Magnetic Interfaces and Nanostructures Technical Group
Room 618/619 - Session MI+NS-ThM

Patterned or Self-Assembled Magnetic Nanostructures

Moderator: Z.Q. Qiu, University of California, Berkeley

8:20am **MI+NS-ThM1 1-D Propagation of a Magnetic Domain Wall in Submicron Magnetic Wire**, ***T. Ono***, *H. Miyajima,* Keio University, Japan; *K. Shigeto, K. Mibu, N. Hosoito, T. Shinjo,* Kyoto University, Japan **INVITED**

A novel method to detect single domain wall motion in a submicron magnetic wire by utilizing the giant magnetoresistance (GMR) effect is presented.@footnote 1@ Recent developments of nanolithography techniques make it possible to prepare submicron dots or wires with well-defined shape, leading to the current attention on the quantum phenomena in mesoscopic magnetic materials, such as macroscopic quantum tunneling and macroscopic quantum coherence. However, the direct magnetization measurements of mesoscopic magnetic materials are practically difficult because of their small volume, and have been performed using samples consisting of a huge number of presumably identical particles. As a result, the essential magnetic properties of a single particle or wire were masked by the inevitable distribution of size or shape. Up to now, quantitative measurements on dynamical properties of a domain wall in a submicron magnetic wire, such as velocity estimation were almost impossible. The method described in this paper has a great advantage to detect a single magnetic domain wall motion, since the GMR change is directly proportional to the magnitude of the switching layer magnetization in a magnetic wire. It should be noticed that the domain wall position can be determined by this method as a function of time, and, thus, we can measure the velocity of a single domain. The wall velocity linearly depends on the applied magnetic field H and is described as v = µ(H - H@sub 0@), where v is the wall velocity, µ so-called wall mobility. In case of NiFe wire 40 nm in thickness and 500 nm in width, it was obtained that µ = 2.6 (m/sOe), and H@sub 0@ = 38 (Oe) at 100 K. @FootnoteText@ @footnote 1@ T. Ono, H. Miyajima, K. Shigeto, K. Mibu, N. Hosoito and T. Shinjo, Science, 284 (1999) 468-470.

9:00am **MI+NS-ThM3 Magnetism of Interconnected Co Nanodots Grown on the N-modified Cu(001) Surface**, ***K.D. Lee***, *T. Iimori, F. Komori,* University of Tokyo, Japan

Square arrays of ultrathin Co nano-size dots interconnected by 1 monolayer-height Co nanostripes are grown on the N-modifed Cu(001)c(2x2) substrate. Scanning tunneling microscopy shows the Co atoms are nucleated at the naked Cu(001) substrate exposed between ordered arrays of c(2x2) square patches forming such a novel Co nanostructure. The sizes of Co dots and interconnecting nanostripes are controlled by the amount of Co deposition at room temperature. Magnetic properties of these nanostructures have been investigated by using magento-optical Kerr effect between 100 K and 450 K. Analysis of hysteresis loops as a funtion of temperature as well as thickness reveals that these Co dot arrays have remarkably different magnetic properties from ultrathin fcc Co films grown on clean Cu(001) surface with the same average thickness, such as two-step increase of the saturation magnetization and coercivity with decreasing temperature. We attribute these novel magnetic properties to the magnetic interaction among Co dots mediated by the interconnecting Co stripes.

9:20am **MI+NS-ThM4 Periodic Magnetic Microstructures using Glancing Angle Deposition**, ***B. Dick***[1], *M.J. Brett, M. Malac, R.F. Egerton,* University of Alberta, Canada

Arrays of magnetic pillars have been proposed as a potential high-density data storage medium.@footnote 1@ The advanced deposition technique known as GLancing Angle Deposition (GLAD)@footnote 2@ has been used to fabricate Ni and Co posts. Because of the nature of initial film nucleation, these posts were distributed randomly on the substrate surface with a large-scale periodicity of around 350nm and individual post diameters of 100 to 150nm. We have grown arrays of posts by suppressing the randomness inherent within the initial nucleation stage of film growth. Shadowing sites were fabricated by pre-patterning a thin Cr or Ti layer on silicon substrates into a square array using electron beam lithography. These sites shadow regions of the substrate from incident flux during film deposition and act as preferred nucleation sites for the Ni and Co pillars. Using this process, we have obtained a regular post period of 500nm, with post diameters and heights of 300nm and 375nm respectively. This presentation will describe the GLAD deposition process, report on the film's periodic structure, and characterise the film's domain structure (MFM) and hysteresis response curve. Further development on decreasing the period between individual posts is continuing, and we exptect that 200nm spacing should be attainable using this simple, single-step evaporation process. @FootnoteText@ @footnote 1@S.Y. Chou. Proceedings of the IEEE. 85(4), 1997. @footnote 2@K. Robbie, J.C. Sit, M.J. Brett. J. Vac. Sci. Technol. B. 16(3), 1998.

