MA 11: Magnetic Thin Films I

Time: Tuesday 10:15–13:00 Location: H10

MA 11.1 Tue 10:15 H10

Structural and magnetic properties of epitaxial Pr-Co films with varying rare-earth content — •Ajit Kumar Patra[1,2], Volker Neu[1,2], Sebastian Fähler[1,2], Rainer Groetzschel[3], Subhankar Bedanta[4], Wolfgang Kleemann[4], and Ludwig Schultz[1,2] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, 01171 Dresden, Germany — [2]Institute for Physics of Solids, Department of Physics, Dresden University of Technology, 01062 Dresden, Germany — [3]Institute of Ion Beam Physics and Materials Research, Forschungszentrum Rossendorf, P.O. Box 510119, 01314 Dresden, Germany — [4]Angewandte Physik, Universität Duisburg-Essen, D-47048 Duisburg, Germany

Pulsed laser deposited epitaxial Pr_xCo_{100-x} (x = 8.7 to 27.6 at.%) thin films were systematically studied as a function of Pr content. Structural and magnetic measurements reveal different phases for specific composition range and in some cases the phases observed are in contrast to their bulk counterpart. Uniaxial anisotropy at room temperature is observed in all the films enabling excellent hard magnetic properties. For the optimum combination of coercivity and polarization, the measured $(BH)_{max}$ reaches values of 310 kJ/m^3, which exceeds the highest energy product value reported for RE-Co (RE = Rare Earth) systems. Temperature dependent ac susceptibilty measurements reveal that films x = 8.7 to 20.4 undergo a spin reorientation from easy axis to easy cone, but films with x = 22.9 to 27.6 maintain their uniaxial anisotropy throughout the temperature range of investigation.

MA 11.2 Tue 10:30 H10

Epitaxial Nd-Fe-B films grown on Mo buffers — •Ah-Ram Kwon, Sebastian Fähler, Volker Neu, Ruben Hühne, Bernhard Holzapfel, and Ludwig Schultz — IFW Dresden, P.O. Box 270116, D-01171 Dresden

Nd-Fe-B films are attractive for perpendicular magnetic recording due to the typically achieved c-axis texture and therefore high perpendicular anisotropy. Magnetic recording requires smooth film surfaces, in contrast to the rough morphology and discontinuous growth observed for thin films deposited on Ta or W. In order to achieve epitaxial growth with full control of the crystallite orientation, a Mo buffer layer is grown on MgO(100), MgO buffered Si(100) and TiN-IBAD(100) substrates by pulse laser deposition. Prepared directly on MgO(100) substrates, Mo grows epitaxially with a (00l) orientation and Nd-Fe-B films onto this buffer possess the desired (00l) out-of-plane orientation with one in-plane epitaxy relation. These films have smoother and continuous surfaces than earlier prepared films on Ta and the magnetic contrast reveals continuous band domains. At 520 °C, films show the largest magnetic anisotropy. Saturation magnetization reaches 1.5 T, but coercivity is low (Hc < 0.5 T) due to the continuous film microstructure. MgO buffered Si substrates behave differently from MgO substrates. MgO grows fiber textured, and Mo grows with both (110) and (100) orientations.

MA 11.3 Tue 10:45 H10

Micromagnetic analysis of the coercivity of hard magnetic $L1_0$-FePt thin films — •Dagmar Goll, Nam Hoon Goo, and Wilfried Sigle — Max-Planck-Institut für Metallforschung, Heisenbergstr. 3, 70569 Stuttgart

FePt thin films in the ordered face-centered tetragonal structure ($L1_0$-phase) have gained significant attention for ultrahigh-density magnetic recording and high-performance permanent magnets due to their outstanding intrinsic magnetic properties and their chemical stability. Starting from Fe-Pt-multilayers of different individual layer thicknesses by postannealing either highly textured or isotropic $L1_0$-FePt monolayers are formed. The formation of the $L1_0$ phase has been studied in situ during annealing by using high-resolution transmission electron microscopy. The determination of the microstructural parameters allows a quantitative correlation between the microstructure and the magnetic properties.

