Thin Film
Room: 102 C - Session TF+MI-WeM

Magnetic Thin Films and Nanostructures
Moderator: S. Gupta, The University of Alabama

8:00am **TF+MI-WeM1 Recent Advances and Challenges in Magnetic Recording Media**, ***M. Desai***, *C. Papusoi, K. Srinivasan, R. Acharya*, Western Digital Corporation **INVITED**

For perpendicular magnetic recording (PMR) beyond areal density of 700 Gb/in^2, signal to noise ratio (SNR) and write-ability improvements are becoming extremely challenging to realize. The present exchanged coupled composite (ECC) recording medium has become quite complex and consists of multiple magnetic layers. To enable 1Tb/in^2 areal density, it is required to (i) improve grain isolation for SNR (ii) increase magnetic anisotropy for thermal stability and (iii) reduce all the dimensions, such as thicknesses of the magnetic layers and media grain size. Improvement in grain isolation with maintaining magnetic anisotropy poses challenges on material selection and process optimization and higher anisotropy materials limits the write-ability of the media. It was estimated that the media grain size <8nm can achieve higher SNR due to reduced jitter and transition noise. However, for last several years, the media grain size has hardly changed in optimized PMR media. The increased inter-granular exchange coupling in small grain size media degrades recording media noise characteristics. Also, thermal stability is compromised on media with small grain size. Here, we discuss recent developments and efforts on perpendicular recording media with small grain size and will present our major findings in terms of SNR, write-ability and thermal stability characteristics. We will also discuss advanced ECC media structure with multiple exchange break layers that offers advantages towards enabling reduced grain size. We also describe advanced characterization methods to quantify the effect of inter granular interactions and their relation with materials and sputtering processes.

8:40am **TF+MI-WeM3 FePt Nanopillars for Advanced Media by Glancing Angle Deposition**, *H. Su*, ***A. Montgomery***, *S. Gupta*, The University of Alabama

Granular $L1_0$ FePt films are leading candidates for next generation magnetic recording, for instance, heat assisted magnetic recording (HAMR). This is due to its high magnetocrystalline energy constant (~7.0 x 10^7 erg/cm^3), which can maintain thermal stability even with a reduced grain size of 3nm [1]. However, post-deposition annealing at high temperatures or substrate heating during deposition is required to obtain the $L1_0$ –phase. Meanwhile, glancing angle deposition (GLAD) is a physical vapor deposition method in which the incoming flux from the source impinges on the substrate at oblique angles, causing increased shadowing and forming nanorods and other nanostructured films [2-5]. Herein we report for the first time the fabrication of FePt, utilizing glancing angle deposition (GLAD) with lower annealing temperatures to obtain $L1_0$ phase FePt. The samples were co-sputtered using elemental iron and platinum targets. X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), and alternating gradient magnetometry (AGM) were employed to characterize the structural and magnetic properties. SEM micrographs indicated that the nanorods were approximately 12 nm in diameter, the angle between the substrate plane and the growth direction was about 78 degrees, while the lengths of the nanorods varied, depending on deposition time. The angles between the substrate plane and incident flux ranged from 47 degrees to 82 degrees as the substrate presented itself at different angles to the target during the planetary deposition. After annealing, M-H loops showed that the planetary GLAD samples had higher coercivity than that of normally deposited samples. XRD confirms the $L1_0$ structure for FePt. Our preliminary results indicate a novel and promising approach to $L1_0$-phase FePt for HAMR that is the subject of intense research in the data storage industry.

Acknowledgements

This work was supported by National Science Foundation Grant ECCS-0901858, “GOALI: Nanopatterned Graded Media”. The authors acknowledge the Central Analytical Facility (CAF) and Microfabrication Facility (uamicro)for their support and facilities.

Reference

[1] J.Chen, C. Sun and G. M. Chow, Int. J. Product Development, **5**, 238(2008)

[2] M. M. Hawkeye and M. J. Brett, J. Vac. Sci. Technol. A **25**, 1317 (2007).

[3] T. Smy, D.Vick, M.J.Brett, S. K. Dew, A.T. Wu, J. C. Sit and K. D. Harris, J. Vac. Sci. Technol. A **18**, 2507(2000).

