Magnetic Interfaces and Nanostructures
Room 316 - Session MI-MoA

Magnetic Recording and Magnetoresistive Structures
Moderator: M.C. Tondra, NVE Corp.

2:00pm **MI-MoA1 Materials/Structures for High Areal Density Write Poles**, ***M.K. Minor***, *T.J. Klemmer, M.A. Seigler, O. Mryasov,* Seagate Technology*; M. Kim, A.J. Freeman,* Northwestern University **INVITED**

The maximum effective write field of a head is related to head geometry and the saturation magnetization (4@pi@M@sub S@) of the pole material. Typically, head designs require a pole material at the air bearing surface (ABS) which exhibits a large 4@pi@M@sub S@, low coercivity, and a well-defined uniaxial anisotropy. The material with the largest known 4@pi@M@sub S@ at room temperature is exhibited by Fe@sub 65@Co@sub 35@ which has a value of ~2.4T. One of the problems with FeCo that prevents it from being used as a pole material is that the material is not uniaxial, therefore, it has nearly zero permeability which results in an inefficient write head. This lack of uniaxiality or magnetic "softness" is a direct result of the relatively large value of magnetocrystalline anisotropy exhibited by the high moment FeCo alloys. This talk will review some of the methods employed to induce magnetic softness in the high moment FeCo alloys. These methods include the effects of various processing conditions, the use of buffer layers, and laminated structures which are magnetostatically coupled. For each of these methods magnetic properties and film microstructure will be reviewed. A large portion of this talk will focus on FeCo multilayered structures fabricated via dc magnetron sputtering. Some modeling and experimental results will be presented. These results include enhanced moment prediction and effect of multilayering on anisotropy. The modeling results are compared to experimental results where we will show structural and magnetic properties of the FeCo multilayers.

2:40pm **MI-MoA3 Influence of Pd and Pt Buffers on the Soft Magnetic Properties of Fe@sub 70@Co@sub 30@ Thin Films**, ***C.L. Platt***, *J.K. Howard,* Seagate Technology*; D.J. Smith,* Arizona State University

Writer pole materials with large saturation magnetization are desired to maximize the available writing field for magnetic recording. A 5 nm thick Pd or Pt buffer layer is sufficient to significantly alter the magnetic and structural properties of sputtered high moment (2.4 T) Fe@sub 70@Co@sub 30@ thin films. A 50 nm thick FeCo film with no buffer grown on an amorphous SiO@sub 2@ substrate had a coercivity of 40 Oe and showed no evidence of an induced easy axis, although the film was grown in an applied field of 50 Oe. This is typical of high moment FeCo alloys which usually do not exhibit soft magnetic properties due to large magnetostriction and difficulty controlling magnetic ripple structure. Use of 5 nm Pd or Pt buffer reduced the coercivity of 50 nm FeCo films to about 15 Oe with a definable easy axis. Structurally, the primary influence of the Pd or Pt buffer was a reduction in the average FeCo grain size and more clearly defined columnar grain boundaries. This is similar to what has been observed using other fcc buffers.@footnote 1,2@ Growing thicker FeCo films (200 nm) resulted in a significant increase in average column width and a loss of soft magnetic properties regardless of the buffer. @FootnoteText@ @footnote 1@H. S. Jung, W. D. Doyle, J. E. Wittig, J. F. Al-Sharab, and J. Bentley, Appl. Phys. Lett. 81, 2415 (2002).@footnote 2@C. L. Platt, A. E. Berkowitz, D. J. Smith, and M. R. McCartney, J. Appl. Phys. 88, 2058 (2000).

