Magnetic Interfaces and Nanostructures
Room 316 - Session MI+TF-WeA

Magnetic Thin Films

Moderator: D.P. Pappas, National Institute of Standards and Technology

2:00pm **MI+TF-WeA1 Electrodeposition of Epitaxially Grown Fe Films on n-type GaAs**, *C. Scheck, **Y.-K. Liu,*** The University of Alabama; *G. Zangari,* University of Virginia; *R. Schad,* The University of Alabama

Epitaxial growth of Fe thin films on both n-type GaAs(001) and n-type GaAs(011) substrates have been demonstrated using Molecular Beam Epitaxy (MBE) in the past. Indeed, Fe and GaAs lattice constants match very well leading to easy epitaxial growth. However, special surface preparation or growth at elevated temperature were needed to obtain good quality films. Also diffusion and segregation of substrate material (As) at the surface, characteristic of intermixing at the interface, were observed on MBE grown films. Electrodeposition (ECD) technique on the contrary is an equilibrium process which thus releases much less energy per absorbed atom than other deposition techniques (MBE). This allows preparation of chemically sharp interfaces (i.e. no intermixing) which otherwise show a high degree of reactivity and interdiffusion. We reported for the first time the epitaxial growth of high quality Fe thin films on both n-type GaAs(001) and n-type GaAs(011) substrates using ECD. Two different electrolytes FeSO4 and FeC§¤2 solutions 0.1M were used at pH 2.5. Results from X-Ray Diffraction (XRD) show Fe(001)[110]//GaAs(001)[110] and Fe(011)[100]//GaAs(011)[100] as the primary epitaxial relations similarly to Fe films grown by MBE. These films' in-plane magnetic anisotropy is related to the crystalline structure. Their coercivity Hc is around 30-100 Oe.

2:20pm **MI+TF-WeA2 Epitaxial Growth of Ferromagnetic Fe Overlayers on CH@sub 3@CSNH@sub 2@ - Passivated GaAs(100)-S(2x1) Reconstruction**, ***E.D. Lu**, H.T. Johnson-Steigelman, P.F. Lyman,* University of Wisconsin, Milwaukee

Epitaxial growth of ferromagnetic metallic Fe overlayers on thioacetamide (CH@sub 3@CSNH@sub 2@)-passivated GaAs(100)-S(2x1) reconstructed surfaces at room temperature (RT) has been investigated by low energy electron diffraction (LEED), x-ray photoelectron spectroscopy (XPS) and Auger electron spectroscopy (AES). Prior to Fe deposition, GaAs(100) wafers were passivated by CH@sub 3@CSNH@sub 2@ solution then annealed between 320°C and 450°C under UHV. A clear (2x1) reconstructed LEED pattern with around 1 monolayer (ML) sulfur coverage resulted. Upon deposition of Fe at RT, epitaxial bcc(100) Fe overlayers could be grown from 3 to 40 ML. XPS and AES have revealed that only an initial interface reaction (<4ML) takes place between the evaporated Fe overlayer and GaS sulfide passivation layers. Upon annealing, the Fe/S-GaAs(100) heterostructure appears stable up to 320°C; solid state reaction and/or interdiffusion of the layers starts at higher annealing temperatures, becoming severe by 450°C. Nonetheless, a LEED pattern is observed even after intermixing. These results indicate that the S passivation layer may inhibit Ga and As outdiffusion at modest substrate temperatures, and may thus suppress or reduce the formation of an anti-ferromagnetic Fe@sub 2@As dead layer or other unfavorable Fe@sub 3@Ga@Sub 2-x@As@sub x@ phases.