[4] J. Wang, H. Huang, S. V. Kesapragada and D. Gall, Nano Lett. **5**, 2505(2005)

[5]A. Dolatshahi-Pirouz, D. S. Sutherland, M. Foss, F. Besenbacher, Appl. Surf. Sci. 257, 2226(2011)

9:00am **TF+MI-WeM4 Mössbauer Study of Disordering in Thin Sputtered FeCo–SiO$_2$ and FeCo Films**, ***S.S. Maklakov***, *S.A. Maklakov, I.A. Ryzhikov*, Institute for Theoretical and Applied Electromagnetics, Russian Federation, *V.A. Amelichev, K.V. Pokholok,* M.V. Lomonosov Moscow State University, Russian Federation, *K.N. Rozanov, A.V. Osipov, A.N. Lagarkov*, Institute for Theoretical and Applied Electromagnetics, Russian Federation

Thin ferromagnetic films possess perspective applications for a data recording devices, magnetic field sensors, and microwave devices[1]. Thin nanocomposite films, which are prepared of a dielectric matrix and ferromagnetic filler, show interesting magnetic properties. In the case, magnetic properties are determined by exchange interactions and dipole-dipole interactions between ferromagnetic nanoparticles. Among the other techniques, magnetron sputtering results in the composite films with high uniformity. The report demonstrates structural modification in a solid solution $Fe_{70}Co_{30}$ which is caused by additional energy flux towards the substrate during a $(Fe_{70}Co_{30})_{95}(SiO_2)_5$ composite growth comparing with the metal film growth.

Thin metal films (h = 130 nm) were deposited via DC magnetron sputtering onto a PET substrate; the DC magnetron operating regime (time, pressure and discharge parameters) was identical during the composite synthesis. To sputter SiO_2, a RF magnetron was applied; both magnetrons were sputtering simultaneously. To derive structure information, a Mossbauer spectroscopy, X-ray diffraction (GIXD) and electron microscopy data were gathered. Magnetic properties were studied using VSM and a coaxial line technique for a microwave permeability.

Thin $Fe_{70}Co_{30}$ and $(Fe_{70}Co_{30})_{95}(SiO_2)_5$ films show differently broadened Mossbauer sextet. Composite film possess unusually high effective field at iron nuclei H_e = 371(3) kOe. We propose a model which describes H_e values depending on environment of a reference iron atom[2]. With this construction, $Fe_{70}Co_{30}$ solid solution possesses higher *CsCl*-type ordering degree when in form of the composite. Such modification is the result of surface processes during film growth. SiO_2 injection also decreases FMR frequency from 10 to 3 GHz, depending on a composition.

The results reported may be applied to design thin film microwave devices.

Literature

1. *S.S. Maklakov, S.A. Maklakov, I.A. Ryzhikov, K.N. Rozanov, A.V. Osipov.* Thin Co films with tunable ferromagnetic resonance frequency. // J. Magn. Magn. Mater. 324 **(2012)** 2108-2112

2. *S.S. Maklakov, S.A. Maklakov, I.A. Ryzhikov, V.A. Amelichev, K.V. Pokholok , A.N. Lagarkov.* Mossbauer study of disordering in thin sputtered FeCo–SiO$_2$ and FeCo films. // J. Alloys. Compd. 536 **(2012)** 33-37

9:20am **TF+MI-WeM5 Comparing Deep Reactive Ion Etching vs. Ion Milling for Block Copolymer Templating for Bit Patterned Media**, ***A. Owen***, *S. Gupta, A. Highsmith, A. Montgomery, H. Su, R. Douglas*, University of Alabama