3:00pm **MI-MoA4 Atomistic Simulations of Metal/Metal Oxide Heterostructures**, ***X.W. Zhou***, *H.N.G. Wadley,* University of Virginia

A thin aluminum oxide layer sandwiched between a pair of ferromagnetic metal layers forms a spin-dependent tunnel junction that can be used to construct random access memory. Atomistic simulations based upon interatomic potentials provide a way to identify the best conditions to synthesize these structures. However, unlike the approaches that have been successfully used to simulate metal multilayer deposition, atomic simulation methods for metal and metal oxide heterostructures are poorly developed. Metal oxides involve a significant ionic interaction between constituent cations and anions. Traditional fixed charge ionic potentials do not allow the introduction of different oxidation states and cannot ensure charge neutrality during simulation of oxide vapor deposition. They also significantly overestimate the cohesive energy of oxides. Because their charges are designated (for a given bulk oxide), they are not applicable to metal oxide heterostructures and cannot address metal/oxide interfaces. A charge transfer ionic potential (CTIP) model proposed by Streitz and Mintmire has attempted to overcome these deficiencies. However, we found that this charge transfer model is unstable and can only be applied to single metal-oxygen binary systems. By incorporation of the physical principle of elemental valency we have found an expedient solution to the limitations of the original CTIP model. The improved CTIP potential has been combined with an existing embedded atom method (EAM) metal potential to dynamically address both ionic and metallic components of the interatomic interactions in an O-Al-Ni-Co-Fe system during atomistic simulations. Application of this novel approach in the oxidation of aluminum layer in Ni65Co20Fe15/Al2O3/Ni65Co20Fe15 spin-dependent tunnel junction multilayer is reported and the roles of processing conditions used to synthesis the aluminum oxide layer are discussed.

3:20pm **MI-MoA5 Quantum-size Effect of Tunneling Magnetoresistance in Magnetic Tunnel Junctions**, ***S. Yuasa***, AIST and PREST-JST, Japan*; T. Nagahama, Y. Suzuki,* AIST and CREST-JST, Japan **INVITED**

We fabricated magnetic tunnel junctions (MTJs) with single-crystal bottom electrodes and observed new phenomena such as the crystal-orientation dependence of the tunneling magnetoresistance (TMR) effect,@footnote 1@ the quantum-size effect of TMR,@footnote 2@ and the spin-polarized resonant tunneling.@footnote 3@ Here, we report the results on three types of MTJs with a single-crystal bottom electrode; (i) MTJ with an ultrathin ferromagnetic electrode, (ii) MTJ with an ultrathin nonmagnetic electrode grown on a ferromagnetic layer, and (iii) MTJ with an antiferromagnetic electrode grown on a ferromagnetic layer. The results are discussed in terms of spin lifetime of tunneling electrons. @FootnoteText@@footnote 1@S. Yuasa et al.: Europhys. Lett. 52, 344 (2000). @footnote 2@T. Nagahama, S. Yuasa, Y. Suzuki, E. Tamura: Appl. Phys. Lett. 79, 4381 (2001). @footnote 3@S. Yuasa, T. Nagahama, Y. Suzuki: Science 297, 234 (2002).

4:00pm **MI-MoA7 Magnetization Dynamics and Magneto-transport in Epitaxial Nano-structures**, ***R.A. Lukaszew***, *D. Pearson, Z. Zhang,* University of Toledo*; A. Zambano,* Michigan State University

Abstract: The latest results on ballistic magneto-resistance (BMR) research have shown surprising ballistic magnetoresistance.@footnote 1@ It has been postulated that the BMR effect arises from non-adiabatic spin scattering across very narrow magnetic domain walls trapped at nano-sized constrictions.@footnote 2@ The reported BMR effect has been observed in nano-contacts electrodeposited between Ni wires. Much of the publish data so far, is still poorly understood. In an attempt to clarify some of the possible processes present in the observed phenomena we applied e-beam lithography to epitaxial Ni films to fabricate nano-bridges with more controlled geometry than the ones made with electrochemical deposition. Epitaxial ferromagnetic thin films exhibit narrow domain walls that may favor ballistic regime provided that the nano-contact is small enough. We have modeled the magnetization reversal in epitaxial films and have established that the unusually high coercive field observed along hard axes is due to a second order type transition prior reversal that induces high density of domain walls at the reversal.@footnote 3@ Thus we expect that a patterned nano-structure with segments parallel to magnetization hard axes will be more likely to experience domain-wall related effects in magneto-transport. Therefore we patterned a similar T geometry to that utilized by Chopra and Garcia.@footnote 1,3@ Our preliminary results indicate that magnetic domains do play a role in the magneto-resistance of these nano-bridges but the order of magnitude of the observed effect is considerably smaller than the reported observations for electrochemically prepared nano-contacts. @FootnoteText@@footnote 1@B. D. Chopra and S. Z. Hua, Phys. Rev. B. 66, 020403(R), 2002. @footnote 2@P. Bruno, Phys. Rev. Lett. 83, 2425 (1999). @footnote 3@Lukaszew, R.A. and Clarke R., unpublished. @footnote 4@N. Garcia, M. Munioz, V. V. Osipov, E. V. Ponizovskaya, G. G. Quian, I.G. Saveliev and Y.-W. Zhao, J. Magn. Magn. Mater. 240, 92 (2002).