2:40pm **MI+TF-WeA3 On the Magnetic Properties of Ultra Thin Epitaxial Fe Films on GaAs(001)**, *S.A. Morton,* Lawrence Livermore National Laboratory; *J.R. Neal, M. Spangenberg, T.-H. Shen,* University of Salford, UK; *A.E.R. Malins, E.A. Seddon,* CLRC Daresbury Laboratory, UK; *D. Greig,* University of Leeds, UK; *J.A.D. Matthew,* University of York, UK; ***G.D. Waddill,*** University of Missouri, Rolla; *J.G. Tobin,* Lawrence Livermore National Laboratory

The magnetic properties of epitaxial Fe films on GaAs have attracted considerable interest in recent years because of their potential for use as spin injection sources for spintronic devices; however, previous studies have been unable to demonstrate a magnetic signature in films with thicknesses below approximately 5 ML. A number of possible explanations for this observation have been proposed such as the presence of a magnetically dead interfacial layer of Fe2As. However, by measuring the thickness and temperature dependence of the Fe 3p core level magnetic linear dichroism signal we have shown that such films are indeed ferromagnetic but that their Curie temperature is substantially below room temperature. For instance a Tc of approximately 240K was measured for thin films with a nominal thickness of 0.9 nm. Furthermore the values of the Curie temperature in this thickness regime have been shown to be extremely sensitive both to initial substrate conditions and to the overall film thickness; an increase in the thickness of 0.35nm results in a Curie temperature above room temperature. These measurements have been complemented with spin resolved and angle resolved measurements of the Fe/GaAs valence band and core levels; together with ex-situ XRD and SPM studies of sample growth. The origins of the evolving magnetic behavior of Fe films on GaAs(001) from 1-50ML is discussed in terms of the spin dependent electronic band structure and the stoichiometry and growth morphology.

3:00pm **MI+TF-WeA4 Correlated Structural and Magnetization Reversal Studies on Epitaxial Ni Films Grown with MBE and with Sputtering**, ***Z. Zhang***[1], *R.A. Lukaszew,* University of Toledo; *A. Zambano,* Michigan State University; *C. Cionca,* University of Michigan, Ann Arbor; *D. Walko,* Argonne National Laboratory; *E. Dufresne,* University of Michigan, Ann Arbor; *M. Yeadon,* National University of Singapore, Singapore; *R. Clarke,* University of Michigan, Ann Arbor

The study of epitaxial magnetic thin films is important to understand structure-property correlations. We have studied the correlation between film structure and azimuthal dependence of the magnetization reversal on (001) epitaxial Ni films grown on MgO substrates with two different deposition techniques: molecular beam epitaxy (MBE) and DC magnetron sputtering . The films were grown and annealed in-situ under identical conditions. The magnetization reversal was investigated using MOKE. The coercive field in the sputtered films exhibits 4-fold symmetry as expected for a crystal of good epitaxial quality. The MBE grown films exhibit an additional uniaxial symmetry superimposed to the four-fold symmetry. We note that films of the same thickness made with these two deposition techniques, exhibited the same average coercivity. We performed high-resolution XRD at the Advanced Photon Source (ANL) in order to establish similarities and differences in the structure of the films. Both types of films exhibit epitaxial growth and very good crystalline quality with no indication of strain, and don't exhibit fundamental structural differences. The main difference between the films was the surface morphology. STM images of the surface of the MBE grown films indicated self-assembled periodic stripe nano-patterning, while STM images of the sputtered films didn't exhibit any regular patterning of the surface. Cross sectional TEM studies performed on the films will be correlated with the surface morphology and with the magnetic anisotropy.

3:20pm **MI+TF-WeA5 Adsorption-induced Giant Stress and Surface Relaxation in Ni/W(110)**, ***H.L. Meyerheim**, D. Sander, R. Popescu,* Max-Planck-Institut f. Mikrostrukturphysik, Germany; *O. Robach, S. Ferrer,* ESRF, France; *J. Kirschner,* Max-Planck-Institut f. Mikrostrukturphysik, Germany

