The magnetization reversal was studied by regular longitudinal vector MOKE in specular geometry as well as in Bragg MOKE geometry, using the diffraction spots from the grating for hysteresis measurements. The measurements are compared with the results of micromagnetic simulation, which allow a detailed interpretation of the experimental data. We find that the remagnetization process in an external magnetic field strongly depends on the size and the interparticle spacing between the islands. The magnetization in remanence is imaged using magnetic force microscopy and photoemission electron microscopy. It shows a well ordered state even for sample orientations where strong magnetic frustration has been excepted.

We acknowledge financial support through SFB 491.

MA 23.4 Thu 11:00 H22

Magnetization Reversal of Microstructured Fe spirals — •Andreas Westphalen, Arndt Remhof, and Hartmut Zabel — Institut für Experimentalphysik/Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany

A magnetic spiral structure (thickness: 20 nm, radius 2.8 μm, linewidth 100 nm) is used as a base for four different structure patterns. In contrast to a ring structure, in a spiral the magnetization cannot exhibit a closed flux configuration during the remagnetization process . Therefore, the process should prefer domain formation. The remagnetization processes in the spiral patterns are investigated with vector and Bragg MOKE in combination with micromagnetic simulations. We found that the magnetic reversal is the same in all four patterns. No notches, slits or other defects are introduced in the spiral which could influence the domain configuration during the magnetic reversal process. But the arrangement of the spiral patterns has an influence on the coercive field of the hysteresis curve. In the remanent state the micromagnetic simulations predict an onion-like state of the magnetization: the magnetization is divided at the horizontal axis, which is parallel to the applied magnetic field, in a lower and in an upper part where the magnetization follows the curvature of the spiral building magnetic poles at the horizontal axis. From the Bragg MOKE measurements we concluded that the switching process of the domains during the remagnetization is driven by domain wall movement.

We acknowledge financial support through SFB 491.

MA 23.5 Thu 11:15 H22

Longitudinal Bragg- and Vector-MOKE investigation on the rotational sense of vortices in Permalloy Nanodots — •Min-Sang Lee[1], Andreas Westphalen[1], Arndt Remhof[1], Alexandra Schumann[1], Thorsten Last[2], Ulrich Kunze[2], and Hartmut Zabel[1] — [1]Institut für Experimentalphysik IV (Festkörperphysik), Ruhr-Universität Bochum, 44780 Bochum — [2]Institut für Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, 44780 Bochum

We have used the Bragg-MOKE technique in longitudinal geometry (L-MOKE) for the first time to study the rotational sense of vortices in Py nanodots. The dots were shaped such that only one uniqely defined rotational sense was present in the whole dot array. Due to the fact that the rotational sense manifests itself in the sign of the imaginary part of magnetic form factors, we have been able to show that the rotational sense can be extracted from the hysteresis loops recorded for positive and negative diffraction order. We have also developed a formalism describing the relation between the magnetic form factor and the Bragg-MOKE signal. This theoretical work has been needed because there is no such formalism regarding the L-MOKE applied to dot arrays. The validity of our formalism is tested by comparsion with the measurement results on the Py dots, which shows a good agreement. We conclude that the L-MOKE is an eligible method for studying the rotational sense of vortices. This work was financially supported by the SFB 491.

MA 23.6 Thu 11:30 H22

Magnetic antidot arrays with perpendicular or in-plane magnetization orientation — •Sabine Pütter[1], Holger Stillrich[1], Andreas Frömsdorf[2], and Hans Peter Oepen[1] — [1]Institut für Angewandte Physik, Jungiusstr. 11, 20355 Hamburg — [2]Institut für Physikalische Chemie, Grindelallee 117, 20146 Hamburg

Hexagonal magnetic antidot arrays with periods below 100 nm are fabricated utilizing self organized patterns of diblock copolymer micelles as masks. Two methods for antidot array production in Co/Pt multilayers are presented. In the first method, the Co/Pt films are grown on top of the micelles preserving the morphology of the height modulated micelle pattern. Via Ar^+ sputtering at grazing incidence the film on the micelle caps is removed. Alternatively, micelles filled with SiO_2 are deposited on the magnetic film. Ion milling at normal incidence produces an antidot array due to preferred sputtering of the

SiO_2 cores.

Varying the Co or Pt thickness of the multilayers the easy axis of magnetization of the antidot array is tuned to be in-plane or out-of-plane. For ion milling at normal incidence, however, high Ar^+ ion energies (> 500 eV) cause a reorientation of the magnetization from out-of-plane to in-plane during structuring.

We have investigated the morphology and topography of the arrays by SEM and AFM. The results of the afore mentioned studies are correlated with the magnetic behaviour observed via the magneto optical Kerr effect.

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MA 23.7 Thu 11:45 H22

Lorentz microscopy studies of cross-tie states in multi-scale NiFe elements — •Nils Wiese[1], Stephen McVitie[1], John Chapman[1], Felix Otto[2], Stefan Müller[3], and Antonio DeSimone[4] — [1]University of Glasgow, Dept. for Physics & Astronomy, Glasgow, United Kingdom — [2]Institut für Angewandte Mathematik der Universität Bonn, Germany — [3]Max Planck Institute for Mathematics in the Sciences, Leipzig, Germany — [4]Intern. School for Advanced Studies, Trieste, Italy

Modelling of the magnetic structure and magnetisation processes in discrete thin films is routinely achieved using micromagnetic methods. However, in certain cases micromagnetics may not give accurate predictions and a particular example where this can apply is for structures containing extended domain walls, e.g. cross-tie walls. In such cases, analytical models provide an alternative route for predicting the behaviour on the micromagnetic scale.

