SL24

Magnetization reversal modes in narrow FePt nanowires with high perpendicular anisotropy

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In this contribution, we present the dependence of magnetization reversal modes in FePt nanowires with the width ranging from 2000 nm to 30nm using magneto-transport and magnetic force microscopy (MFM) measurements. Magneto-transport measurements showed an enhancement of magnetic coercivity when reducing the width. Theoretical calculations suggest that this coercivity increase is not only due to the suppression of available propagation paths but also to the contribution of the roughness. Further study of the magnetization reversal process using MFM shows that three different reversal modes can appear. Indeed, for widths above 500 nm, the structure of the reversed magnetic domains appears to be similar to those of the continuous FePt film: the reversed magnetic domain grows and expands within a dendritic structure. For widths below the characteristic dendrite width (~300 nm), the reversal takes place by propagation of a single DW that reverse the whole wire. Finally, we show that another behavior appears at very low widths: when reducing the widths below 50 nm, the propagation field becomes larger than the nucleation field. Nucleation thus occurs randomly, the reversal consisting in a mix of nucleation and propagation. Such behavior could prevent the use of ultra-narrow wires for DW-based spintronic devices.

J. P. Attane et al., Phys. Rev. B, 84, 144418 (2011) J. P. Attane et al., Phys. Rev. B, 82, 024408 (2010)

SL25

Structural and magnetic behaviour of nanocrystalline $CaFe_2O_4$

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Abstract. Study of the structural and magnetic properties of the nanoparticles of large cation substituted ferrite, $CaFe_2O_4$ have been reported here. The cubic spinel phase of $CaFe_2O_4$ could be synthesized effectively in nanocrystalline form of size 5.9 nm using advanced sol-gel method. The sample was then heated at 1000 °C leading to bulk size of orthorhombic structure. Very interestingly, the nanoparticles of $CaFe_2O_4$ get transformed from cubic spinel structure to its characteristic orthorhombic structure on annealing at 1000 0C. Rietveld profile refinement of the XRD patterns was performed to study the nature of crystal structure. The SQUID magnetization measurements divulged that the nanocrystalline sample is superparamagnetic above the blocking temperature of 150 K whereas the bulk sample is ferromagnetic even at room temperature. The reduction in saturation magnetization in the case of nanoparticles as compared to its bulk counterpart has been explained on the basis that the magnetic moments in the surface layers of a nanoparticle are in a state of frozen disorder. The departure of the field cooled curve from the zero field cooled curves in the moment-versus-temperature plot, further confirmed the room temperature superparamagnetic behavior of the nanocrystalline $CaFe_2O_4$.

SL26

Magnetoresistance of helimagnetic ordering in single crystal FeGe nanowires

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We report on the synthesis, structural characterization, and magneto-transport of single crystalline FeGe NWs. Transition metal silicides and germanides have attracted a lot of attention because of their chiral cubic helimagnetism as a consequence of the Dzyaloshinskii-Moriya interaction. FeGe is known to have a high Neel temperature and helical spin order with a relatively long period. In addition, one dimensional-confinement of the spin structure might enhance the helical magnetic ordering of FeGe NWs as the nano-confinement often alter or improve the properties. We have synthesized single crystalline FeGe NWs by CVD process without any catalyst. We have investigated the helimagnetic ordering in FeGe NWs by using electrical and magneto-transport measurements. When the magnetic field was applied longitudinal to the NW axis, the signature of the helimagnetism in the FeGe NWs was observed up to near room temperature. The magneto-transport measurements reveal three magnetic states of the FeGe NWs: the helimagnetic state, conical helimagnetic state, and ferromagnetic state. The magnetic transitions from the conical helimagnetic state to ferromagnetic state in FeGe NWs was clearly observed and occurred at much higher field those observed in the bulk FeGe. The relationship between nano-sized confinement and the conical helimagnetic state will be discussed in detail.

SL27

Arrays of interacting ferromagnetic nanofilaments: small-angle neutron diffraction study

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Magnetic properties of spatially ordered arrays of interacting nanofilaments have been studied by means of small-angle diffraction of polarized neutrons. Several diffraction maxima or rings that correspond to the scattering of the highly ordered structure of pores/filaments with hexagonal packing have been observed in neutron scattering intensity maps. The interference (nuclear-magnetic) and pure magnetic contributions to the scattering have been analyzed during the magnetic reversal of the nanofilament array in a field applied perpendicular to the nanofilament axis. The average magnetization and the interference contribution proportional to it increase with the field and are saturated at H = Hs. The magnetic reversal process occurs almost without hysteresis. The intensity of the magnetic contribution has hysteresis behavior in the magnetic reversal process for both the positive and negative fields that form the field dependence of the intensity in a butterfly shape. It has been shown that this dependence is due to the magnetostatic interaction between the filaments in the field range of H ≤ Hs. A theory for describing the magnetic properties of the arrays of interacting ferromagnetic nanofilaments in the magnetic field has been proposed.