Surface stress has been recognized as a decisive factor, which determines a variety of phenomena like self-assembled pattern formation on the nano-scale, shape evolution of nano-objects and surface reconstruction. Our work reveals an important aspect of adsorbate-induced stress which might be of key importance for the general understanding of stress-strain relations in the monolayer range. We identify an intimate correlation between structure and stress from an in-situ combination of surface x-ray diffraction and stress measurements. We show that one atomic layer of Ni induces substantial lateral shifts of the top W-atoms of up to 0.5 Å. At this coverage we measure an anisotropic change of the surface stress induced by Ni. The experiments were carried out at the ESRF in Grenoble (France). Surface stress was measured by the crystal curvature technique.@footnote 1@ From earlier experiments@footnote 2@ it is known that Ni forms a c(1x7) superstructure on W(110) at a coverage above 0.8 monolayers (ML, 1ML=1.41x10@super15@ atoms/cm@super2@). Up to 0.8 ML the stress measurements indicate compressive stress along [001] and tensile stress along [1-10]. The emergence of the c(1x7)-structure coincides with the formation of compressive stress along [1-10]. The x-ray analysis shows that the Ni-atoms form a distorted densely packed hexagonal adlayer. However, the most important and astonishing aspect is the pronounced shifts (up to 0.5 Å) of the first layer W-atoms out of their bulk positions along [1-10]. The structure consists of alternating Ni-W-Ni-chains running along [1-11]. In conclusion we have measured a substantial adsorbate-induced relaxation in a system, which is generally considered to be structurally inert upon adsorbate deposition. There is a striking correlation between the onset of lateral shifts of atomic positions and compressive surface stress. @FootnoteText@@footnote 1@D. Sander et al. Rev. Sci. Instr. 66, 4734 (1995); @footnote 2@D. Sander et al. Phys. Rev. B57, 1406 (1998).

[1] **Falicov Student Award Finalist**

3:40pm **MI+TF-WeA6 Ion Deposited Co and DLC Films Generated from Laser Excitation*, F.J. Cadieu,*** *L. Chen,* Queens College of CUNY

A modified pulsed laser deposition system has been used to deposit films from ions generated due to the impact of 248 nm excimer laser pulses. A synchronously pulsed magnetic field coil with a wide entrance throat and a tapered bore in conjunction with a set of permanent magnets has been used to capture and concentrate the ion and electron beam flux under vacuum conditions onto the substrates. Co and other films such as diamond like carbon, DLC, are strongly adherent when deposited onto even room temperature substrates. The ion collection and concentration factor is such that Co films deposited on glass to an optical density of 3.0, approximately 7 nm thickness, with coil pulsing and magnets only exhibited an optical density of 0.10 without coil pulsing and magnets for the same number of laser pulses. Films have been characterized by x-ray reflectivity, x-ray diffraction, scanning electron microscopy, SEM, and magnetoresistivity measurements when combined with other magnetic layers. Over an order of magnitude intensity modulation has been observed in x-ray reflectivity measurements for Co films, 7-15 nm thickness, deposited onto R-plane sapphire substrates and onto Si (111) substrates. In contrast to this Co films simultaneously deposited onto A-plane sapphire substrates hardly exhibited x-ray reflectivity fringes indicating a large surface roughness. Similarly DLC films deposited onto (111) Si substrates exhibited order of magnitude intensity modulations indicating a very small surface roughness. X-ray reflectivity measurements of DLC, Co layers on (111) Si are used to show the conditions necessary to make smooth and hence insulating DLC films onto the metallic layer. SEM measurements indicated smooth films were obtained with no discernible particulates. X-ray pole figures are used to characterize single crystal films versus polycrystalline growth modes.

4:00pm **MI+TF-WeA7 Ultrathin Magnetic Layers Electrodeposited on Au(111)and Related Technological Substrates*, P. Allongue,*** *F. Maroun,* CNRS, France*; J.E. Schmidt, A. Gundel,* UFRGS*; M.L. Munford,* UFSC*; T. Devolder,* IEF, France **INVITED**

