Magnetic Interfaces and Nanostructures
Room Hall A-C - Session MI-WeP
Poster Session

MI-WeP4 Magnetic and Structural Properties of Fe@sub 3@Pt/Fe Thin Films*, **M.A.I. Nahid**, T. Suzuki,* Toyota Technological Institute, Japan

Recently hcp phase of Fe@sub 3@Pt is stabilized by e-beam evaporation which shows 6-fold in-plane magnetic anisotropy (K@sub in@) of the order of 2x10@super 5@erg/cc.@footnote 1@ However it does not show significant perpendicular magnetic anisotropy (K@sub per@).Theoretical calculation by A. Sakuma predicts that uniaxial anisotropy is expected in a Fe@sub 3@Pt/Fe system.@footnote 2@ Therefore it is investigated the magnetic properties of Fe@sub 3@Pt/Fe system in conjunction with structure. The thickness of Fe underlayer(d) was varied from 0-300Å. The hcp phase of Fe@sub 3@Pt thin films has been synthesized onto Al@sub 2@O@sub 3@(00.1) substrate using Fe underlayer by e-beam evaporation at deposition temperature 400°C. The epitaxial relationship is found as Al@sub 2@O@sub 3@(00.1)[10.0]||Fe(110)[1-10]||Fe@sub 3@Pt(00.1)[11.0]. The superlattice peak (00.1) intensity of Fe@sub 3@Pt changes with Fe underlayer thickness and becomes maximum at the 100Å. The 6-fold symmetry of Fe@sub 3@Pt was observed in the so called @PHI@-scan measurement when the X-ray is irradiated at the grazing angle. From the perpendicular hysteresis loop of Fe@sub 3@Pt measured by MO polar kerr instrument, the coercivity and remanence is found to increase with Fe thickness and becomes constant after d=200Å. This suggests that a perpendicular magnetic anisotropy (K@sub per@) exists in the Fe@sub 3@Pt thin films by using Fe underlayer. The maximum K@sub per@ is about 3x10@super 6@erg/cc at d=100-150Å. Besides the K@sub per@, the Fe@sub 3@Pt films possess the 6-fold in-plane magnetic anisotropy (K@sub in@) which increase with increasing d and become constant after 200Å. The maximum K@sub in@ of Fe@sub 3@Pt is obtained about 3.2x10@super 5@erg/cc which is much larger than that of Co.@footnote 3@ @FootnoteText@ @footnote 1@M.A.I. Nahid and T.Suzuki: Accepted for publication in the IEEE trans. on Magn. Sep,2003. @footnote 2@A.Sakuma: J. Phy. Soc. Japan. 64,4317(1995). @footnote 3@Y. Kadena: J.Sci. Hiroshima Univ.31,21(1967). .

MI-WeP5 Ultrafast Laser Measurements of Electron and Spin Dynamics in Half-metallic CrO@sub 2@ Thin Films*, **H. Huang**, K. Seu, A.C. Reilly,* College of William and Mary*; W.F. Egelhoff, Y. Kadmon,* National Institute of Standards and Technology

Half-metallic ferromagnets are an important class of materials in which one spin state is conducting while the other has a semiconductor-like gap. While evidence of half-metallic behavior has been found, there are still many questions regarding the bandstructure and dynamics in these materials. Ultrafast laser pump-probe techniques have shown great promise for elucidating such information in a variety of materials. Recently, such pump-probe techniques have been applied to study spin dynamics@footnote 1@ in Sr@sub 2@FeMoO@sub 6@ and coherent magnetization rotation@footnote 2@ in CrO@sub 2@. We will present measurements of charge and spin dynamics in half-metallic CrO@sub 2@ thin films by ultrafast laser pump-probe reflection, transmission and MOKE experiments as a function of temperature and energy (wavelength). We find that the pump-probe reflection and transmission consist of components simlar to those seen in the other half-metallic systems such as LCMO and Sr@sub 2@FeMoO@sub 6@: An initial fast peak which decays within ~ 1 ps, and a longer component with a rise of ~ 10 ps and a decay time of ~ 500 ps. This may indicate similar mechanisms for these systems. We attempt to correlate the temperature dependence with the two-order-of-magnitude increase in resistivity with temperature that is taken as a signature of the half-metallic behavior. The wavelength dependence is used to explore the bandstructure. For example, we observe different electron and spin dynamics for excitation energies of 1.5 eV and 3 eV, corresponding to the energies of excitation within the conducting spin-up band and across the gap for the spin-down state. @FootnoteText@ @footnote 1@T. Kise et al., Phys. Rev. Lett., 85, 1986 (2000). @footnote 2@Qiang Zhang et al., Phys. Rev. Lett., 89, 177402 (2002).