9:40am **MI+NS-ThM5 Magnetic Quantum Cellular Automata**, ***R.P. Cowburn***, University of Cambridge, UK, United Kingdom; *D.K. Koltsov, A.O. Adeyeye, M.E. Welland,* University of Cambridge, UK **INVITED**

Nanometre scale magnetic particles (nanomagnets) are promising candidates for implementing Magnetic Quantum Cellular Automata (MQCA) architectures. In order to use nanomagnets in this way their magnetic properties must be fully understood. In particular, the conditions required to obtain a single domain state (and hence the ability to signal a 1 or a 0) must be established. Furthermore, in order to achieve room temperature operation of MQCA, magnetostatic coupling between nanomagnets must be understood and controlled. We have performed a detailed experimental and theoretical investigation into these aspects of nanomagnetism. We have used high resolution electron beam lithography to fabricate nanomagnets in the size range 40-500nm with elliptical or circular geometries. We find that the shape anisotropy introduced by the elliptical form greatly stabilises the single domain state; in the absence of any ellipticity, all of the nanomagnets greater than approximately 100nm in diameter collapse into a flux closing vortex state. We have then fabricated chains of sub-100nm nanomagnets with gaps as small as 15nm between neighbouring edges. We find experimental evidence for strong magnetostatic coupling. We have thus achieved the conditions necessary for a MQCA implementation, i.e. a well defined digital state even at room temperature which can be switched by interactions from neighbouring cells. We have used the finding described above to make a working room temperature MQCA gate. CMOS electronic signals are interfaced directly to the magnetic system by passing a small current through a gold track underneath part of the gate; outputs are currently read by focusing a laser beam onto a magnetic test point and using the magneto-optic Kerr effect to monitor its magnetic state. The gate achieves an overall power gain (and hence the ability to work at room temperature and to fan out) by an applied oscillating magnetic field.

10:20am **MI+NS-ThM7 Growth, Magnetization, and Magnetoresistance of Self-Assembled Lateral Multilayers**, *E.D. Tober,* Lawrence Berkeley National Laboratory; ***R.F. Marks***, *D.D. Chambliss, R.F.C. Farrow,* IBM Almaden Research Center

The angular dependent magnetoresistance, magnetization, and growth of epitaxial Fe@sub eta@Ag@sub 1 - eta@ self-assembled lateral multilayers@footnote 1@ (SALMs)have been examined via MOKE, 4-point resistance probes, STM, LEED, X-ray MCD, and TEM. SALMs consist of epitaxial thin film alloys of immiscible metals grown on Mo(110)/Al@sub 2@O@sub 3@(11-20) template layers and display a unique form of compositional ordering not observed in the bulk. These systems are observed to form a compositionally ordered alloy of alternating, contiguous stripes of Fe and Ag with the long axis of the stripe coinciding with the Mo[001] direction in the plane of the substrate. The average stripe periodicities are on the order of 1.8 to 2.3 nm along the Mo[-110] (perpendicular to the stripes) direction depending on film stoichiometry. These films are found to contain a high degree of magnetic anisotropy with the easy direction lying in-plane parallel to the Mo[001] direction. The low temperature anisotropic magnetoresistance (AMR) and low field magnetoresistance (MR) are examined as a function of field angle for two nearly orthogonal current directions. The SALM structures are observed to display a significant AMR (roughly 10% maximum for the entire structure). Furthermore, a pronounced MR is observed with a maximum @Delta@R/R of 0.88% (~29% in the active layer) at 2.7 K. @FootnoteText@ @footnote 1@ "Self-assembled lateral multilayers from thin film alloys of immiscible metals", E. D. Tober, R. Farrow, R. Marks, K. Kalki, G. Witte, and D. D. Chambliss, Phys. Rev. Lett. 81 N9, 1897.

10:40am **MI+NS-ThM8 Stripe Domains in Ultraflat Fe/Cu(001) Particles**, ***C. Stamm***, *A. Vaterlaus, U. Maier, D. Pescia,* ETH Zuerich, Switzerland

Atomically thin particles of Fe on Cu(001), grown at room temperature, are investigated using a Scanning Electron Microscope with Polarization Analysis (SEMPA): a Mott detector is used to analyze the perpendicular as well as one of the in-plane spin components of the secondary electrons.

[1] **Falicov Student Award Finalist**

The magnetic particles with thickness of a few atomic layers are produced by Molecular Beam Epitaxy through a mask placed in front of the Cu substrate. As in laterally extended thin films of Fe/Cu(001), particles whose lateral size exceed 1 µm contain stripe domains with magnetization perpendicular to the film plane. The width of the stripes is independent of the lateral size of the particles and their shape. Sizing down the Fe particle leads to a single-domain configuration. In contrast, in-plane magnetized ultrathin Co/Cu(001) particles are found in a single domain state, irrespective of their lateral size.@footnote 1@ @FootnoteText@ @footnote 1@C. Stamm, F. Marty, A. Vaterlaus, V. Weich, S. Egger, U. Maier, U. Ramsperger, H. Fuhrmann and D. Pescia, Science 282, 449 (1998).