SL28

Magnetic properties of nanometer scale FeCr antidot array system

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In this work, we have fabricated periodic nanometer scale antidot array of FeCr. The deposition was done using electron beam evaporation. The substrate was first coated with 100nm of a suitable resist (ZEP-520A) using spin coating. Then, the mask was patterned on the substrate using an electron beam attached to field emission scanning electron microscope to generate the necessary pattern. After the development, the FeCr (40nm) was coated onto the resist at 0.1A/s using electron beam evaporation. The antidot pitch was maintained at 400nm and the antidot diameter was found to be 300nm. The magnetic nature of the sample was characterized using vibrating sample magnetometer and the in-plane magnetic anisotropy of the system was investigated using torque magnetometer. Further, the magnetoresistance measurements were taken using an inline four point probe. The results indicate that the antidot array system has a predominant ferromagnetic nature, has an n-fold rotational symmetry with relation to the magnetic anisotropy. The easy axis, the hard axis of magnetization along with the net anisotropic energy has also been determined. All data have been appropriate discussed in the work. The use of antidot array systems for various applications is an intriguing new area of research.

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SL29

Fabrication of Al-Ni core-shell structured particles via electroless ni plating

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Al alloy powders have been of much interest in recent years due to their various applications such as metallurgical, chemical, paint & pigment industries, aerospace applications due to their lightness in weight and processability. Major research efforts have been made for improving their functionalities by addition or deposition of alloying elements such as Ni and by controlling the structure. However, it is difficult to fabricate these alloy powders by traditional metallurgical process and it is necessary to evolve new methods. Core-shell structured particles are attracting considerable attention as a consequence of their potential application in different areas of science and technology. Functionalizing the Al core with suitable shell materials indeed opens the door to specific physical, chemical and optical performances of Al. However, due to the oxide layer present on Al surface, it is difficult to plate Al with any metal or metallic base surface coating by post wet deposition techniques. Thus, we fabricated Al-Ni core-shell structured powders using electroless Ni plating. The pre-treatment was conducted for the formation of Ni shell as well as removal of the oxide layer. The formation of Ni shell on Al core powder was confirmed by SEM, XRD and VSM results.

SM01

Breakdown of barkhausen critical scaling behavior with increasing domain wall pinning in fe thin films

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We report a breakdown of Barkhausen critical scaling behavior in Fe films with increasing domain wall pinning by means of a Kerr microscope, capable of direct domain observation. From the the domain reversal patterns in the films, we find that the Barkhausen jump size generally decreases with increasing Fe thickness, showing the increased domain wall pinning density. Surprisingly, the power-law scaling behavior of Barkhausen jump size distribution gradually disappears as pinning of domain walls in the Fe layer increases. This is due to the fact that magnetization reversal mechanism is changed from a random Barkhausen avalanche dominant mode to thermally activated domain wall creep dominant mode.

SM02

Enhanced critical fields in MnSi thin films

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The magnetic properties of the cubic helimagnet MnSi are governed by the Dzyaloshinskii- Moriya interaction which in the bulk stabilizes a helical ground state below 29 K with a spin-helix wavelength of 18 nm and a propagation vector along the [111] direction. Recently, MnSi has attracted a lot of attention after a skyrmion lattice had been discovered in the so called A-phase. We have prepared thin MnSi films on Si(111) substrate by alloying a single Mn layer into the substrate as well as by codeposition of Mn and Si. RHEED analysis in combination with TEM investigation reveals that codeposition leads to smooth films whereas the alloying process generates rather three dimensional MnSi islands. In comparison to bulk material, the films show an enhanced magnetic ordering temperature of 45 K, which has been determined using SQUID magnetometry. Magnetization, resistivity, magnetoresistance, and Hall effect measurements have been performed on the films. They show that the critical fields describing the transition from the helical to a conical spin phase and from the conical phase to a parallel spin alignment are dependent on the film thickness and enhanced in comparison to single crystalline MnSi.