4:20pm **MI-MoA8 Artifacts in Ballistic Magnetoresistance Measurements**, ***W.F. Egelhoff***, *M.D. Stiles, T.P. Moffat, J. Mallett, R.D. McMichael, H. Ettedugi, A.J. Shapiro, C.J. Powell,* National Institute of Standards and Technology*; E.B Svedberg,* Seagate

The Ballistic Magnetoresistance (BMR) effect has attracted much attention in the past year with BMR values as large as 100,000% having been reported in Physical Review@footnote 1@ and 1,000,000% reported at Intermag2003.@footnote 2@. Naturally, such impressive results have led many researchers to attempt to reproduce large BMR values. Unfortunately, these attempts have widely failed. This failure has led to much skepticism over whether BMR is a real effect. In our research, we

have found several artifacts caused by magnetostriction and magnetostatics that can produce what appear to be huge BMR values. In this talk, we will illustrate these artifacts, provide an assessment of the implications these artifacts have for the field of BMR, and give guidelines for performing BMR measurements in an artifact-free manner. We will also present results of new BMR measurements in which we follow our recommended procedures. @FootnoteText@@footnote 1@S. Z. Hua and H. D. Chopra Phys. Rev. B 67, 060401 (2003). @footnote 2@Nicolas Garcia, invited talk, Intermag2003.

4:40pm **MI-MoA9 Arrays of Magnetoresistive Sensors for Non-destructive Testing**, ***A.V. Nazarov,*** National Institute of Standards and Technology*; F.C.S. da Silva,* National Institute of Standards and Technology, US*; P. Kabos, D.P. Pappas,* National Institute of Standards and Technology

Magnetic field mapping is a powerful tool that can provide high sensitivity and high spatial resolution for current localization.@footnote 1@ In this work, we used magnetic field mapping to non-destructively analyze the current distribution in integrated circuit chips and localize wiring defects. The magnetic field produced by current distributions was simultaneously measured with arrays of magnetoresistive (MR) sensors in order to increase the effective speed of the scan. Arrays of eight permalloy barber-pole type MR sensors were fabricated using a two step lift-off lithography process. The sensors were 40 µm long, 4 µm wide, and separated by 210 µm. The nominal resistance of the sensors was in the 24.9 to 25.2 @ohm@ range and the MR change was 1.8 %. A broadband, simultaneous, 8-channel, computer-based digital lock-in technique was developed for data acquisition and analysis. The measured magnetic field distributions were directly converted to current images using normalized discrete 1-d Fourier transforms. Measurements of test structures show the absence of cross-talk between sensors and that the spatial resolution is approximately z/2 where z is the distance between current plane and the sensor. This work was supported by the National Institute of Standards and Technology Office of Law Enforcement Standards, the Federal Bureau of Investigation, the National Security Agency, the National Institute of Justice, and the Advanced Technology Program. @FootnoteText@ @footnote 1@S. Chatraphorn, E. F. Fleet, F. C. Wellstood, L. A. Knauss, and T. M. Eiles, Appl. Phys. Lett. 76, 2304 (2000).

Author Index

Bold page numbers indicate presenter