Magnetic Interfaces and Nanostructures
Room: Hall 3 - Session MI-ThP

Magnetic Interfaces and Nanostructures Poster Session

MI-ThP1 Characterization of Aluminum Oxide Tunnel Barrier for use in a Non-Local Spin Detection Device, ***J.R. Abel***, *J.J. Garramone, E. Bersch, A.C Diebold, V.P. LaBella*, University at Albany

Aluminum oxide can be utilized as an interface layer between ferromagnetic metals and silicon to achieve spin injection into silicon. Utilizing the spin of the electron as well as its charge has the potential to be utilized for logic devices in the post CMOS era. The goal of our research is to inject and readout spins using a non-local measurement device that utilizes 1-2 nm aluminum oxide interface layers as tunnel barriers.

The first step of fabricating a non-local measurement device out of silicon is the growth of an aluminum oxide tunnel barrier[1]. Si (001) wafers were dipped in 49% HF solution for approximately 2 min to remove the native oxide layer. The wafers were then immediately loaded into an ultrahigh vacuum MBE machine, degassed at 400 C and cooled to room temperature. After cooling, a desired thickness of aluminum was deposited from a Knudsen cell. The sample was then transferred back into the load lock and exposed to approximately 130 mTorr of pure O_2 for 20 min. The process was repeated to create samples with a thickness of 1 nm, 2 nm, and 3 nm of aluminum oxide. Each thickness was grown in 0.5 nm and 1 nm steps. In addition, a 2 nm sample was grown, in one 2 nm step.

X-ray photoelectron spectroscopy was performed to characterize the film stoichiometry. It was observed that all the aluminum was bonded to the oxygen for the films grown in 0.5 nm and 1 nm steps. Whereas the 2 nm sample grown in one 2 nm step not all the aluminum bonded to oxygen, leaving a partially un-oxidized aluminum film. In addition XPS was used to measure the band gap of the fully oxidized films to be 6.61 eV in good agreement with films of similar thickness[2]. We will also report on current voltage measurements of these films after they have been capped with metal and application of "Rowell criteria" to demonstrate tunneling as the dominant transport mechanism.

References:

[1] O. van't Erve, A. Hanbicki, M. Holub, C. Li, C. Awo-Affouda, P. Thompson and B. Jonker, Appl. Phys. Lett. **91**, 212109 (2007).

[2] H.Y. Yu, et al., *Appl. Phys. Lett.*, 81:376, 2002

MI-ThP2 Highly Selective Etching of Magnetic Layer using Organic Gases in an Inductively Coupled Plasma Etching System, ***S.K. Kang***, *M.H. Jeon, J.Y. Park*, SKKU Advanced Institute of NanoTechnology (SAINT), S. Korea, *B.J. Park, TH. Min, G.Y. Yeom*, Sungkyunkwan University, S. Korea

Magnetic random access memory (MRAM) has made a prominent progress in memory performance and has brought a bright prospect for the next generation nonvolatile memory technologies due to its excellent advantages. Dry etching process of magnetic thin films is one of the important issues for the magnetic devices such as magnetic tunneling junctions (MTJs) based MRAM. MTJs which are the basic elements of MRAM can be used as bits for information storage. CoFeB is a well-known soft ferromagnetic material, of particular interest for magnetic tunnel junctions (MTJs) and other devices based on tunneling magneto-resistance (TMR), such as spin-transfer-torque MRAM. One particular example is the CoFeB–MgO–CoFeB system, which has already been integrated in MRAM. In all of these applications, knowledge of and control over the etching properties of CoFeB is crucial. Recently, transferring the pattern by using an Ar^+ ion milling is a commonly used, although the redeposition of back-sputtered etch products on the sidewalls and the low etch rate of this method are main disadvantages. So the other method which has reported about much higher etch rates of >50 Å/s for magnetic multilayer structures using Cl_2/Ar plasmas is proposed. However, the chlorinated etch residues on the sidewalls of the etched features tend to severely corrode the magnetic material. Besides avoiding corrosion, during etching facets form at the sidewalls of the mask due to physical sputtering of the mask material.

Therefore, in this work, magnetic material such as CoFeB was etched in an ICP using the gases which can be expected to form volatile metallo-organic compounds. As the gases, carbon monoxide (CO) and ammonia (NH_3) were used as etching gases to form carbonyl volatiles, and the etched features of CoFeB thin films under by Ta masking material were observed with electron microscopy to confirm etched resolution. And the etch conditions such as bias power, gas combination flow, process pressure, and source power were varied to find out and control the properties of magnetic layer during the process.

