July 1998

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Meldrim, J.M.; Kirby, Roger D.; DeVries, M.J.; Woollam, John A.; and Sellmyer, David J., "Magnetic and Magneto-optic Study of a Layered Co/Pt - Dysprosium-Iron-Garnet System" (1998). *Faculty Publications, Department of Physics and Astronomy*. 54.
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Magnetic and Magneto-Optic Study of a Layered Co/Pt – Dysprosium-Iron-Garnet System

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Abstract—We have studied the effects of placing Co/Pt multilayers on dysprosium-iron-garnet doped with bismuth and aluminum. The garnet was deposited by RF-magnetron sputtering and crystallized by rapid thermal annealing. The Co/Pt multilayers were then deposited by DC-magnetron sputtering. The garnet thickness was held constant at 1000Å while the Co/Pt multilayer had the form of $[3\text{ÅCo}/9\text{ÅPt}]_n$ with n ranging from 1 to 16. Coercivities of the samples ranged from about 300 to 2000 Oe. Kerr rotations were as high as 1.8° and ellipticities up to 2° depending upon the wavelength of light and the number of Co/Pt bilayers. Magneto-optic signal figures of merit are determined for several of these composite systems.

Index Terms—Cobalt, garnet, magneto-optic, platinum

I. INTRODUCTION

Due to their magneto-optic activity in the blue wavelength region, both cobalt-platinum and rare-earth-iron garnet systems have been studied for potential use in ultra high-density magneto-optic recording. Cobalt-platinum systems are ideal for their large Kerr rotations, appropriate coercivities, and high squareness of the hysteresis loop [1]-[4]. Rare-earth-iron garnets tend to exhibit even larger rotations [5]–[9]. Recent work has shown that multilayering of garnets with transition metals such as Co [9] or Fe [5], especially when combined with rapid thermal annealing (RTA), can provide grain sizes as small as about 10 nm. Such small grain sizes minimize recording and read-out noise due to crystalline and magnetic-domain edge inhomogeneities, but the signal-to-noise ratio (SNR) is still found to be marginal [10]. In this study we investigate the magneto-optic response of a composite system in which both components contribute to the Kerr signal. Co/Pt multilayers were deposited on top of a suitably doped garnet and a figure of merit has been determined as a function of wavelength.

II. EXPERIMENT

A $Dy_{1.6}Bi_{1.4}Fe_{4.4}Al_{0.6}O_{12}$ (DIG) sputtering target was made using standard pressed-powder sintering techniques. A 1000Å DIG film was RF-magnetron sputtered from this target onto a 500 Å thick Pt underlayer that was DC-magnetron sputtered on a Si (111) wafer. All sputtering was done in a 5 mTorr argon atmosphere on a water-cooled substrate. The DIG samples were crystallized in a flowing argon atmosphere with a six-pulse rapid-thermal-annealing technique. Each thermal pulse consisted of ramping the temperature to 650°C at a rate of 50°C/s. The temperature was held at 650°C for 20 s, followed by 120 s cool down. The temperature fell to around 160°C during this time. The DIG films were then covered with $[3\text{ÅCo}/9\text{ÅPt}]_n$ multilayers that were sputtered at rates of 2.7 Å/s (Pt) and 0.75 Å/s (Co). Magnetic measurements were taken using an alternating gradient force magnetometer. Magneto-optical measurements were made using a photo-elastic modulator-based system. Reflectance measurements were obtained by a Perkin Elmer Lambda-9 spectrophotometer.

III. EXPERIMENTAL RESULTS AND DISCUSSION

Fig. 1 shows the magnetization perpendicular to the film plane per unit area for various numbers of Co/Pt bilayers. In-plane magnetization measurements showed that all films displayed perpendicular anisotropy. The coercivities of the two systems individually are different, around 2000 Oe for DIG and 300 Oe for Co/Pt. The total moment of the DIG is rather small compared to that of the Co/Pt system. This is because DIG is a ferrimagnet and the sample used has a composition near the compensation point. As n increases beyond 3, it is possible to clearly identify a "low-field" reversal process at fields of about 300 Oe and a "high-field" process completed at 2000 Oe or more. The hysteresis loop for n = 16 has a shape similar to a curve created by adding the hysteresis loops of 1000 Å DIG and [3 Å Co/9 Å Pt]x10.

