Magnetic Interfaces and Nanostructures Technical Group
Room 324/325 - Session MI+EM-WeM

Spin-dependent Devices: Technology and Processing

Moderator: B.A. Everitt, Seagate Technology

8:20am **MI+EM-WeM1 Limiting Factors in Dense Pseudo Spin Valve and Spin Dependent Tunneling Memory Arrays*, A.V. Pohm,*** *M.C. Tondra, C.A. Nordman, J.M. Anderson,* Nonvolatile Electronics **INVITED**

For pseudo spin valve or spin dependent memory technology to persist for the coming decades, they must be able to exploit the evolving sub-micron semiconductor technology and adjust to the diminishing conductor widths. However, as pseudo spin valve and spin dependent memory arrays are scaled to 0.1 micron widths or less, a number of factors play a role in limiting ultimately the memory array densities which can be achieved. An analysis has been performed which shows that to achieve adequate stability against thermal agitation for half selected cells, the shape anisotropy in the 25 Angstrom storage layer must be at least 300 Oe for 0.1 x 0.3 micron cells. Half select fields of 100 to 150 Oe are required for the write operation. This necessitates current densities in the GMR sandwich in the 10@super 8@ A/cm@super 2@ range for the sense lines and 10@super 7@ A/cm@super 2@ in the word lines. Although GMR sandwiches can tolerate the high current densities, thin dielectrics and careful use of heat sinks are required to keep the temperature rise modest. Materials such as tungsten must be used for the word line in order to have adequate electro-migration limits. Because of the high resistance and capacitance in the spin dependent tunneling memory cells, semiconductor isolation is necessary for high performance. As a consequence, maximum array density is about ½ of that for pseudo spin valve cells.

9:00am **MI+EM-WeM3 New Aspects of GMR Spin Valves: Enhancing Specular Electron Scattering and Using Surfactants for Improved Growth*, W.F. Egelhoff, Jr.,*** National Institute of Standards and Technology

We have investigated the deposition and processing of a variety of giant magnetoresistance (GMR) spin valves with the aim of optimizing their properties. We have found that many of the magnetic and magnetoresisitive properties of spin valves are strongly influenced by surface and interface effects occurring during growth. These effects include the balance of surface and interface free energies, surface diffusion, interdiffusion at interfaces, low temperature deposition, the use of surfactants to modify growth, and specular electron scattering at surfaces. In some cases, it is possible to control these factors or to use them to manipulate the growth or improve post-growth processing of spin valves to improve their magnetic and magnetoresistive properties. For example, specular scattering is particularly important for achieving the largest possible GMR values in simple spin valves. For symmetric (or dual) spin valves GMR values as large as 24.8% have been achieved, and for simple spin valves (containing only one Cu layer) GMR values as large as 19.0% have been achieved. The best hope for someday achieving GMR values in simple spin valves as large as those reported for GMR superlattices appears to be increasing the degree of specular scattering and reducing the bulk defect scattering. The author would like to acknowledge his collaborators in this work, including P. J. Chen, C. J. Powell, M. D. Stiles, R. D. McMichael, J. H. Judy, K. Takano, A. E. Berkowitz, and J. M. Daughton.

9:20am **MI+EM-WeM4 High Temperature Pinning Properties of IrMn vs. FeMn in Spin Valves*, M.C. Tondra,*** *D. Wang,* Nonvolatile Electronics

The antiferromagnetic pinning properties of IrMn and FeMn have been observed by building spin valve samples with the structure NiFeCo / CoFe / Cu / CoFe / NiFeCo / (IrMn or FeMn) and measuring their magnetoresistive properties. The pinning strength was evaluated in terms of the break field, defined as the field applied in the direction opposite to the magnetization of the pinned layer at which the pinned layer switches. At room temperature, the break fields for both the IrMn and FeMn samples were about 250 Oe. But as the temperature increased, the break field for samples pinned with IrMn held up considerably better than for those pinned with FeMn. Specifically, the pinning of the FeMn spin valves was gone at 150°C while the pinning of the IrMn spin valves persisted to temperatures above 225°C. The IrMn spin valves performed as well as the FeMn spin valves in terms of magnetoresistance and lithographic process compatibility.

9:40am **MI+EM-WeM5 Magnetisation Reversal Studies by TEM of Continuous and Patterned GMR Films*, J.N. Chapman,*** University of Glasgow, United Kingdom **INVITED**

A highly modified transmission electron microscope has been used to study magnetisation processes in a range of GMR films suitable for application in devices. Films were deposited onto silicon nitride "window" substrates suitable for study in the TEM directly after growth or following patterning. Application of fields in-situ allowed the evolution of the magnetic domain structure to be followed in real time in both continuous films and elements. The latter frequently had dimensions in the sub-micron regime. Reversal of the free layer in spin-valve films is found to depend on the strength of coupling between free and pinned layers and the orientation of the applied field, the latter being readily under the control of the experimenter. Conditions under which quasi-coherent rotation of magnetisation takes place have been established. However, very significant changes take place as the dimensions of the films are reduced and magnetostatic energy contributions play an enhanced role. Domain nucleation at corners can lead to undesirable reversal modes and for elements with micron-sized dimensions the reversal depends critically on size, shape and the nature of the pinning layer. Examples will be given of how shape modification can change the characteristic of the reversal to suit sensing or storage application. In the case of Co/Cu multilayers reversal mechanisms quite different from those in spin-valves are observed and depend critically on the nature of the coupling between the layers. Thus films with strong biquadratic coupling tend to reverse in a relatively simple manner resembling processes in single layer films whilst films with weak antiferromagnetic coupling reverse through the formation and evolution of complex sub-micron "patch" domains. Irreversible processes are prevalent in the latter case but can be effectively suppressed in the former making films with biquadratic coupling suitable for applications where low hysteresis is essential.

