Magnetic Interfaces and Nanostructures Technical Group Room 618/619 - Session MI+VM+AS-TuM

Magnetic Recording: Media

Moderator: H.T. Hardner, Seagate Technology

8:20am **MI+VM+AS-TuM1 Perpendicular Patterned Media: Fabrication and Demonstration of Data Storage**, ***J. Wong***[1], *A. Scherer,* California Institute of Technology*; M. Todorovic, S. Schultz,* University of California, San Diego

Patterned media has been proposed as one of the solutions to extending data storage densities beyond 100Gbits/in@super 2@. We have fabricated perpendicular patterned media using a combination of high resolution electron beam lithography, dry etching, and electroplating. Futhermore, we have successfully demonstrated data storage in such structures. We first use vector scanned electron beam lithography to define the dot array pattern on the PMMA coated Al@sub 0.9@Ga@sub 0.1@As/GaAs substrate. After development, this pattern is transferred into the substrate using Chemically Assisted Ion Beam Etching (CAIBE). Immediately following CAIBE, we convert the Al@sub 0.9@Ga@sub 0.1@As layer into (Al@sub 0.9@Ga@sub 0.1@)@sub 2@O@sub 3@ using wet thermal oxidation. We take advantage of the highly selective etching properties of GaAs and the durable masking properties of (Al@sub 0.9@Ga@sub 0.1@)@sub 2@O@sub 3@ to create high aspect ratio Ni columns. After the dot arrays are defined in the substrate, we use electroplating to fill the etched holes with Ni, followed by polishing.@footnote 1@ Using Magnetic Force Microscopy, we find that the Ni columns are stable single domain magnets. We demonstrate data storage in these structures by controllably orienting the magnetization of individual 170nm diameter Ni columns using conventional thin film write poles. We subsequently read back the stored information using current MR or GMR read heads.@footnote 2@ This demonstration bridges the gap between the fabrication of such structures and their use in actual magnetic storage systems. Work is in progress to characterize higher density arrays (~1.3, 2.6, and 5.2Gbits/in@super 2@) in the form of data tracks (1µm in the x-direction and 0.5, 0.25, and 0.125µm apart respectively in the y-direction). @FootnoteText@ @footnote 1@ J. Wong et al., J. Appl. Phys. 85, 5489, 1999. @footnote 2@ M. Todorovic et al., Appl. Phys. Lett. 74, 2516, 1999.

8:40am **MI+VM+AS-TuM2 Ion Beam Patterning of Magnetic Recording Media With a Stencil Mask**, ***B.D. Terris****, L. Folks, D. Weller, J.E.E. Baglin, A.J. Kellock,* IBM Almaden Research Center*; H. Rothuizen,* IBM Zurich Research Lab*; P. Vettiger,* IBM Zurich Research Lab, Switzerland

In conventional scaling of magnetic recording media, the grain size is reduced as the bit density is increased, while the number of grains per bit is held approximately constant to maintain signal to noise levels. This scaling approach, however, will reach a fundamental limit when the grain sizes become so small that they are subject to reversal due to thermal excitation on time scales of less than the required data retention time. One approach to circumventing this thermal limit is to create magnetic bits that behave as single magnetic entities, e.g. either single domains or a collection of strongly coupled grains, rather than the hundreds of weakly coupled grains per bit found in conventional granular recording media. In one approach to patterned media, ion beam irradiation is used to locally alter the magnetic properties of thin Co/Pt multilayer films.@footnote 1@ With sufficient ion dose, the easy axis of magnetization is rotated from out-of-plane to in-plane. We have used this process in conjunction with a silicon stencil mask having 1 micrometer diameter holes to pattern regularly spaced micrometer-sized regions of magnetically altered material over areas of a square millimeter. The nature of these magnetic structures has been investigated by magnetic force microscopy. The technique is demonstrated with mask-sample spacing as large as 0.5 mm. In addition, smaller regions of magnetic contrast, down to 100 nm, were created by using two masks with partially overlapping micrometer holes. Unlike other patterning techniques, this approach is non-contact and does not require post-processing to clean the disk, both potential manufacturing advantages. @FootnoteText@ @footnote 1@ C. Chappert et al., Science 280,1919(1998).

9:00am **MI+VM+AS-TuM3 Ion Induced Magnetization Reorientation in Co/Pt Multilayers for Patterned Media**, ***D. Weller****, J.E.E. Baglin, K.A. Hannibal, M.F. Toney, L. Folks, A.J. Kellock, M.E. Best, B.D. Terris,* IBM Almaden Research Center