As can be seen in Fig. 2, the magneto-optic activity of 1000 Å DIG greatly varies with wavelength around 425 nm due to optical interference effects. Thus data in Fig. 3, was taken at 500 nm to avoid major changes in the data due to slight DIG thickness differences between samples. At this wavelength, the rotation of each system individually is around 0.3°. However, the ellipticities of the two materials are quite different at this wavelength, -0.5° for DIG and +0.2°

Manuscript received October 17, 1997

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This work supported in part by the National Science Foundation under grant Grant DMR-9623982 and the Center for Materials Research and Analysis.

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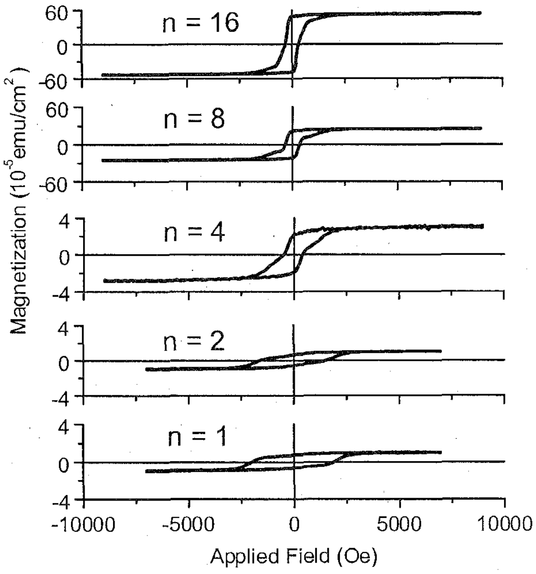

Fig. 1. Magnetization per unit area as a function of applied field for increasing n layers of [3 Å Co/9 Å Pt]$_n$ on 1000Å DIG.

for Co/Pt. For n = 1 or 2, the magneto-optic properties are clearly dominated by the thicker DIG layer with $H_c \cong 2$ kOe. On the other hand for $n \geq 4$, Co/Pt dominates the rotation but the ellipticity shows features controlled by DIG to fields beyond the coercivity of the softer Co/Pt multilayers.

We have also measured the figure of merit, r_{xy}, defined as

$$r_{xy} = \sqrt{R(\theta_k^2 + \varepsilon_k^2)}$$

where R is the reflectance, θ_k is the Kerr rotation, and ε_k is the Kerr ellipticity both in radians [11]. Fig. 4 shows that for the pure garnet, the peak in r_{xy} occurs between 400 and 460 nm. As the number of Co/Pt bilayers increases, the values of r_{xy} decrease towards those of a pure Co/Pt system, as expected. An optimum figure of merit often used is given by [11]

$$FOM = \frac{|\varepsilon_{xy}|}{2\,\mathrm{Im}(\varepsilon_{xx})}$$

where ε_{xx} and ε_{xy} are the diagonal and off-diagonal elements of the dielectric tensor, respectively. But this definition is difficult to apply when more than one layer in the system is magneto-optically active.

