Magnetic Interfaces and Nanostructures
Room 206 - Session MI-FrM

Magnetic Recording: Media and Heads

Moderator: D.K. Weller, IBM Almaden Research Center

8:20am **MI-FrM1 Focused Ion Beam Patterning of Magnetic Films*, B.D. Terris*, *C.T. Rettner, M.E. Best,* IBM Almaden Research Center **INVITED**

In the future it may be necessary to pattern magnetic recording media to achieve data densities beyond 100 Gb/sq. in. The required patterning should have minimal cost and leave a surface suitable for flying a recording head. One promising approach to achieving such patterning is to use ion beams to directly modify the magnetic properties of thin films. It has been shown previously that Co/Pt multilayers can be modified magnetically by exposure to a uniform beam of ions (eg. He+, N+), where the easy magnetization axis of the film is rotated from out-of-plane in the as grown film to in-plane in the irradiated film. Local areas of in-plane magnetization can thus be produced by exposing the film through masks.@footnote 1-3@ We have now demonstrated that such films can be also be patterned using a focused ion beam (FIB) of Ga+ ions without the use of a mask. In addition to patterning the multilayer Co/Pt films by easy axis rotation, films of granular CoPtCr have been patterned by removal of the magnetic film by Ga+ milling. The remanent magnetization state of square islands ranging from 80 nm to 230 nm in size was studied by MFM and the smallest islands appear to be single domain. Remanent hysteresis loops generated from MFM data show that the coercivity of the CoPtCr films is unchanged by the FIB patterning, in contrast to the FIB patterning of Co/Pt multilayers where the coercivity decreases with increasing ion dose and decreasing island size. @FootnoteText@ @footnote 1@C. Chappert et al., Science 280, 1919 (1998) @footnote 2@B. D. Terris et al., Appl. Phys. Lett.75, 403 (1999) @footnote 3@T. Devolder et al., Appl. Phys. Lett. 74, 3383 (1999)

9:00am **MI-FrM3 Interface Reactions between Quaternary Cobalt Alloys and Carbon Overcoats in Thin Film Disk Media*, J.-U. Thiele*, *D.J. Pocker, R.L. White,* IBM Storage Technology Division

In the magnetic disk drive industry's quest for ever higher data storage areal densities, the head-to-disk spacing and consequently the film thicknesses of all functional layers of magnetic media continue to decrease. In the future the thicknesses of magnetic storage layers and carbon overcoat can be expected to approach the typical thicknesses of chemical interface reactions, i.e. thicknesses of the order of a few nanometers. Here we present a core level X-ray photoelectron spectroscopy study of interface reactions between CoPtCrB and CoPtCrTa magnetic alloy layers and 35 Å thick protective hydrogenated and nitrogenated carbon overcoats on metal hard disks. In comparing CoPtCrTa alloy films with a nitrogenated carbon overcoat to the same media with hydrogenated carbon overcoats we find a drop in coercivity of up to 200 Oe. The formation of tantalum nitride as well as small amounts of chromium nitride was detected in the photoelectron spectra. Conversely, spectra of nitrogenated carbon films on B-containing alloys showed the formation of boron nitride and small amounts of chromium nitride at the interface. The amount of boron nitride varies depending on substrate bias voltage and temperature. Surprisingly, no effects of these interface reactions on the magnetic properties of the disks could be detected. In summary, while the formation of boron nitride at the interface of CoPtCrB media and protective carbon overcoat does not affect the magnetic properties of the disks in the range of boron and nitrogen concentrations investigated here, small changes in the chemical environment of Ta and/or Cr can lead to significant changes in the magnetic properties of the CoPtCrTa media.

9:20am **MI-FrM4 Corrosion Behavior of CoSm Based Magnetic Media*, I. Zana*, *G. Zangari,* The University of Alabama

Future state-of the-art magnetic recording media require high coercivity and magnetization and from a low noise stand point, a small grain size. To achieve these properties, alloys and compounds with high anisotropy are being considered. Among them, we previously reported on rare-earth transition metal CoSm thin films@foontote 1@ with very good magnetic properties. Despite these attractive magnetic properties, the potentially high susceptibility to corrosion, due particularly to the rare-earth element, rises the question of chemical stability for these alloys and therefore on the practicality of CoSm system. In order to investigate the chemical stability of a CoSm system, we fabricated a series of samples on glass substrates, by sputtering. To evaluate the influence of the roughness of both underlayer and magnetic layer, we sputter Cr as underlayer with thickness of 20, 60 and 100 nm. Onto each Cr underlayer, the magnetic layer has a thickness of 8 and 16 nm. These samples were further coated, without breaking the vacuum, with a protective layer of C-N and Si3N4 (2 to 8 nm thickness). A series of samples has been left intentionally unprotected. Corrosion resistance of the samples has been tested by high temperature /humidity accelerated aging and annealing under various atmospheres. Structural and chemical uniformity, roughness as well as stability of the magnetic properties of aged samples have been evaluated by use of x-ray photoelectron spectroscopy, electron microscopy, x-ray diffraction and magnetometry. By comparison with unprotected samples and with commercial disk structure, we found that (a) Si3N4 protective layer strongly improve the corrosion resistance and stability of the magnetic layer and (b) CoSm layers protected by Si3N4 exhibit stability comparable or superior to commercial hard disk. @FootnoteText@@footnote 1@I. Zana, G. Zangari, "Magnetic Interactions and Thermal Stability in CoSm Thin Films", accepted to publication in IEEE Transactions on Magnetics.