MI-WeP7 Spin-polarized Scanning Tunneling Microscopy Study of Ferromagnetic Arrays Fabricated by In-situ Alumina Shadow Mask*, **J.H. Choi**, T.-H. Kim, S.H. Kim, Y. Kuk,* CSNS and Seoul National University, Korea

Spin-polarized scanning tunneling microscopy(SPSTM) can detect the local electron spin density of the sample surface in atomic resolution, so it has been used to study magnetic properties of ferromagnetic materials. However, SPSTM study of patterned nanomagnetic arrays has not been done because all the fabrication process of nanomagnetic arrays must be done in-situ in UHV chamber to avoid contamination problems. We fabricated a shadow mask for in-situ SPSTM study of nanomagnetic arrays on Si wafer. 500nm thick aluminum was thermally evaporated on Si wafer and indented by SiC mold to produce an ordered pore of porous alumina. The sample was electrochemically anodized in oxalic acid. After pore widening and removing barrier layer, we opened 5x5mm@super 2@ window on backside Si substrate by photolithography and etched Si wafer completely using deep silicon etch process until the aluminum layer was appeared. Fabricated shadow mask was mounted in front of Si substrate in UHV chamber. Fe was evaporated on a Si wafer through shadow mask, forming nanomagnetic arrays of 30-80nm dia. The magnetic properties of ferromagnetic arrays studied by SPSTM will be discussed.

MI-WeP8 Properties of Self-assembled Nanowires Fabricated using Glancing Angle Deposition*, **H. Alouach**, G.J. Mankey,* University of Alabama

The spin-dependent transport in nanoscale spin electronic devices, such as Current Perpendicular to the Plane Giant Magnetoresistive (CPP-GMR) devices, is closely dependent on the spin arrangement and physical properties of single wires. Self-assembled Cu and permalloy nanowires were deposited using glancing angle electron beam evaporation technique with and without substrate rotation. Wire texture and crystallographic orientation of such features are known to be strongly dependent on the deposition parameters. We report an unprecedented and efficient method allowing determination of the crystal orientation independent of the geometrical wire and grain orientation. For Cu wires deposited without substrate rotation, the (111) crystal orientation, which corresponds to the close packed low energy surface of Cu, coincides with the geometrical wire orientation. Whereas, for Cu wires deposited with azimuthal rotation of the substrate, the (111)-crystal direction and the wire orientation are different depending on the rotation speed. We compared the validity of the empirical tangent rule@footnote 1@ and the geometrical Tait rule@footnote 2@ which are different equations which describe the relationship between the incident flux angle and the resulting wire orientation. Applications in nanowire circuits will also be discussed. @FootnoteText@ @footnote 1@ J.M. Nieuwenhuizen and H.B Hannstra., Philips Tech. Rev. 27, 87 (1966)@footnote 2@ R.N. Tait, T. Smy and M.J. Brett, Thin Solid Films 226, 196 (1993) .

MI-WeP9 Characterization and Room-temperature Ferromagnetic Properties Of Ti@sub 1-x@Co@sub x@O@sub 2@ Films Prepared by Cobalt Implantation*, K.H. Cheng, K.W. Lo, C.F. Chow, Y.W. LAI, W.M. Tsang, N. Ke, W.Y. Cheung,* Chinese University of Hong Kong*; **S.P. Wong**,* Chinese University of Hong Kong, Hong Kong

