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## MAGNETO-OPTIC SUPERLATTICE THIN FILMS: FABRICATION, STRUCTURAL AND MAGNETIC CHARACTERIZATION

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### PROGRESS

During this quarter we extended our studies to determine the electronic contribution to the perpendicular interface anisotropy in Co-based multilayers. Using *in situ* Kerr effect measurements, we investigated the influences of different transition metals (TM = Ag, Au, Cu, and Pd) on the magnetic properties of single-crystal Co films grown on Pd (111) and Au (111) surfaces. We reported last quarter the discovery of a large peak in the perpendicular anisotropy when approximately one monolayer of Cu or Ag is deposited on the Co surface.

We now have added a computer-controlled stepper-motor drive to our MBE sample transfer mechanism. The motor allows us to move the sample at a constant velocity from behind a shutter during deposition. The film, therefore, is deposited as a wedge with a linear variation of thickness across the substrate. In this way, we can study a continuous range of coverage on a single sample. The stepper motor also provides the necessary control for precisely positioning the sample in the laser beam for Kerr effect measurements at the different coverages.

Also during this quarter we have continued our work on MnSb alloy films. We have made sputtered  $Mn_xSb_{1-x}$  ( $x \approx .50$ ) alloy films using DC triode system with a 3N5 Mn target and 5N Sb target both bonded to Cu backing plates.\* The typical sputtering power for Sb was 60 Watts (15 Watt/in<sup>2</sup>) and 120 Watts (30 Watts/in<sup>2</sup>) for Mn. Typical system pressure before sputtering was  $\approx 1 \times 10^{-7}$  Torr. Normal argon sputtering pressure was 7 mTorr, although samples were made in pressures ranging from 3 mTorr to 20 mTorr. Substrate height varied from 3.63 in. to 7.06 in. Samples were deposited on substrates either at room temperature or  $\sim 250$  °C. Substrates were normally at ground potential but in some instances also were biased to +55 VDC and to -55 VDC during deposition.

Films of pure Sb and Mn approximately 1000 Å thick were sputtered on carbon and 90° orientated Al<sub>2</sub>O<sub>3</sub>. Precise measurements of the deposition rates were determined by Rutherford backscattering spectrometry ( $\pm 3\%$ ) and the film structure was analyzed by x-ray diffraction. Standard Bragg-Brentano  $\theta$ - $2\theta$  x-ray diffraction techniques showed the Sb film to be rhombohedral and polycrystalline with the (001) orientation dominant, although many other orientations were present. Bragg-Brentano spectra of the Mn film consisted of only one small peak possibly attributable to Mn. Subsequent measurements were performed using a Seemann-Bohlin x-ray diffractometer with a glancing angle of incidence of 6° so that the effective film thickness is increased to approximately ten times the

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\*3N5 means 3 nines 5. It is the way buyers and sellers of materials specify chemical purity. Ed.

actual thickness. This technique showed that the film was polycrystalline  $\alpha$ -Mn phase with predominant (330, 411) orientation.

The  $\text{Mn}_x\text{Sb}_{1-x}$  films were deposited by rotating the substrates over the sputtering guns and sequentially depositing thin layers of each of the two materials. The sputtering power was set so that the ratio of the thicknesses,  $t_{\text{Sb}}/t_{\text{Mn}}$ , was 2.47. This results in 50 at. % of each material ( $x = .50$ ). With this setup, arbitrary layer thicknesses can be deposited by simply changing the sample rotation speed. Typical layer thicknesses for Mn was 2.6 Å and for Sb was 6.4 Å. Total films thicknesses were approximately 1000 Å. We have used different substrates to try to influence the growth of the  $\text{Mn}_x\text{Sb}_{1-x}$ . These include: glass, Si(111), Si(001), GaAs(110),  $\text{Al}_2\text{O}_3$ , mica and quartz. To determine the effect of different buffer layers on the  $\text{Mn}_x\text{Sb}_{1-x}$  films, we deposited polycrystalline films of Mn, Sb and Cu on these same substrates.

Bragg-Brentano x-ray diffraction performed on the MnSb films showed that the films were polycrystalline with two orientations normal to the film plane: (101) and (110). Even though the peak intensities were low, their widths were narrow. Calculations of the crystallite size from the peak widths using the Scherrer equation yielded values between 300 Å and 400 Å. We did not observe any peaks due to  $\text{Mn}_2\text{Sb}$ , Mn or Sb. While the single crystal substrates generally resulted in higher intensity peaks, possibly due to a smoother starting surface, there was no significant difference in the orientation of the films due to different substrates. Films grown on buffer layers of polycrystalline Sb, Mn, and Cu also were not significantly different from each other or from those without buffers. To date, we have systematically varied sputtering rates, sputtering pressure, substrate height, substrate bias, buffer layers, amorphous- or single-crystal substrates, and layer thicknesses. We have not yet found a technique that results in c-axis oriented films.

*Ex situ* annealing of a film at 300 °C for 5 minutes or 400 °C for 10 minutes in an Ar atmosphere did not change the structure; however the film appearance degraded significantly for the higher temperature. A comparison of x-ray spectra showed little change except that the x-ray intensity increased for the MnSb(101) and decreased for the MnSb(103) peak after annealing.

VSM measurements indicate in-plane magnetization with values of  $M_s = 2.0 - 2.2 \mu_B/\text{Mn atom}$ . This is lower than the bulk value of  $M_s$ , which is  $3.3 \mu_B/\text{Mn atom}$ . Samples deposited on Si had values of  $2.2 \mu_B/\text{Mn atom}$ , while those samples on glass were  $2.0 \mu_B/\text{Mn atom}$ . In-plane coercive fields ranged from 100 Oe to 200 Oe. Measurements of polar Kerr rotation yielded typical values of  $0.2^\circ$  regardless of substrate type, while the polar ellipticity,  $\epsilon_k$ , was much smaller at  $\sim 0.02^\circ$ .

We have recently begun deposition of MnSb by MBE. The work is in preliminary stages and results will be reported next quarter.

## PLANS

During the next quarter we will extend our studies of Co interface anisotropy and the Mn/Sb system. We are interested in the magneto-optic and magnetic properties of c-axis oriented MnSb alloy films. Therefore, we will use MBE to produce highly textured films for study. From these high-quality films, we will be able to estimate the fundamental performance limits of the oriented MnSb alloy and, therefore, guide our sputtering studies of more practical media.