9:40am **MI-FrM5 Preparation and Characterization of High-Coercivity Cobalt Ferrite Particles Using Microemulsions*, H. Du*, *Y. Kim, S.L. Lim, L. Si, J. Ding,* National University of Singapore*; W.S. Chin,* National University of Singapore, Singapore

Ferrite materials in nano-scale are potential candidate for application on magnetic recording in high density and the study of nanoscale magnetic domains is of both fundamental and technical interest. In order to get uniform particles in nanosize, we attempted to separate the nucleation and growth processes. The nuclei of precursor hydroxides were formed in reverse micelles of sodium dioctyl sulfosuccinate (AOT). After separation from the microemulsion, the nanoparticles of about 10nm were calcined and the growth process was monitored. Transmission Electron Microscopy (TEM) results show that the irregular precursor nuclei will tend to form cubic shape and the particles grow larger to 20-30nm when the calcinations temperature is increased to 600°C. Lower temperature and longer calcination duration were favorable for the formation of monodispersed smaller particles. X-ray Diffraction (XRD) confirmed the crystalline nature of the ferrite particles. The compositions of the products was found to be determined by both the feed ratio of metal salts and the pH values of the microemulsion, which were analyzed through X-ray Photoelectron Spectroscopy (XPS) and Elemental Analysis. The magnetic properties of the nano-ferrites were measured using a Superconducting Vibration Sample Magnetometer (VSM). The cobalt ferrites nanoparticles synthesized had a relatively high coercivity (1555 Oe) and a saturation magnetization (77.32emu/g). The relationship between the magnetic properties and the crystal structure as well as the domain size will be discussed.

10:00am **MI-FrM6 Measuring Drive and Media Performance using Quantitative Analysis of MFM Images*, D.A. Chernoff*, *D.L. Burkhead, C.S. Cook,* Advanced Surface Microscopy, Inc.

MFM imaging of magnetic hard disks provides a direct physical examination of magnetic marks that complements electrical measurements made on test stands. Valuable information can be obtained because the MFM is free of interference from cross-talk and other read head limitations. Such images have mostly been used for qualitative analyses, such as bit shape, erase band structure, and missing information (defects). However, quantitative analysis of track and bit position and of bit signal amplitude can provide important information to aid in the design and engineering of higher density drives. To assess the accuracy of disk drive servo tracking or of the disk servo writer, we captured several MFM images, each showing 10-15 tracks in the data or the servo mark areas of an ordinary disk. We have demonstrated that our proprietary method@footnote 1@ for calibration and measurement can measure track pitch with precision better than 0.3% (1 s.d.) on calibration specimens and on optical discs.@footnote 2@ For data tracks on a magnetic disk, track pitch variation (1 s.d.) was 3% of the mean track pitch. Drive system engineers can use this information to set target values and tolerances for track pitch. To assess media performance and noise, we captured images of a special test disk, written with constant frequency test patterns. Using similar tools, we analyzed the bit position and amplitude data. Bit position variation (1 s.d.) was 1.5% of the bit spacing and bit amplitude variation was 6.3% of mean amplitude. The variation in bit position (jitter) and in bit amplitude are fundamental sources of digital errors and can be a figure of merit for media response at a given spatial frequency. @FootnoteText@ @footnote 1@ MagneTrack and DiscTrack Plus Media Measurement Systems, www.asmicro.com. @footnote 2@ Automated, high precision measurement of critical dimensions using the Atomic Force Microscope, D. A. Chernoff and D. L. Burkhead, J. Vac. Sci. Technol. A 17, 1457 (1999).

10:20am **MI-FrM7 Femtosecond Spin Dynamics in Ferromagnetic Layered Systems***, **B. Koopmans,*** Eindhoven University of Technology, The Netherlands **INVITED**