MI-ThP3 Instrumentation for the Investigation of Switching Field Distribution on Permalloy ($Ni_{81}Fe_{19}$) Nanoscale Structures, ***J. Bates***, *C.V. Cojocaru, Y. Miyahara, P. Grutter*, McGill University, Canada

There is an ongoing interest in understanding the switching field distribution (SFD) of nanoscale patterned magnetic elements, which show great potential for novel applications such as magnetic quantum cellular automata [1] or magnetic random access memory [2] architectures. To make these architectures technologically viable, it is essential for patterned magnetic elements, to have a reproducible and controllable magnetic switching mechanism, thus a narrow SFD. Factors that affect the SFD are not known *a priori* and might be of various natures: thermal effects, shape, imperfections in fabrication, microstructure, edge roughness, seed-layer, anisotropy variations and magnetostatic interactions with neighbors etc.

To address these issues we used a combination of atomic/magnetic force microscopy (AFM/MFM) [3] and transmission electron microscopy (TEM) on indexed arrays of permalloy nanoscale structures, sputter-deposited via stenciling on ultra thin silicon nitride membranes. The stencil-masks used during the deposition process features ordered arrays of nano-apertures, prepared by focused ion beam milling. The stenciling process is parallel, resistless, and allows for the direct organization of structures having different aspect ratios (length/width) into any desired architecture.

Permalloy structures were characterized initially by AFM to assess their topography. Then MFM was used in constant height mode in order to obtain magnetic state (domains) and SFD of the structures. Magnetization reversal was studied by applying an *in situ* magnetic field parallel to the sample surface with a pair of rotating NdFeB permanent magnets. Structures with in plane aspect ratios below 4:1(400nm:100nm) revealed a multidomain state thus complex switching behavior, while structures with an aspect ratio above showed a bipolar state and switched coherently. Structures that switched at lower fields were identified as "early" switchers and structures that switched at larger fields were identified as "late" switchers. TEM images of the "early" and "late" switchers have been compared to normal switchers to look for structural variations, which may induce differences in behavior and broaden the SFD.

[1] R. Cowburn et al., NJP 1, 161(1999)

[2] B. D. Terries et al., J. Phys. D: Appl. Phys. 38, R199 (2005)

[3] X. Zhu and P. Grutter, Phys. Rev. B 66, 024423 (2002)

MI-ThP4 Core and Valence Band Photoemission of M[TCNE] Organic-based Magnets, *M.S. Driver, S.Z. Janjua*, University of Missouri - Kansas City, *K.I. Pokhodnya*, North Dakota State University, ***A.N. Caruso***, University of Missouri - Kansas City

A family of organic-based magnets of $M^{II}[TCNE]_x \bullet zS$ (M = V, Mn, Fe, Co, Ni; TCNE = tetracyanoethylene; S = CH_2Cl_2) composition exhibit ordering temperatures ranging from 44 (M = Co, Ni) to ~400 K for M = V. The exchange mechanism in this class of magnets is not well understood and changes dramatically with transition metal type. Core and valence band photoemission have been completed, above and below the transition temperature for the above systems and will be presented. The binding energies of the metal and organic core levels, relative to M^{II} and $[TCNE]^{\bullet-}$ will be presented within the context of exchange strength, transition temperature and metal-to-ligand symmetry overlap. The goal of our groups is to provide, through multiple spectroscopies (some pressure dependent), a picture for the binding energy and spin polarization of the occupied/unoccupied electronic structure as well as the exchange mechanism and bonding as the transition metal type is varied in roughly the same physical structure.

MI-ThP5 Electrical Spin injection from Fe into ZnSe, ***A.T. Hanbicki***, *G. Kioseoglou, M.A. Holub, O.M.J. van 't Erve, B.T. Jonker*, Naval Research Laboratory

The wide bandgap semiconductor ZnSe is an opto-electronic material with a comparable spin lifetime and small lattice mismatch to GaAs. Novel spintronic devices that incorporate ZnSe/GaAs heterostructures will require the facile transport of spin information across several heterointerfaces including spin injection into the ZnSe. We have electrically injected spin-polarized electrons from a ferromagnetic Fe contact into a ZnSe epilayer grown on a GaAs heterostructure. The injected carriers proceed through 300 nm of ZnSe and recombine in the GaAs emitting light characteristic of the bulk GaAs exciton. We measure spin polarizations in excess of 40% in the GaAs based on analysis of the circular polarization of the electroluminescence. We report results as a function of applied magnetic

field, device current and temperature. The spin injection process and transport through the ZnSe layer sustains significant spin populations in this heterostructure.

This work was supported by core programs at NRL.

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