Block copolymer templating has been used to pattern perpendicular magnetic anisotropy Co/Pd multilayers.[1] A multilayer stack of Ta 5Pd 5/[Co 0.3/Pd 1]$_{20}$ /Pd 5 nm nanolayers was sputter deposited onto a bare silicon wafer. The block copolymer used was polystyrene polyferrocenyldimethylsilane[2] (PS-b-PFS). This was spin coated onto the wafer and annealed to cause phase separation.[2] The wafer was ashed in an oxygen plasma to remove the polystyrene matrix and reveal the PFS nanospheres. The Co/Pd multilayer films were subsequently etched using an ion mill and a deep reactive ion etching tool.[3] In order to optimize the size tuning of the PFS nanospheres and the coercivity of the magnetic films,response surface methodology was performed to optimize the power, etching times and ashing time of the block copolymer mask and magnetic film. This statistical Design of Experiments was used for both ion milling and deep reactive ion etching. We will discuss some of the shapes of the resulting nanopillars from the different etching techniques. Magentometry was taken to characterize the films before and after patterning, showing a significant improvement in the coercivity, increasing from 1.5 kOe to 3.6 kOe.

Acknowledgements

NSF ECCS 0901858 "GOALI: Nanopatterned Graded Media" is acknowledged for partial support. The UA Microfabrication Facility and the Central Analytical Facility are acknowledged for support and use of facilities.

References

1. 1. O. Hellwig, J. K. Bosworth, E. Dobisz, D. Kercher, T. Hauet et al. ,Appl. Phys. Lett. **96**, 052511 (2010)

2. 2. Joy Y. Cheng, Feng Zhang, Henry I. Smith, G. Julius Vancso, and Caroline A. Ross, Adv. Mater., **18**, 597,(2006)

3. 3. Xiao Li, Z.R. Tadisina, S. Gupta, G. Ju, J. Vac. Sci. Technol. A **27**, 1062, (2009)

10:40am **TF+MI-WeM9 Atomic Layer Deposition Enabled Synthesis of Nanostructured Composite $BiFeO_3/CoFe_2O_4$ Thin Films for Multiferroic Applications**, ***C. Pham***, *J.P. Chang*, University of California at Los Angeles

Multiferroic materials are a class of material which exhibit two or more forms of ferroic order such as (anti)ferroelectricity, (anti)ferromagnetism, or ferroelasticity and have been proposed for use in future devices in which magnetism is switched upon the application of a electric field. While the existence of intrinsic multiferroic materials, such as $BiFeO_3$, have been demonstrated, composite multiferroics offer improved switching performance, consisting of a piezoelectric and a magnetostrictive material coupled together via interfacial strain. In addition, nanoscale composites have been shown in literature to have even greater coupling when compared to other composites. For this project, atomic layer deposition (ALD) is used to enable the precise control of the composition and thickness by manipulating the pulsing sequence of the precursors. In addition, two approaches to multiferroic composites emphasize the flexibility of the ALD technique; for a 2D composite approach, the ability to deposit nanoscale laminates; while for a 3D composite approach, the ability to uniformly coat films over a nanoscale porous template.

In this work, $BiFeO_3$ (BFO) and $CoFe_2O_4$ (CFO) were deposited by ALD to synthesize 2D nanoscale multiferroic composite multilayers. The ALD processes used the metallorganic precursors $Bi(tmhd)_3$, $Co(tmhd)_2$, and $Fe(tmhd)_3$ alongside oxygen atoms produced from a microwave atomic beam source. The ALD BFO and CFO films were able to be grown with a stoichiometric ratio Bi:Fe close to unity and Co:Fe close to 1:2, respectively, and with a controlled linear growth rate. The ALD BFO and CFO processes were then combined to deposit multilayer nanolaminates which repeated between the two oxides at varying thicknesses between 5-20 nm and number of repeating layers. Additionally, ALD BFO was integrated with a 3D mesoporous CFO template consisting of approximately 14 nm diameter pores, which was synthesized using a di-block copolymer self-assembly technique. The conformal aspect of ALD deposition was demonstrated by covering the pores at varying thicknesses until the pores were completely filled.

To compare the material performance of the ALD enabled BFO/CFO films to previously reported benchmarks, measurements of magnetic and ferroelectric properties were accomplished using SQUID magnetometry and Sawyer-Tower circuit methods, respectively. For the 3D mesoporous composite, SEM and XPS confirmed that BFO was able to be deposited onto the nanoscale high aspect-ratio structure of the CFO conformally. The magnetoelectric coupling properties in the composite films were studied by taking magnetic measurements with and without an *ex-situ* electric poling.

Authors Index

Bold page numbers indicate the presenter