Ultrafast spin dynamics in ferromagnetic metals is an issue of great current interest. Pump-and-probe pulsed laser techniques have been successfully applied to study magnetism down to femtosecond time scales. Several groups have reported on an almost instantaneous (< 100 femtosecond) loss of magneto-optical contrast in nickel and cobalt films after excitation by a short laser pulse.@footnote 1@ These observations have triggered fundamental discussions as to the ultimate magnetic time scales, and the responsible scattering processes. In this presentation an introduction to time-resolved magneto-optical techniques and an overview of the rapidly developing field will be presented. In particular, it will be shown that ultimate care has to been taken in the interpretation of these experiments. Using a novel configuration we were able to demonstrate that during the first hundreds of femtoseconds a direct relation between magneto-optics and magnetism in ferromagnetic nickel does not exist. Nevertheless, using the distinct temperature dependence of the true demagnetization and that of optical artifacts, such as state-filling effects, we have been able to access the genuine magnetization dynamics. In our experiments on epitaxially grown Cu/Ni/Cu wedges evidence was found that the equilibration of the electron and spin systems takes place within approximately 0.5-1 picosecond. Oscillations on a much slower time scale, hundreds of picoseconds, were interpreted as a precession of the magnetization vector, triggered by the optical heating pulse. The latter phenomenon may be applied as all-optical real-time ferromagnetic resonance for the investigation of magnetic devices with a sub-micrometer spatial resolution. . @FootnoteText@ @footnote 1@ See e.g. E. Beaurepaire et al., Phys. Rev. Lett. 76, 4250 (1996); J. Hohlfeld et al., Phys. Rev. Lett. 78, 4861 (1997); J. Gadde et al., Phys. Rev. B 59, R6608 (1999).

11:00am **MI-FrM9 Magnetic Force Microsopy on Inductive Recording Heads***, **A. Moser,** M.E. Best, D.K. Weller,* IBM Almaden Research Center

Magnetic Force Microscopy (MFM) has been used to characterize the magnetic stray field generated by the inductive write elements of heads as a function of the amplitude and the pulse width of the write current. The permeability of the write element has been quantified by energizing the head with an offset current that is modulated with a sinusoidal waveform. This current modulation leads to a periodic change in the resonance frequency of the cantilever which has been monitored using a lock-in amplifier. 2D maps of the cantilever resonance frequency show that the write head first saturates at the gap. The saturation current is discussed for different materials and physical structures of the write poles. In a second experiment, the energizing current has been additionally pulsed with pulse widths as short as few nanoseconds to measure the high-frequency behavior of write heads. Here, we observe that larger write current are needed to saturate the write heads at higher frequencies.

11:20am **MI-FrM10 Surface Processing with Gas Cluster Ions to Improve GMR Films***, **D.B. Fenner,** J. Hautala, L.P. Allen, J.A. Greer, W.A. Skinner,* Epion Corporation*; A. Al-Jibouri,* Nordiko Limited, England*; J.I. Budnick,* University of Connecticut

Reduction of roughness and removal of contamination on surfaces of substrates and films for giant magneto-resistance (GMR) will be essential in the development of advanced devices. Tools and methods to accomplish this are limited at present. Gas-cluster ion beam (GCIB) technology shows promise as a dry process that can provide substantial improvement, and can be integrated into GMR-film deposition-and-etch tools. Here we describe recent work developing GCIB techniques and processes for tantalum, alumina, copper, permalloy and other types of GMR-device films relevant to the spin valve, tunneling-MR (TMR) and nano-oxide layer (NOL) technologies. With argon GCIB it is possible to reduce the roughness of tantalum films to well below a nanometer (rms), and the roughness falls exponentially with dose. The exposure to GCIB rapidly reduces the presence of asperities on surfaces and removes other contamination. @FootnoteText@ Supported by NIST-ATP.

11:40am **MI-FrM11 Study of Exchange Anisotropy of Ni@sub 80@Fe@sub 20@/Fe@sub 60@Mn@sub 40@(111) Epitaxial Films@footnote 1@***, **C. Liu,** G.J. Mankey,* University of Alabama

Ferro-antiferromagnetic interfacial exchange anisotropy has been studied extensively.@footnote 2,3@ We have grown Ni@sub 80@Fe@sub 20@/Fe@sub 60@Mn@sub40@ fcc (111) films on epitaxial Cu(111) buffer layers on Si(110). With increasing Cu buffer layer thickness, LEED and RHEED show improving film crystal quality while atomic force microscopy reveals an increase in interfacial roughness. Films with Cu buffer layers thinner than 10 nm had coercivities less than 13 Oe, and the exchange anisotropies deduced from the hard axis initial susceptibility were consistent with the results of hysteresis loop measurements. Films with thicker Cu buffer layer had coercivities and exchange anisotropies deduced from hard axis initial susceptibility that were larger than the results of hysteresis loop measurements. For all films, the angular dependencies of exchange bias H@sub eb@ were not sinusoidal, and surprisingly, all films showed a deviation of pinned direction from the direction of the applied field during film growth. Specifically, the film with thickest Cu buffer layer (100 nm) had the largest deviation (57Â°). This film also exhibited the largest coercivity (47 Oe). Magnetic force microscopy measurements showed a strong ripple pattern for this film, with a length scale of 2 microns, characteristic of a strong stray field in the film. All the results revealed the inhomogeneous nature of the pinning in the films which is closely related to the canting of interfacial spins. We interpret these results based on the combination of effects of roughness and structure induced change of intrinsic magnetic properties. @FootnoteText@ @footnote 1@Funded by ARO #DAAH 04-96-1-0316 and NSF #DMR-9809423. @footnote 2@A.E. Berkowitz and Kentaro Takano, J. Magn. Magn. Mater. 200, 552(1999). @footnote 3@Joo-Von Kim, et al., Phys. Rev. B 61, 8888(2000).

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