MA 11.4 Tue 11:00 H10

Magnetocrystalline Anisotropy in Permalloy Revisited — Lifeng Yin[1], Dahai Wei[1], Na Lei[1], •Lihui Zhou[1], Chuanshan Tian[1], Guosheng Dong[1], Xiaofeng Jin[1], Liping Guo[2], Quanjie Jia[2], and Ruqian Wu[3] — [1]Surface Physics Laboratory, Fudan University, Shanghai 200433, China — [2]Beijing Synchrotron Radiation Facility, Beijing 100049, China — [3]Department of Physics and Astronomy, University of California at Irvine, Irvine, California 92697, USA

We present our observation on the magnetic properties of Permalloy (Py) with a bcc structure1 to address the long-standing issue that why Py is a soft magnet.

bcc Py, which does not exist in nature, has been achieved on GaAs(001) by molecular beam epitaxy at 200K. It is ferromagnetic with the Tc lower than that of the conventional Py - its fcc counterpart, and with the magnetic moment almost equal to that of fcc Py. Most strikingly, depending not on the atomic structure but only on the stoichiometry of Fe and Ni of the alloy, the cubic magnetocrystalline anisotropy of bcc Py is also vanishing, which directly challenges the standard cancellation model2. The experimental result is further confirmed by first-principles electronic-structure calculations, and attributed to the charge redistribution after alloying.

1.L. F. Yin et al., Phys. Rev. Lett. 97, 067203 (2006). 2.Derek Craik, Magnetism: Principles and Applications (John Wiley and Sons, Chichester, 1995), p. 392.

MA 11.5 Tue 11:15 H10

Pinning and exchange coupling in epitaxial $SmCo_5$ films — Aarti Singh[1], •Volker Neu[1,2], Sebastian Fähler[1,2], Konstantin Nenkov[1], Ludwig Schultz[1,2], and Bernhard Holzapfel[1] — [1]IFW Dresden, P.O. Box: 2270116, 01171 Dresden, Germany — [2]Institute for Physics of Solids, Department of Physics, Dresden University of Technology, 01062 Dresden, Germany

Highly coercive $SmCo_5$ thin films (Hc = 3.6 T) were epitaxially prepared by pulsed laser deposition on Cr buffered MgO(100) substrates with two orthogonal orientations of the easy axis in the film plane [1]. Magnetic hysteresis measurements for fields applied at different in-plane angles show two steps in the demagnetisation branch. These correspond to the switching of areas with different easy axes orientation at different applied fields. Both switching fields H_{sw1} and H_{sw2} follow an inverse $\cos\theta$ behaviour, which points towards a pinning dominated magnetization process but also reveals an independent magnetisation switching for grains with perpendicular orientation. Thus the behaviour suggest, that the film consists of partially decoupled grains. On the other hand, a detailed remanence analysis results in a strong positive δJ, which is indicative of exchange coupling between grains. These two contradictory pictures can be merged by assuming that grains with parallel c-axis form a strongly coupled network which behaves independent from the orthogonal grain network during the reversal process.

[1] A. Singh, V. Neu, R. Tamm, K. Subba Rao, S. Fähler, W. Skrotzki, L. Schultz and B. Holzapfel, APL 87, 2005, 072505

MA 11.6 Tue 11:30 H10

In-situ strain effect on extrinsic magnetotransport in polycrystalline and ste-edge-junction manganite films — •Ramesh Babu Gangineni, Kathrin Dörr, Konstantin Nenkov, Ingolf Mönch, and Ludwig Schultz — IFW, Dresden, Germany

Grain boundaries and step-edge junctions in ferromagnetic manganites $La_{0.7}A_{0.3}MnO_3$ (A = Sr; Ca) typically act as tunnel junctions for the spin-polarized transport. Variable biaxial strain applied to such a manganite sample may affect the tunnel transport, additionally to the intra-grain effect. Thin polycrystalline films of $La_{0.7}A_{0.3}MnO_3$ (A = Sr; Ca) have been grown by Pulsed Laser Deposition on $YMnO_3$ - buffered piezoelectric PMN-PT(001) substrates. Films containing step- edge junctions were grown on PMN-PT(001) substrates with etched, 600 nm high parallel steps. Magnetization measurements characterize the magnetic behaviour of the film volume. Electrical resistance has been recorded in dependence on in-situ applied reversible biaxial strain at selected temperatures, temperature and magnetic field. Favourably from practical viewpoint, the strain response of polycrystalline films is typically much less temperature-dependent than that of epitaxial films. A step-edge-junction film of $La_{0.7}Sr_{0.3}MnO_3$ shows huge (gauge factor) G values (of up to 400) in a wide temperature range and associated reduction of resistance and magnetoresistance upon piezoelectric in-plane compression of the film. Relations of mi-

crostructure, electric transport mechanism and strain effect will be discussed.