Ion beam patterning of magnetic thin films using stencil masks is a prospective path towards ultrahigh-density magnetic recording media. Co/Pt multilayers are ideally suited for this application, since they undergo a spin-reorientation transition from easy axis out-of-plane to easy axis in-plane upon irradiation with ions of suitable energy and dose.@footnote 1@ The mechanism, leading to the observed modulation in magnetic properties is of great fundamental and technological interest and will be discussed in this paper. Electron beam deposited Co/Pt multilayers with representative structure [Si-substrate/SiNx/20 nm Pt buffer/10x(0.3nm Co/1 nm Pt)/2 nm Pt cap layer] were used. These structures have high coercivity (H@sub C@ = 5000- 8500 Oe) and exhibit square perpendicular hysteresis. The high coercivity is attributed to the the large perpendicular anisotropy (K@sub u@ = 4.3 10@super 7@ erg/cm@super 3@) and granularity of these films as indicated in AFM surface topography measurements. The structures were subjected to various doses and currents of 700 keV N@super +@ ions and investigated after each irradiation step using grazing incidence X-ray reflectivity and Kerr hysteresis loop measurements. Direct evidence for ion beam mixing at the Co/Pt interface is found from the XRD data. In particular, we find an almost linear decrease of the integrated intensity of the first grazing incidence Bragg peak with ion dose. This correlates with the measured remanence ratio and anisotropy, however, not with the coercivity, which drops off much faster. @FootnoteText@ @footnote 1@ C. Chappert et al., Science 280, 1919 (1998).

9:20am **MI+VM+AS-TuM4 Texture and Strain in Cr/NiAl Films Grown on Glass Substrates**, ***G. Khanna***[2]*, B.M. Clemens,* Stanford University

Glass has recently emerged as a promising candidate to replace NiP/Al in magnetic recording media due to its smooth surface and high shock resistance. A NiAl seed layer may be employed to produce the desired (112) orientation in the Cr underlayer and a (1010) orientation in the Co-alloy magnetic layer. Since NiAl forms the template for subsequent growth of Cr and Co, determining its growth texture and strain is critical to understanding the microstructure and magnetic properties of the media. We report on synchrotron radiation experiments on Cr/NiAl films of various thicknesses grown on glass substrates at elevated temperatures. Our results demonstrate that the growth of the NiAl (and consequently the Cr) on glass substrates is markedly different from Cr growth on traditional Al/NiP substrates. While a strong (002) out-of-plane texture develops at elevated temperatures in the latter case, no particular growth orientation dominates in the NiAl. Both (110) and (112) reflections appear out-of-plane in Cr films grown on thin seed layers. This result indicates that both growth orientations are present in the NiAl since the Cr grows epitaxially on the NiAl surface. Furthermore, several out-of-plane reflections appear in thick NiAl films which implies that, initially, there is simultaneous growth of NiAl grains having several different orientations. Integrated intensities of (110) reflections suggest that NiAl (110) grains are overgrown as the film thickness increases. A comparison of pole figures shows that the NiAl (110) peak is shifted to @Delta@ @psi@ = 30 from the out-of-plane direction for thicker films. The evolution of the texture with depth may be quantified using grazing incidence geometry and varying the incident angle. Intensity ratios from GIXS in-plane reflections corresponding to particular out-of-plane orientations are used to depth profile the texture. The in-plane reflections may also be used to determine the inhomogeneous strain in both layers.

9:40am **MI+VM+AS-TuM5 Ultrafast Magnetization Dynamics in Magnetic Thin Films**, ***T.M. Crawford****,* Seagate Research **INVITED**

If one extrapolates the current growth trends for disc drive data rates, the data rate expected by the year 2005 is 2.4 Gbits/sec, requiring magnetization reversal frequencies in the GHz range. However, Permalloy (NiFe), a standard material used for inductive write heads, exhibits ferromagnetic resonance (FMR) at ~ 630 MHz, which is a 10%-90%, precession-limited switching time of 550 ps. While increasing the saturation magnetization and/or anisotropy shifts this resonance to higher frequencies, the gain in switching speed is proportional to only the square root of such increases. As a result, operating magnetic recording heads at or near the FMR frequency may be a necessity to achieve the desired data rates in future storage devices. This rapid increase in data rate toward the

[1] **Falicov Student Award Finalist**

[2] **Falicov Student Award Finalist**

fundamental switching speed limit has generated renewed interest in the field of high speed magnetic switching and magnetodynamics, originally studied extensively in the 1950's and 1960's. This renewal has been assisted by the availability of faster electronic and optical techniques with improved signal-to-noise for characterizing magnetic materials and devices at times well below 1 ns. Recent contributions to this field in the form of time-domain switching measurements, where the film magnetization is driven far from equilibrium, will be reviewed. Subtle material-dependent phenomena which have been observed by these techniques, including possible differences in bulk and surface magnetic properties, will be discussed, as will the possibility of actively controlling the magnetodynamics to achieve a desired behavior. Finally, the extension of these techniques to more complicated materials systems and nanoscale device structures will be addressed.