In this work, TiO@sub 2@ thin films were prepared by RF sputtering onto thermally grown oxide layers on Si substrates. Cobalt implantation was performed using a metal vapor vacuum arc (MEVVA) ion source at an extraction voltage of 65 kV to doses ranging from 1.4x10@super 16@ cm@super -2@ to 1.4x10@super 17@ cm@super -2@. Annealing was performed in vacuum at 600@super o@C for 2h. The cobalt composition and distribution in these implanted Ti@sub 1-x@Co@sub x@O@sub 2@ films was studied using Rutherford backscattering spectrometry. The crystal structures were studied using x-ray diffraction. The optical properties were studied using spectroscopic ellipsometry in the wavelength range from 350 to 700 nm. The magnetic properties were measured by vibrating sample magnetometry. We observed clear room-temperature ferromagnetic properties for all the as-implanted and annealed samples prepared under the above conditions. The measured M@sub S@ values ranged from 0.5 µ@sub B@/Co atom to 2.1 µ@sub B@/Co atom and the coercivity values ranged from 200 Oe to 500 Oe, depending on the Co dose and annealing conditions. The correlation between the optical properties, the magnetic properties and their structures will be discussed. This work is supported in part by the Research Grants Council of Hong Kong SAR (Ref. number: CUHK4216/00E and CUHK4221/00E).

MI-WeP10 Characterization of Transition Metal Doped CVD-grown ZnO Films*, D. Hill, J. Quinn, L. Wielunski, **R.A. Bartynski**, P. Wu, Y. Lu, G. Popov, M. Greenblatt,* Rutgers University

A crucial element for the success of spintronics is finding a material that combines the desirable properties of ferromagnets and semiconductors. Diluted magnetic semiconductors (DMS) are intriguing materials that offer the possibility of studying magnetic phenomena in crystals with a simple band structure and excellent magneto-optical and transport properties. ZnO, a wide bandgap (~3.3 eV) semiconductor that has received increasing attention due to its broad applications and its many desirable material properties, has recently has been identified as a promising DMS candidate for room temperature spintronics. We have characterized the chemical, compositional, and magnetic properties of TM-doped ZnO films grown by MOCVD. Doping using V, Mn, Fe, Co, and Ni has been investigated. X-ray photoelectron spectroscopy indicates that the TM dopant is in the 2+ oxidation state and thus may be substitutional for Zn. Squid magnetometry measurement show that the Mn- and Fe-doped films exhibit ferromagnetic behavior, with Mn-doped films having a Curie temperature of ~ 45K. For Fe-doped films, the Curie temperature is above room temperature. Both Rutherford backscattering spectrometry and XPS depth profiling indicate that Mn and Ni show extensive diffusion while Fe and Co exhibit more penetration into the ZnO film.

MI-WeP11 Epitaxial Growth, Structural, and Magnetic Properties of a Chalcopyrite Magnetic Semiconductor: MnGeN2, *S. Hardcastle, **L. Li**,* University of Wisconsin, Milwaukee

Epitaxial thin films of MnGeN2 were grown on Al2O3(0001), 6H-SiC(0001), and MgO(111) substrates using ECR plasma assisted MBE at 500 C. In situ RHEED studies indicated that the growth was 3D, consistent with ex situ AFM investigations. X-ray diffraction studies revealed that the films are single-phased material. Hysteresis loop with a coercive field of 100 Oe was observed at 300 K using a SQUID magnetometer, indicating ferromagnetic ordering at room temperature.

MI-WeP12 Ferromagnetism in Epitaxial Mn:Ge Films, ***A.P. Li,*** Oak Ridge National Laboratory*; C. Zeng,* The University of Tennessee*; Z. Gai, J.F. Wendelken,* Oak Ridge National Laboratory*; H.H. Weitering,* The University of Tennessee and Oak Ridge National Laboratory*; J. Shen,* Oak Ridge National Laboratory