MA 11.7 Tue 11:45 H10

Magnetic superstructure in Fe/native Fe-oxide multilayers — •Sebastien Couet, Thomas Diederich, and Ralf Röhlsberger — Hamburger Synchrotron Strahlungslabor (HASYLAB) at Deutsches Elektronen-Synchrotron (DESY), Notkestr. 85, 22607 Hamburg

It has been discovered recently that Fe/native Fe-oxide multilayers carry an anomalously high magnetic moment [1], the origin of which is not understood yet. We present here a study on the magnetic structure of such systems. Multilayer samples are prepared by repeated deposition of 2.3 nm of Fe and subsequent exposure to oxygen that forms a native oxide layer of about 1.6 nm. Using the isotope sensitive technique of nuclear resonant scattering of synchrotron radiation we are able to selectively probe the magnetic structure of the metallic Fe of the system. A non-collinear alignment is found between adjacent Fe layers coupled through the oxide spacer with a canting angle close to 90° in low fields. The measured magnetic field dependence shows that the spin system rotates as a rigid unit upon magnetization reversal while the coupling angle slowly decreases in high field. This behavior can be explained by a proximity magnetism model which implies an antiferromagnetically ordered oxide spacer layer [2].

[1] G.S.D. Beach et al., Phys. Rev. Lett. 91, 267201 (2003).
[2] J.C. Slonczewski, J. Magn. Magn. Mater. 150, 13 (1995).

MA 11.8 Tue 12:00 H10

Strain-controlled magnetic anisotropy of magnetite thin films — •Andreas Brandlmaier[1], Mathias Weiler[1], Stephan Geprägs[1], Matthias Opel[1], Hans Huebl[2], Christoph Bihler[2], Martin S. Brandt[2], Sebastian T. B. Goennenwein[1], and Rudolf Gross[1] — [1]Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Walter Schottky Institut, Technische Universität München, 85748 Garching, Germany

Controlling the crystalline strain in ferromagnetic thin films is a promising approach to multifunctional spintronic devices, since crystalline and magnetic degrees of freedom are connected via magnetostrictive effects. We have investigated magnetite (Fe_3O_4) thin films grown on (001)-oriented MgO substrates by pulsed laser deposition. Upon attaching these samples to piezoelectric actuators such that the main actuator elongation is parallel to a magnetite [100] direction, the magnetic anisotropy of the Fe_3O_4 layer can be manipulated. We quantify the effect of the piezo-induced strain on the magnetic anisotropy by monitoring the dependence of the Fe_3O_4 ferromagnetic resonance spectrum on the voltage V applied to the actuator. We find that at room temperature, the in-plane and out-of-plane uniaxial magnetic anisotropy constants $K_u^{[010]}$ and $K_u^{[001]}$ can be tuned by several 10 percent and about one percent, respectively, within the range of voltages applicable to the actuator. We quantitatively compare these findings to the magneto-strictive effects expected in magnetite, using high-resolution x-ray diffraction experiments as a function of V to determine the piezo-induced crystalline strain.

MA 11.9 Tue 12:15 H10

Der Einfluss von Querfeldern auf die Domänenwandbewegung in 200nm GMR-Streifen — •Sascha Glathe und Roland Mattheis — IPHT Jena e.V., A.-Einstein-Str. 9, D-07745 Jena