Magnetic properties such as interface perpendicular anisotropy (PMA) is strongly depending on the coupling between the substrate, generally a noble metal, and the ultrathin ferromagnetic layer. Both the film and interface structures are also critically influencing the strength of PMA. We recently showed that electrodeposited Cu/Co/Au(111) structures exhibit strong PMA due to an excellent 2D epitaxial growth of cobalt and some residual elastic stress at the interface. This talk will be divided into two parts. In the first one, I will present in situ structural and magnetic characterizations of M / Au(111) ultrathin layers, with M = Co, Ni and Fe using STM, EXAFS and real time in situ magnetic characterizations (AGFM and PMOKE) with sub-monolayer sensitivity. It will be shown that the latter measurements, performed in the electrolytic environment, yield new information regarding the relationship between the deposition conditions (potential, pH etc.) and the magnetic state of layers. While Co and Fe layers are ferromagnetic at submonolayer coverages, results show that Ni layers become ferromagnetic only after the deposition of 5-6 monolayers. By proper adjustment of the deposition condition, so as to avoid dramatic H-incorporation, ultrathin ferromagnetic Ni layers may however be prepared. The strength of PMA at Co/Au(111) layers will be discussed in details. The second part of the talk will address the deposition of cobalt on epitaxial Au(111) layers on vicinal H-Si(111) surfaces. We are able to prepare ultraflat Au films or Au films consisting in nm-sized dots aligned along the step edges. As a consequence, we may prepare Co/Au/Si films with quite different magnetic properties. For instance, in the case of Au dots in plane anisotropy is obtained and it is possible to vary the coupling between lines of Co dots by changing the Si miscut. These results will be discussed in details at the conference.

4:40pm **MI+TF-WeA9 The Effect of Interlayer Coupling to the Magnetic Phase Transition of Thin Films*, C. Won,*** *Y.Z. Wu,* University of California at Berkeley*; A. Scholl, A. Doran,* Lawrence Berkeley National Laboratory*; N. Kurahashi, H.W. Zhao, Z.Q. Qiu,* University of California at Berkeley

Magnetic phase transition of two-dimensional systems is one of the intensively studied topic in condensed matter physics. One of the basic questions on this subject is how the addition of the interlayer coupling changes the magnetic phase transition. The coupled magnetic sandwiches of Co/Fe/Ni/Cu(100) and Co/Cu/Ni/Cu(100) were investigated by photoemission electron microscopy(PEEM). Element-specific magnetic domain images were taken at room temperature to reveal the critical thickness at which the magnetic phase transition occurs. The phase diagrams with thickness of each magnetic film were constructed under a few selected coupling conditions. The results shows three different types of magnetic phase transitions depending on the relative ferromagnetic film thickness. If the magnetic orders of two magnetic films are similar, both films undergo magnetic phase transition simultaneously. This means the lost of magnetic order of one film can be compensated by the interlayer coupling with the other magnetic film and two magnetic films are highly correlated each other in the interlayer coupling strength. Other two phase-transitions happened when one film is coupled with the other film that is too thin to have magnetism even with the help of coupling or that is ferromagnetic already by its own magnetic order. The difference of the critical thickness for these two cases shows that interlayer coupling increases Curie temperature. The strength and sign of coupling was changed to see how the coupling strength changes this behavior and we found that not the sign but the coupling strength has main role in the phase transition. And Monte-Carlo simulations based on 2 dimensional Ising model were performed to explain this experimental results.

5:00pm **MI+TF-WeA10 Biased Target Ion Beam Deposition of GMR Multilayers***, H.N.G. Wadley,* ***X.W. Zhou****, J.J. Quan, S. Subha,* University of Virginia*; T. Hylton, D. Baldwin,* 4Wave, Inc.

Detailed atomistic simulations have identified the preferred deposition conditions for growing the ideal atomic structures that maximize the performance of giant magneto resistive (GMR) multilayers. They reveal that increasing the velocity (energy) of condensing atoms or assisting ion fluxes flattens interfaces, but promotes atomic interlayer mixing. The maximum magneto resistance is believed to occur for the lowest combination of interfacial roughness and interlayer mixing. Low values of this metric have been predicted to occur using a constant intermediate energy of a few electron volts throughout the growth process. However, the lowest values of the metric have been predicted to occur when a modulation of the energy during deposition of each material layer is used. It is difficult to implement such processes in a conventional PVD or ion beam system. We have developed a biased target ion beam deposition system to overcome these difficulties and report its design and the characteristics of the spintronic devices grown with it.

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