We report on the magnetic properties of Mn-doped homo-epitaxial Ge films. Two different approaches are used to fabricate ferromagnetic Ge films. In the first approach, Mn-doped Ge films were grown on (2x1) reconstructed Ge(100) using molecular beam epitaxy (MBE) as was reported by Y.D. Park et al (Science 295, 651 (2002)). The Mn-concentration was varied between 1% and 5%. The Ge films show ferromagnetic ordering with Curie temperatures ranging from 25 K to 295 K, which have been determined from the remnant magnetization measured with a SQUID magnetometer. The magnetic response appears to consist of two different contributions, namely the ferromagnetic response from the dilute magnetic semiconductor (DMS) and the response from ferromagnetic alloy precipitates. X-ray diffraction (XRD), Rutherford Backscattering, and ion-channeling experiments were used to characterize the stoichiometry, homogeneity, and epitaxial quality of the films. In the second approach, a 40 nm Mn film is deposited onto Ge(111) and annealed to 150 °C for several minutes. Scanning Tunneling Microscope and XRD measurements show a high-quality epitaxial Mn@sub 5@Ge@sub 3@ alloy film with Mn@sub 5@Ge@sub 3@(001)//Ge(111). The Curie temperature of this ferromagnetic alloy film is 295 K, which is similar to that of bulk Mn@sub 5@Ge@sub 3@. The identical Tc of the epitaxial alloy film and Mn-doped Ge(100) films strongly suggests that the DMS film contains bulk Mn@sub 5@Ge@sub 3@ precipitates. These precipitates are below the detection limit of XRD. This thin film ferromagnetic system has good potential for spin-injection studies in silicon-compatible semiconductors. This research was sponsored by the LDRD Program of Oak Ridge National Laboratory, managed by UT-Battelle, LLC, for the U.S. Department of Energy under Contract No. DE-AC05-00OR22725.

MI-WeP13 Increase of Conductance and Magnetoconductance with Oxygen Exposure During Deposition of Spinvalves, ***A.T. McCallum**, S.E. Russek,* National Institute of Standards and Technology

It has been found that the magnetoconductance and conductance of spinvalves increase when a small partial pressure of oxygen(1 x 10@super -9@ - 5 x 10@super -9@ torr)is present during deposition. Conductance measurements made during the sputter deposition of spin valves show directly that the conductance increases are occurring in the active layers of the spin valve flims. The Ne`el coupling between the free layer and the pinned layer is also reduced suggesting that the oxygen is leading to smoother growth. Eventually a high enough partial pressure of oxygen will lead to oxidation of the deposited metal and a drop in giant magnetoresistance. A series of conductance measurements at different gas flows show the onset of oxidation beginning with the NiFe and Cu layers. Relatively thick layers of material also have a higher conductance when grown in the presence of oxygen. The in-situ conductance measurement for NiFe layers reveal that the increase in conductance is starts at 1 nm and ends at 5 nm. After this the differential conductivity is the same for samples grown with and without oxygen. This is consistent with the samples grown in oxygen having a smoother surface but essentially the same microstructure.

MI-WeP14 Exploring Spintronic Materials and Structures with Interatomic Potentials, ***D.A. Murdick**, X.W. Zhou, H.N.G. Wadley,* University of Virginia*; D.G. Pettifor, D. Nguyen-Manh,* University of Oxford

The use of interatomic potentials in atomistic simulations has become a powerful approach for studying the atomic structures of materials. Molecular dynamic atomic simulations allow assembly phenomena encountered during the synthesis of spintronic devices to be analyzed in detail and allow the optimization of process conditions for desired spintronic structures and compounds. This approach has been successfully applied in metal/metal oxide multilayer systems to identify the deposition conditions for creating atomically smooth interfaces with minimized interlayer mixing. The extension of such an approach into semiconductors is very promising. The key to this is the availability of a high fidelity interatomic potential that can accurately describe covalent bonding in doped compound semiconductors and can be used for simulation of vapor deposition to reveal the time-dependent atomic structure as a function of processing conditions. We demonstrate that the existing literature multi-component interatomic potentials are too limited for spintronic applications. We describe a new class of bond-order potentials that overcome these limitations. The bond order potential has been successfully applied for GaAs systems and is being extended to (Ga,Mn)As/GaAs heterostructures and other doped semiconductors of group IV and III-V semiconductors.