Die Ummagnetisierung von 200 nm breiten und 15 nm dicken NiFe-Schichten, welche die Sensorschicht eines GMR-Stapels bilden, geschieht durch Nukleation und Bewegung von 180° Domänenwänden und wird mit Hilfe zeitaufgelöster Widerstandsmessung untersucht. Ohne Querfeld sind Felder um 12 kA/m zur Nukleation nötig. Bei dieser Feldstärke bewegt sich die Domänenwand mit einer Geschwindigkeit von 265 m/s durch den 0,5 mm langen NiFe-Draht. Ein gleichzeitig angelegtes Querfeld von 1 bis 20 kA/m führt zu einer linearen Abnahme des zur Nukleation nötigen Längsfeldes auf 4.4 kA/m. Bei steigendem Querfeld nimmt die Geschwindigkeit bis ca. 8 kA/m ebenfalls linear auf Werte um 210 m/s ab. Überaschenderweise steigt sie mit weiter ansteigendem Querfeld auf Werte von 300 m/s (bei 20 kA/m) an. Wir erklären dieses Verhalten mit dem Einfluss von Querfeldern auf die in diesen NiFe-Strukturen auftretenden Instabilitäten der Domänenwandbewegung oberhalb des so genannten kritischen Walkerfeldes.

MA 11.10 Tue 12:30 H10

GMI in galvanisch FeNiMo-beschichteten Cu-Mikrodrähte — Thomas Nentwig, Wai-Yip Man, Christian Schiefer, •Andres Gabriel Munoz und Erhard Kisker — Institut für Angewandte Physik, Heinrich-Heine-Universität Düsseldorf, Universitätsstr. 1, 40225 Düsseldorf

Die galvanische Beschichtung von Kupfermikrodrähte mit weichmagnetischen FeNiMo-Legierungen zeigt ein grosses Interesse wegen des wachsenden Bedürfnisses, immer kleinere und empfindlichere magnetische Sensoren herzustellen, die eine direkte Anwendung u.a. in der Aufbau von Navigationssysteme und in der Messung von Hirnwellenaktivitäten finden. Drähte mit Beschichtungen von 1-2 Mikrometers und einer Zusammensetzung von Fe0.22Ni0.69Mo0.09 haben unter dem Einfluss von kleinen externen Magnetfeldern bis 40 Oe und mit Wechselstromfrequenzen f > 1MHz bereits einen GMI-Quotienten von 70 % pro Oe, zusammen mit einem GMI-Maximum von bis zu 1000 % und einem Anisotropiefeld von 6-8 Oe, gezeigt. Der Effekt ist deutlich höher als die von FeNiCo- Legierungen und kann zusätzlich durch die nachträgliche Temperung unter einem Magnetfeld und die daraus folgende Modifizierung der transversalen Anisotropie verbessert werden. Die Anwesenheit von Mo spielt bei diesem Effekt eine wesentliche Rolle, dieser wird vorgestellt. Der Einfluss des Anlegens eines Magnetfeldes während der galvanischen Abscheidung auf die magnetische Anisotropie als auch auf den Verlauf der Mo-Abscheidung wird in Zusammenhang mit der Struktur und Zusammensetzung der abgeschiedenen Schichten diskutiert.

MA 11.11 Tue 12:45 H10

Magnetic ordering in amorphous nanolaminates — Panagiotis Korelis[1], •Andreas Liebig[1], Hans Lidbaum[2], Björgvin Hjörvarsson[1], and Klaus Leifer[2] — [1]Department of Physics, Uppsala University, Box-530, SE-75121 Uppsala, Sweden — [2]Department of Engineering Sciences, Uppsala University, Box-534, SE-75121 Uppsala, Sweden

The magnetic properties of $Fe_{90}Zr_{10}/Al_{70}Zr_{30}$ amorphous nanolaminates were explored using the Magneto Optical Kerr Effect. The structural quality was determined using X-ray reflectivity as well as High Resolution Transmission Electron Microscopy. The samples exhibited well-defined total-, as well as layer- thicknesses. The absence of long range order was established by X-ray diffraction, and the chemical composition by Rutherford Back scattering.

The critical temperature of the nanolaminates is extremely well defined, consistent with chemical and structural homogenity. The moment is confined within the layers and no in-plane anisotropy is observed. The ordering temperature scales with the inverse thickness of the $Fe_{90}Zr_{10}$ layers, when the coupling across the $Al_{70}Zr_{30}$ layers is weak. The critical temperature was determined to be 200 K, in the thick film limit, which is similar to the value obtained for bulk samples with the same composition.

We will discuss the influence of the interlayer coupling on the ordering and illustrate the presence of a dimensional crossover when the thickness of the magnetic layers reaches a critical thickness.