SM03

Magnetism and Cr_2O_3-Fe_2O_3 structure of CoFe/Cr-NOL surface

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Magnetoelectric (ME) effect has been investigated for realizing electric controlled spintronic device, such as MERAM. Cr_2O_3 is the most promising material for the application due to high Neel temperature (TN : ~307K). Switching exchange bias field by applying electric field using bulk Cr_2O_3 (0.6mm) has been reported [1]. Recently, we have observed high blocking temperature (TB : ~250K) of CoFe/Cr-NOL (Nano-Oxide-Layer) containing Cr_2O_3 and Fe_2O_3 (TN ~ 950K) in its surface, in spite of the ultrathin thickness (less than 1nm). The NOL is prepared by Natural Oxidation (N.O.) of CoFe and ultrathin (1ML) Cr layer [2]. To clarify the reason of high TB of the NOL is important for achieving thin Cr_2O_3 film that shows ME effect higher than room temperature. In this study, we have investigated the structure and magnetic property of CoFe/Cr-NOL by varying constitution condition, such as deposition system and N.O. intensity. It was found that mixing of Cr into CoFe layer before N.O. and high N.O. intensity cause the formation of Cr_2O_3-Fe_2O_3 solid solution in NOL surface, which lower the TB. It is indicated that the presence of not Cr_2O_3-Fe_2O_3 solid solution but the existence of both Cr_2O_3 and Fe_2O_3 is needed for high TB.

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SM04

Magnetic phase diagram for non-epitaxial Cr/Gd/Cr-multilayers

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In this work, the low-temperature phase and critical behavior at high temperature of inhomogeneous gadolinium-chromium samples were investigated using DC magnetization measurements. The samples were prepared as Cr(50nm)/Gd(100nm)/Cr(50nm) multilayers grown onto Si(110) single crystal substrates by means of sputter deposition. The samples' inhomogeneity was controlled by annealing at different temperatures Tan = 200, 400, and 500ºC during 10 minutes, and their magnetization was measured using zero field cooling (ZFC) and field cooling (FC) procedures at several applied fields. In the vicinity of room temperature, the magnetic behavior of the samples is compatible with a ferromagnetic ground state, which undergoes a rounded ferromagnetic (F)-paramagnetic (P) phase transition at a critical temperature, Tc. At temperatures below Tc, however, differences between the magnetization measured in the zero field cooling (Mzfc) and field cooling (Mfc) procedures are observed. Mfc decreases with increasing temperature. Mzfc increases with increasing temperature and, in addition to the F-P phase transition at Tc, shows a peak at a certain temperature Tg < Tc. It was also found that Mzfc is time dependent at low field and irreversible below an irreversible temperature Ti(H). A (H,T) phase diagram that contains Tc, Ti(H) and Tg(H) is presented for each of the samples.

SM05

Revealing the volume magnetic anisotropy of Fe films epitaxied on GaAs(001) surface

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Fe film grown on GaAs(001) is a model system for studying the spin injection from a ferromagnetic layer into the semiconductor substrate. The Fe/GaAs(001) system exhibits a remarkable in-plane uniaxial magnetic anisotropy (UMA) with an easy axis (EA) parallel to the GaAs[110] direction, and such UMA is usually believed to originate entirely from the Fe/GaAs interface. In this contribution, we will show our quantitative studies on the thickness dependent magnetic anisotropy in Au/Fe/GaAs(001) system using the magneto-optic Kerr effect with a rotating magnetic field. Through a clear 1/dFe relation of the UMA, we found a UMA component with the EA parallel to the GaAs direction which originates from the volume contribution. Such volume UMA is sensitive to the growth temperature and also strongly correlate with the interface anisotropy. We can conclude that both the volume anisotropy and the interfacial anisotropy are related to the ordered atomic structure at Fe/GaAs interface. Our results may introduce a new aspect for further understanding the origin of UMA in Fe/GaAs(001) system.

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SM06

Structures and magnetic properties of ultrathin Ni/Cu(100) in hydrochloric acid

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Microstructure and magnetic properties of ultrathin Ni/Cu(100) prepared by way of electrochemical approaches are investigated. In a pure supporting electrolyte, the STM image of the chloride covered Cu(100) surfaces show the formation of 90-degree step edges of the terraces as a result of the electrochemical annealing [1]. After adding $NiCl_2$, the hydrogen evolution reaction is advanced to a more positive potential. Nickel atoms attach onto the steps and the surface shows single atomic steps corresponding to a layer-by-layer growth. As the coverage of Ni increases, large amount of clusters form on the surface. The adsorption of chloride anions occurs on the top of the films [2]. For thin Ni layers, no magnetic hystsresis is observed due to the lowered Curie temperature for ultrathin overlayers. As the Ni coverage increases, hystsresis loop is observed with in-plane anisotropy of the films. For thicker films spin reorientation transition occurs that may be due to the strain relaxation in the Ni overlayer. The high squareness of the magnetic hysteresis loops confirms the smooth interfaces of the Ni films.

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