MI-WeP15 The Isomer Dependent Semiconductors of Boroncarbide, ***A.N. Caruso**,* University of Nebraska*; L. Bernard,* Ecole Polytechnique Federale de Lausanne*; B. Doudin, P.A. Dowben,* University of Nebraska

We demonstrate that boroncarbide, grown by chemical vapor deposition, is an effective dielectric barrier layer for magnetic tunnel junctions. Decomposition of the insulator closo-1,2 dicarbadodecaborane or orthocarborane (C@sub 2@B@sub 10@H@sub 12@) has been shown to form p-type semiconducting boron carbide (C@sub 2@B@sub 10@).@footnote 1-4@ We present recent photoemission results which indicate that closo-1,7 dicarbadodecaborane or metacarborane (C@sub 2@B@sub 10@H@sub 12@) forms an n-type semiconducting boroncarbide (C@sub 2@B@sub 10@) upon decomposition. Bonding, orientation, and electronic structure of the two materials in both associative and decomposed configurations are compared as adsorbates. The electronic structure of orthocarborane and metacarborane are calculated to be very similar, but there are significant differences in the experimental binding energies for each isomer as an adsorbed species. Metacarborane adsorbs on both Co and Au with the Fermi Level (chemical potential) placed closer to the lowest unoccupied molecular orbital than is observed with orthocarborane adsorbed on Co and Cu. @FootnoteText@@footnote 1@ S. Lee and P.A. Dowben, Appl. Phys. A 58 (1994) 223. @footnote 2@ Dongjin Byun, Seong-don Hwang, Jiandi Zhang, Hong Zeng, F. Keith Perkins, G. Vidali and P.A. Dowben, Jap. Journ. Appl. Phys. Lett. 34 (1995) L941-L944@footnote 3@ D.N. McIlroy, C. Waldfried, T. McAvoy, Jaewu Choi, P.A. Dowben and D. Heskett, Chem. Phys. Lett. 264 (1997) 168-173@footnote 4@ Seong-Don Hwang, Ken Yang, P.A. Dowben, Ahmad A. Ahmad, N.J. Ianno, J.Z. Li, J.Y. Lin, H.X. Jiang and D.N. McIlroy, Appl. Phys. Lett. 70 (1997) 1028-1030 .

MI-WeP16 Extraordinary Hall Effect in Mn Ion-implanted p@super +@GaAs:C*, ***J.D. Lim**, S.B. Shim, K.S. Suh, Y.D. Park,* Seoul National University, Korea*; C.R. Abernathy, S.J. Pearton,* University of Florida*; R.G. Wilson,* Consultant

Gas source molecular beam epitaxy (GSMBE) prepared p@super +@GaAs:C (p = 3 x 10@super 20@cm@super -3@) on SI GaAs substrate was ion-implanted with Mn at 250 keV (at 350° C) with dose ranging from 1 - 5 x 10@super 16@ cm@super -2@. AC-magnetotransport measurements were conducted in Van der Pauw geometry using indium soldered contacts on as-implanted samples (I@sub ac@ = 100@mu@A @@ 17.1 Hz). Resistivity as function of temperature (@rho@ vs. T) for various applied fields showed anomalies consistent with magnetic properties. For various applied fields (up to 9 Tesla) for the temperature range considered (5 K - 400 K), the magnetoresistance (MR) was found to be positive, as oppose to nanometer-sized ferromagnetic clusters embedded in semiconductor matrix systems, which generally show a cross-over in sign of MR.@footnote 1@ Hall Effect measurement show a positive response consistent with overall p-character of the implanted samples. Sheet resistance increased with dose due to the expected implantation damage, and sheet carrier concentration as measured at 300 K increased with dose. Determination of the exact carrier concentration was made difficult with the onset of extraordinary Hall Effect (EHE) below 280 K (where @rho@@sub H@=R@sub o@B + R@sub S@H), again consistent with magnetic properties. For specific temperature range, the dominant EHE mechanism was found to be skew scattering (R@sub s@ ~ c@rho@). An apparent mobility enhancement was not observed as reported in inhomogeneous systems.@footnote 2@ Along with detailed magnetotransport measurements, effects of temperature of sample during implantation process and post-implantation anneal processes will be discussed. @FootnoteText@@footnote *@ partially supported by Samsung Electronics Endowment and KOSEF through CSCMR.@footnote 1@ H. Akinaga et al., Appl. Phys. Lett. 72, 3368 (1998); D.R. Schmidt et al., Phys. Rev. Lett. 82, 823 (1999).@footnote 2@ Sh.U. Yuldashev et al., J. Appl. Phys. 90, 3004 (2001).

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