10:20am **MI+VM+AS-TuM7 Temperature Dependent Characterization of Thermal Stability of Longitudinal Magnetic Recording Media***, **A. Moser**, D. Weller, E. Fullerton, K. Takano,* IBM Almaden Research Center

Temperature dependent characterization of thermal stability was performed on a series of magnetic recording media at temperatures between 300 K and 420 K using a static write/read tester.@footnote 1@ The investigated samples are CoPtCr alloys with thicknesses in the range between 5.5 nm to 13 nm. First, the thermal stability of a recorded bit track was studied by measuring the time-dependence of the read-back amplitude between 0.8 s and 70000 s. Second, the time-dependent coercivity was measured by applying a magnetic field pulse of 5 ns to > 60 s width opposite to the sample's initial magnetization. Finally, the samples were characterized by SQUID magnetometry yielding temperature dependent coercivities, viscosity parameters and irreversible susceptibilities. The measurements are discussed with a quasi-independent particle model. The measured stability ratios (ratio between energy barrier for magnetization reversal to thermal energy) and signal decay rates are found to decrease faster than simple scaling with temperature would predict. @FootnoteText@ @footnote 1@ A. Moser, D. Weller and M.E. Best, J. Appl. Phys. 85, 5018 (1999)

10:40am **MI+VM+AS-TuM8 High Resolution FE-Auger Electron Spectroscopy: Applications in Magnetic Recording, Heads and Media***, **C.A. Fenno**,* Seagate Technology - Colorado Design Center

As the Disk Drive Industry pushes toward higher capacity, smaller form factors, and better performance, head and disc design has changed considerably. Technological advances have resulted in decreased dimensions; thinner layers on the disc and within the head reader element, and lower flight heights. As a result the tools used in material characterization requires improved spatial resolution, increased depth resolution and increased spectral resolution. One answer to the challenge of evaluation and characterization of smaller disc and head features is FE-Auger Electron Spectroscopy. FE-Auger provides elemental analysis with excellent spatial resolution. In the best case the electron spot size can achieve 20nm although in the practical case on disc and head features an electron spot size of 60-100nm is more typical. Features of sub-micron dimensions are routinely analyzed with FE-Auger. In some cases high spectral resolution FE-Auger data can reveal chemistry as in the case of titanium-, silicon-, and aluminum-based particles as well as in the case of some oxides and carbides. This chemical data is obtained from particular energy shifts or peak shape change from the respective materials. This presentation will show several examples where the high spatial and spectral resolution available with FE-Auger was instrumental in diagnoses in drive failure analysis.

11:00am **MI+VM+AS-TuM9 Characterization of Co/CN@sub x@ Granular Media Prepared by Nanolamination***, C. Ruby, J. Du, R. Zhou, **S.C. Street**, J. Barnard,* The University of Alabama

Cobalt-carbon thin films proposed for use as granular magnetic media are generally prepared by co-deposition sputtering. An alternative method is nanolamination of the component layers (media and matrix) followed by annealing. The potential advantages of this approach include precise control over component volume fractions and ease in fabricating large, uniform samples. We have produced and characterized thin film granular structures prepared from nanolaminate layers of Co and CN@sub x@. TEM studies of the microstructure indicate that for certain samples discrete domains are generated, with mean grain sizes of around 20 nm, with near lognormal distribution. These films have coercivities above 1200 Oe. Surface characterization by XPS depth profiling indicates that the annealed films have oxidized cobalt in the very near surface region, although initial study did not show any magnetic hysterisis loop shift. AFM measurements show that the surface of the film roughens significantly upon annealing, with the RMS roughness increasing from 0.2 nm to 1.0 nm. Thus, it appears that the mixing involved in the annealing process, which gives rise to grain formation, also degrades the smooth surface of the CN@sub x@ capping layer and exposes some of the cobalt to ambient. The implications of this process on tribological issues is explored.

11:20am **MI+VM+AS-TuM10 Characterization of Hard Disk Drives by Time-of-Flight Secondary Ion Mass Spectrometry (TOF-SIMS)***, **B. Hagenhoff**, R. Kersting,* TASCON GmbH, Germany*; D. Rading, S. Kayser, E. Niehuis,* ION-TOF GmbH, Germany

Hard disks used in hard disk drives consist of a complex inorganic and organic layer structure. Whereas substrate near layers are inorganic of origin and can be comparatively thick, layers closer to the surface become very thin and are finally covered by an organic F containing lubricant. Defective production processes as well as normal use can change the original layer structure and composition. For an analytical characterization of these changes a technique is required which gives detailed information on the chemical composition in lateral as well in depth directions. Time-of-flight secondary ion mass spectrometry (TOF-SIMS) is ideally suited to perform this task because it offers elemental as well as molecular information with high sensitivity. A 3-D representation of the sample can be obtained by combining sputter depth profiling and imaging. With modern TOF-SIMS instruments meanwhile a lateral resolution of less than 200 nm and a depth resolution of only a few nm can be obtained. We therefore applied TOF-SIMS to the characterization of commercially available hard disks. We concentrated on the identification of the lubricant present in the uppermost monolayer, screening for corrosion spots and layer structure elucidation. Special emphasis was laid on the automation of measurement and data evaluation routines in order to enhance sample throughput for industrial applications. Examples for spectroscopy, imaging and depth profiling will be presented.

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