We have fabricated elongated rectangular permalloy elements of varying thickness and with in-plane dimensions down to 100nm in order to investigate variation in the cross-tie wall structure due to edge proximity compared to that in an infinite film. Domain structures have been characterised in remanent states and during in-situ magnetising experiments in the transmission electron microscope. Our results show that the cross-tie density depends on the element width although the basic geometry of the wall remains unaltered. Results will be presented showing the variation of the wall structure over a large range of lengthscales, and a comparision with analytical models will be made.

MA 23.8 Thu 12:00 H22

Direct laser interference patterning of perpendicular Co/Pd multilayer films — •Philipp Leufke, Stephen Riedel, Paul Leiderer, Johannes Boneberg, and Manfred Albrecht — University of Konstanz, Department of Physics, D-78457 Konstanz, Germany

We report on direct laser interference patterning of Co/Pd multilayer films. The as-grown films show a high perpendicular magnetic anisotropy caused by interfacial effects. When exposed to nanosecond laser pulses the film stack will be annealed locally and as a consequence mixed chemically. This intermixing effect, in particular at the interfaces, will result in a reduction of magnetic anisotropy [1].

Multi-beam laser interference patterning is performend using two, three, and four beams of a Nd:YAG laser system at a wavelength of 532 nm. By altering the angle of incidence or polarization of the beams, different patterns of light intensity can be created [2]. The formed dot or stripe patterns are magnetically softer than the surrounding untreated film material affecting in particular the magnetic reversal mechanism. The latter is being investigated locally by magnetic force microscopy and compared to the hysteresis loops as measured by polar magneto-optical Kerr effect and superconductive quantum interference device magnetometry.

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[1] C. Schuppler *et al.*, *Appl. Phys. Lett.* **88**, 012506 (2006).

[2] A. Aktag *et al.*, *J. Appl. Phys.* **99**, 093901 (2006).

MA 23.9 Thu 12:15 H22

Magnetic Patterning by Focused Ion Beam Irradiation — •Stefan Tibus[1], Denys Makarov[1], Charles T. Rettner[2], Thomas Thomson[3], Bruce D. Terris[3], and Manfred Albrecht[1] — [1]University of Konstanz, Department of Physics, D-78457 Konstanz, Germany — [2]IBM Almaden Research Center, 650 Harry Road, San Jose, CA 95120, USA — [3]Hitachi San Jose Research Center, 650 Harry Road, San Jose, CA 95120, USA

The magnetic properties, i.e. magnetization, coercivity and initially perpendicular magnetic anisotropy, of a granular CoCrPt film can be tuned by Ga irradiation, depending on exposure dose [1]. Focused ion beam irradiation is used to generate a periodic pattern of exposed strips which are magnetically soft, separated by magnetically hard unexposed areas [2]. Investigation with magnetic force microscopy and magneto-optical Kerr effect measurements show several stabilization regions of magnetic domain configurations, which are due to strong magnetic coupling between the strips. The magnetic reversal behavior and domain configurations are investigated by micromagnetic simulations and a comparison with the experimental findings is presented.

[1] Charles T. Rettner et al, *IEEE Trans. Magn.* **38**, 1725–1730 (2002)

[2] Manfred Albrecht et al, *Appl. Phys. Lett.* **83**, 4363–4365 (2003)

MA 23.10 Thu 12:30 H22

Ordering phenomena in focused ion beam structured Co/Pt multilayers. — Markus Becherer[1], •Gyorgy Csaba[2], Rainer Emling[1], Lili Ji[3], Wolfgang Porod[3], Paolo Lugli[2], and Doris Schmitt-Landsiedel[1] — [1]Lehrstuhl für Technische Elektronik, TU München — [2]Lehrstuhl für Nanoelektronik, TU München — [3]Center for Nanoscience and Technology, University of Notre Dame, USA

Computation by field-coupled nanomagnetic dots is a novel computational paradigm on the nanoscale. In the so-called 'magnetic quantum cellular automata', information is represented by the orientation of nanomagnetic dots and the signal is propagated by their magnetic interactions.

We investigate the feasibility of ion-beam patterned Co/Pt multilayers as a possible realization of magnetic field-coupling. We sputtered 40 bilayers of Co/Pt in an rf-magnetron system and employed SQUID measurements to characterize perpendicular anisotropy. The films are patterned with a 50 keV Ga^+ focused ion beam (FIB) into 'checkerboards' of $(200\text{x}200)nm^2$ dot-size. They are demagnetized and in a remanent state mapped by a magnetic force microscope (MFM).

The arrays of 48x48-dots show antiferromagnetic ordering that extends to hundreds of dots without frustration. This indicates strong interdot coupling and small switching field variations from dot to dot, showing that these multilayers are indeed a promising implementation possibility for field-coupling. We will present the first experimental results about strongly coupled dots and will outline the design of logic gates based on them.