11:00am **MI+NS-ThM9 Magnetic Properties of Iron Clusters Deposited on Graphite***, **A. Rosén**, M. Andersson,* Göteborg University, Sweden*; M. Hansson,* Chalmers University of Technology, Sweden*; R. Wäppling, B. Kalska,* Uppsala University, Sweden*; N. Tarras-Wahlberg,* Göteborg University, Sweden*; C. Johansson,* Chalmers University of Technology, Sweden

Magnetic properties of iron clusters deposited on graphite Iron clusters with a wide size distribution were produced in a laser vaporisation source and deposited on a graphite substrate. The magnetic relaxation of the clusters was studied with Mössbauer spectroscopy. At 300 K the sample was dominated by fast superparamagnetic behaviour, whereas the relaxation slowed down at lower temperature and six-peak components, representative for static or near-static spinconfigurations, dominated the Mössbauer spectra at 5 K. This indicates that the sample consists of mono-domain particles having an average size between 5 and 10 nm. From the hysteresis loops we obtained that the saturation magnetization was in the range of bulk a -iron and that the coercivity and the remanence increase with decreasing temperature in the whole temperature range. This behaviour is typical for a system of mono-domain particles with a wide size distribution.

11:20am **MI+NS-ThM10 Magnetic Properties of Co and Fe Particles on Sapphire Single Crystal Surfaces***, **T. Risse**, T. Hill, M. Mozaffari-Afshar, H.-J. Freund,* Fritz-Haber-Institut der Max-Planck-Gesellschaft, Germany

We have used in situ Ferromagnetic Resonance (FMR) to investigate the magnetic properties of small Co and Fe particles deposited on sapphire single crystal surfaces. Co and Fe grow as 3-dimensional particles, as deduced from the angular dependence of the FMR spectra. This result was confirmed by STM studies on an Al@sub 2@O@sub 3@ model surface grown on top of a NiAl(110) single crystal. The FMR spectra of Co or Fe particles deposited at 298 K reveal a uniaxial out-of-plane magnetization with the magnetization lying in the surface plane. A comparison of the measured angular dependence of the resonance position with 2-dimensional films show that experimental results are consistent with a 3-dimensional growth of the particles determined by the STM measurements. A closer examination of the FMR spectra indicates that these small particles exhibit superparamagnetism. With increasing amount of deposited metal the anisotropy of the systems increases indicating a more ferromagnetic behavior of the system. Annealing the samples to elevated temperatures (900K) leads to structural changes of the particles namely an increase of the particle size as deduced from FMR and Auger spectroscopy. Whereas the qualitative behavior of the magnetic anisotropy for Co deposits remains unchanged, the behavior of the iron particles changes drastically. The particles do not show a uniaxial anisotropy of a single resonance line but a complex pattern of several resonance lines. A discussion of this aspects in terms of shape as well as magnetocrystalline anisotropy will be given. Temperature dependent measurements of the Fe particles reveal a reduced Curie temperature compared to the bulk. The strong changes of the line shape with increasing temperature will be discussed in terms of a thermal fluctuations of the magnetization.

11:40am **MI+NS-ThM11 Magnetic Behavior of Nanosize Cobalt Particles in (SiO@sub 2@, MgO, CoO) Matrix***, **J.Y. Yi**, M.L. Rudee,* University of California at San Diego

Magnetic granular composite films composed of nanosize metal particles separated by a non-magnetic matrix, have interesting magnetic properties due to the finite size of the metal particles. Recently we found that ferromagnetic (FM) and antiferromagnetic (AFM) composite films such as Co-CoO films had much larger coercivity (~1 kOe at 300 K) than conventional granular Co-SiO@sub 2@ films (superparamagnetic at 300 K) in the same composition range. The increased coercivity was believed to be due to the exchange coupling between FM Co and AFM CoO, and the microstructure of the Co particles. These results indicated that the overall properties of the metal phase were affected by not only the intrinsic properties of them but also the characteristics of the matrix phase. To examine the matrix effects, Co-SiO@sub 2@, Co-MgO and Co-CoO granular composite films were prepared by co-sputtering from separate Co and each oxide target. Each film had 30~40 volume % of Co. The estimated Co particle size from x-ray peak broadening effect was about 7 nm. Magnetic hysteresis loops showed that the superparamagnetic behavior of Co at room temperature in the Co-SiO@sub 2@ and the Co-MgO systems whereas 500 ~ 1000 Oe of coercivities were observed in the Co-CoO films. AT 10 K the coercivity of the Co-SiO@sub 2@ film increased to 760 Oe while the coercivity of the Co-MgO and Co-CoO films increased to 6 kOe and 10 kOe, respectively. Unlike the Co-SiO@sub 2@ system, a small M-H loop shift was observed in the Co-MgO system at 10 K and disappeared above 50 K. This results indicated that there would be a small amounts of Co oxide phase existed in Co-MgO films and this may be the reason for the high coercivity at low temperature. In the Co-CoO system, the loop shifts were observed up to 250 K. In this presentation the magnetic properties of each film will be discussed based on the microstructural and magnetic effects from the different matrix.

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