Magnetic Interfaces and Nanostructures
Room: C-205 - Session MI-WeM

Magnetic Recording: GMR, Tunneling, and Media
Moderator: W.H. Rippard, NIST

8:20am **MI-WeM1 Perpendicular Recording Media Near 100 Gbit per square inch**, ***D. Weller***, *B. Lu*, *Y. Kubota*, *J. Ahner*, *G. Ju*, *X. Wu*, *D. Karns*, *A. Sunder*, Seagate Research, *C.H. Chang*, *C. Brucker*, *R. Ranjan*, Seagate Recording Media Operations, *M. Kryder*, Seagate Research **INVITED**

Media noise suppression via reduced grain and magnetic cluster size and at the same time thermal stability are general requirements to advancing magnetic recording technology to higher areal densities, beyond 100 Gbit per square inch. In perpendicular recording, using a hard/soft dual layer media scheme, one seeks to use magnetically harder media. Such media sustain smaller stable grains and can be written owing to the improved write field geometry that perpendicular pole heads in conjunction with soft magnetic underlayers offer over the conventional ring head geometry used in longitudinal recording. Modeling suggests, that this technology is extendible to areal densities of the order of Terabit per square inch. In this paper, we review current-state-of the art perpendicular media and review testing results near 100 Gigabit per square inch recording densities. The key challenges relate to controlling average grain sizes and their distributions as well as intergranular exchange coupling in the hard layer and at the same time generating a low noise, high permeability soft magnetic underlayer. We have fabricated both CoPtCr-type alloy and CoCr/Pd-type multilayer media and obtained grain sizes of D=10.5+/-2.2nm and D=13.1+/-2.5 nm, respectively. These media have full remanence squareness (S=1), negative onset fields for reversal > 2000 Oe, thicknesses in the range 10-18 nm and are thermally stable. The soft underlayer material is an amorphous FeCoB alloy with 1.9 T flux density and a static permeability of >400; it is stabilized into a single domain, noise free state, via an induced radial magnetic anisotropy field > 50Oe. The spacer between the soft underlayer and hard layer is an alloy seed layer structure of total thickness less than 5 nm. This interlayer controls the microstructure of the subsequent recording layer and is key to enhancing the performance of perpendicular media.

9:20am **MI-WeM4 High Frequency Noise Measurements in Spin-Valves**, ***N.A. Stutzke***, Boise State University, *S.E. Russek*, NIST, Boulder, *S.L. Burkett*, Boise State University

High-frequency magnetic noise in magnetoresistive devices, being developed for read-sensor and magnetic random access memory applications, may present fundamental limitations on the performance of sub-micrometer magnetic devices.[1] High-frequency magnetic noise arises from intrinsic thermal fluctuations of the device magnetization. High-frequency noise spectroscopy provides a powerful tool to characterize the dynamics and response of multilayer magnetic devices. In this study, the noise characteristics of micrometer-dimension spinvalves have been investigated at frequencies in the range of 0.1-6 GHz. 1/f noise dominates at frequencies below this range. High-frequency noise measurements as a function of temperature, bias current, and magnetic field are obtained for IrMn-exchange biased spinvalves using a 50 GHz spectrum analyzer, low-noise amplifier, and a cryogenic microwave probing system. Temperature is varied from 100-400K. The magnetic noise is obtained by taking the difference between the noise spectrum of the device in a saturated and unsaturated state. The data can be fit to simple models that predict the noise power to be proportional to the imaginary part of the free-layer magnetic susceptibility.[2] Noise is observed to shift to higher frequencies and decrease in amplitude with decreasing temperatures. This is consistent with an increase in magnetostatic anisotropy due to the increase in the saturation magnetization as the temperature is lowered. There are some important differences between the high-frequency noise measurements and direct measurements of the device susceptibility (both at the device and wafer level). The noise measurements show a smaller damping constant (a smaller ferromagnetic resonance linewidth) and show additional features due to the presence of additional magnetostatic modes.

[1]N. Smith and P. Arnett, Appl. Phys. Lett. 78, 1448 (2001).
[2]N. Smith, J. Appl. Phys. 90, 5768 (2001).

9:40am **MI-WeM5 Theory of Spin-dependent Tunneling**, ***J. Mathon***, City University, UK **INVITED**

Rigorous theory of the tunneling magnetoresistance (TMR) based on the real-space Kubo formula and fully realistic tight-binding bands fitted to an ab initio band structure is decribed. It is first applied to calculate the TMR of two Co electrodes separated by a vacuum gap. The calculated TMR ratio reaches some 65% in the tunneling regime but can be as high as 280% in the metallic regime when the vacuum gap is of the order of the Co interatomic distance (abrupt domain wall). It is also shown that the spin polarization P of the tunneling current is negative in the metallic regime but becomes positive P~35% in the tunneling regime. Calculation of the tunneling magnetoresistance of an epitaxial Fe/MgO/Fe(001) junction is also described. The calculated optimistic TMR ratio is in excess of 1000% for an MgO barrier with 20 atomic planes of MgO and the spin polarization of the tunneling current is positive for all MgO thicknesses. Finally, it is demonstrated that the TMR ratio calculated from the Kubo formula remains nonzero when one of the Co electrodes is covered with a copper layer. It is shown that nonzero TMR is due to quantum well states in the Cu layer which do not participate in transport. Since these only occur in the down-spin channel, their loss from transport creates a spin asymmetry of electrons tunneling from a Cu interlayer, i.e. nonzero TMR. Numerical modelling is used to show that diffuse scattering from a random distribution of impurities in the barrier may cause quantum well states to evolve into propagating states, in which case the average TMR tends to zero but large quantum oscillations of TMR about zero average remain.

10:20am **MI-WeM7 In-Situ Conductance Measurements of Giant Magnetoresistive Multilayers**, ***A.T. McCallum***, *S.E. Russek*, National Institute of Standards and Technology

In-situ conductance measurements can detect the changes in electronic structure during deposition of a multilayer with submonolayer resolution. Here, we present conductance verses thickness data, taken every half monolayer, for both top and bottom pinned spin valves at different temperatures. These measurements can clearly identify bulk scattering processes and interfacial scattering. For example, our data shows adding Co onto Cu adds strong interfacial scattering mechanisms. The conductance verses thickness data were compared to a Boltzmann transport equation (BTE) model. Bulk conductivities were measured by extending the measurements out to large layer thicknesses. Bulk electron mean free paths were calculated from the measured conductivites and the results of other experiments. Transmission probabilities and specular reflection probabilities were deduced from this model. The spatial distribution of current density in the multilayer, was then calculated using the BTE model. In-situ conductance measurements were used to characterize thin oxide layers, which are used as insulating barriers in magnetic tunnel junctions and specularly reflecting surfaces in giant magnetoresistance devices. For these applications it may be necessary to completely oxidize one layer of metal and not oxidize the metal underneath. The dynamics of oxidizing an Al surface were observed using in-situ conductance measurements and a vibrating crystal thickness monitor. The thickness monitor measures the oxygen uptake over time while in-situ conductance measures the amount of Al oxidized and the change in specularity due to the oxide. Using these techniques we characterized several oxidization procedures to determine the details of the oxidization process and to find an optimum oxidization procedure.

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