10:20am **MI+EM-WeM7 Deposition and Processing of Novel GMR Structures @footnote 1@*, J.R. Childress,*** University of Florida, Gainesville **INVITED**

Optimized GMR devices may require the development of magnetic multilayer film structures combining binary and ternary alloys, composition gradients, composites, and metal/insulator interfaces. The structural and magnetic optimization of individual components within these multilayers often require specialized deposition and/or processing parameters which may be mutually incompatible, or incompatible with other necessary processing. Additionally, the interfacial structural and magnetic properties of alloys may be different from bulk, further complicating the interpretation of experimental data. Several current examples and experimental approaches will be discussed, such as the development of 100% spin-polarized magnetic films using NiMnSb and other compounds, metallic and insulating antiferromagnets for exchange biasing, and metal/insulator interfaces. @FootnoteText@ @footnote 1@ Author present address: IBM Almaden Research Center, 650 Harry Rd, San Jose, CA 95120

11:00am **MI+EM-WeM9 Direct-Measurement of Spin-Dependent Transport Across Ferromagnetic and Non-Magnetic Thin Films*, S.K. Upadhyay,*** *R.N. Louie,* Cornell University*; R.A. Buhrman,* Cornell University, US

We have used superconductor-ferromagnet nanocontacts to directly measure a>spin-polarization of the current in ferromagnets (Co and Ni) and b>spin dependent transmission rates of thin ferromagnetic (Co, Ni) and non-magnetic (Cu) films. Since the size of the contact (3-10nm) is smaller than other scattering lengths in the system, our measurements can selectively probe the scattering at interfaces of dissimilar metals. We will discuss our results in the context of giant magnetoresistance in thin film magnetic multilayers and their significance in understanding the role of interfacial versus bulk scattering.

11:20am **MI+EM-WeM10 Effect of Noble Gas Addition (He,Ar,Xe) on Cl@sub 2@-Based Etching of NiFe and NiFeCo*, K.B. Jung,*** *H. Cho, Y-.B. Hahn, E.S. Lambers, Y.D. Park, S.J. Pearton,* University of Florida, Gainesville*; J.R. Childress,* IBM Almaden Research Center*; M. Jenson, A.T. Hurst, Jr.,* Honeywell, Inc.

The mechanism for high rate dry etching of NiFe, NiFeCo and other components of multilayer magnetic thin film devices such as read/write heads and magnetic random access memories depends on formation of chlorinated etch products, and their efficient desorption by ion-assisted sputtering. A systematic study of the dependence of noble gas species (He, Ar, Xe) additive to high-density Inductively Coupled Plasma Cl@sub 2@

discharges has been performed. The etch rates of the NiFe and NiFeCo increase in direct proportion to the atomic weight of the noble gas species, which is the dominant factor controlling etch product desorption. Increasing the weight of the additive also leads to a decrease in residual chlorine on the etched surface, as determined by Auger Electron Spectroscopy. The effect of altering the noble gas species on etch selectivity over common mask materials (SiO_2, SiN_X and photoresist) has also been studied. Facetting of the mask edges is a particular problem with Cl_2/Xe discharges.

11:40am **MI+EM-WeM11 Magnetoresistance Properties in Granular Silicide Thin Films Formed by High Dose Iron Implantation***, **M.F. Chiah**, W.Y. Cheung, S.P. Wong, I.H. Wilson,* The Chinese University of Hong Kong, Hong Kong

High dose iron implantation into silicon wafer has been performed with a metal vapor vacuum arc ion source (MEVVA) to doses ranging from $1*10^{16}$ to $2*10^{17}$ cm^{-2} at various beam current densities. The magnetoresistance (MR) effects in these implanted granular layers were studied at temperatures from 15K to 300K. A positive MR effect, i.e, an increase in the resistance at the presence of a magnetic field, was observed at temperatures lower than about 70K in samples prepared under appropriate implantation conditions. The magnitude of the MR effect, defined as $\Delta R/R_o = (R(H)-R_o)/R_o$ where R(H) and R_o denote respectively the resistance value at a magnetic field intensity H and that at zero field, was found to depend on the implantation dose, the beam current density. This is attributed to the beam heating effect during implantation which affects the formation of the microstructures. The ratio $\Delta R/R_o$ was found to attain high values larger than 500% for some samples at low temperatures. The dependence of the MR effects on temperature, implantation dose, substrate dopant concentration and beam current density will be presented and discussed in conjunction with results of Transmission Electron Microscopy and Mössbauer Spectroscopy. The phase of iron silicide, composition and depth of damaged layer were determined by spreading resistance, Rutherford backscattering and XRD measurements. This work is supported in part by a grant from the Research Grants Council of Hong Kong (Ref. No.: CUHK 374/96E)

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