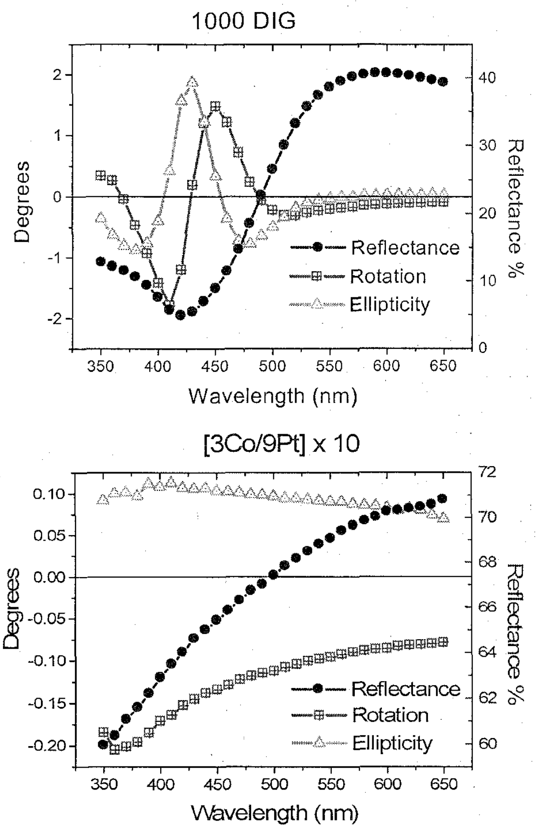

Fig. 2. Kerr rotation, ellipticity, and reflectance vs. wavelength for a single 1000 Å DIG layer on Pt (top) and 10 bilayers of [3ÅCo/9ÅPt] on Pt (bottom).

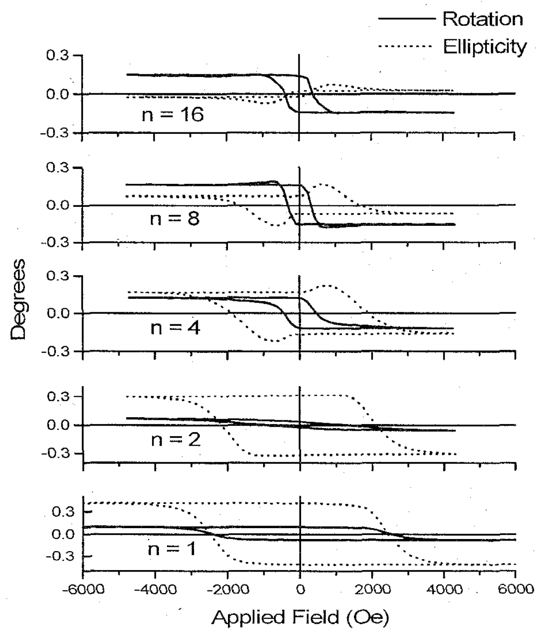

Fig. 3. Kerr rotation and ellipticity vs. applied field at 500 nm for increasing n layers of [3ÅCo/9ÅPt]$_n$ on 1000 Å DIG.

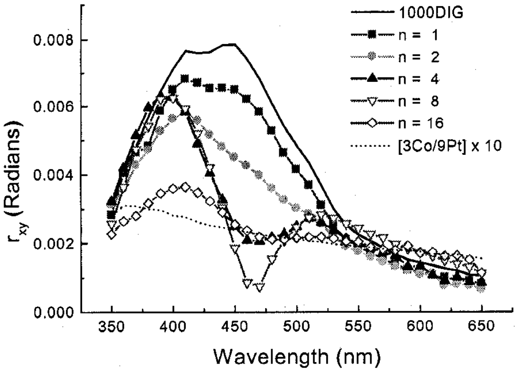

Fig. 4. r_{xy} as a function of wavelength for 1000 Å DIG, increasing n layers of $[3ÅCo/9ÅPt]_n$ on 1000 Å DIG, and, for reference, 10 bilayers of [3ÅCo/9ÅPt] on Pt.

IV. SUMMARY

We have measured the magnetic and magneto-optic properties of the composite system: $[3ÅCo/9ÅPt]_n$- 1000 Å aluminum-bismuth doped dysprosium-iron-garnet where n ranged from 1 to 16. The properties exhibit features of pure Dig and pure Co/Pt and vary in understandable ways as the number of Co/Pt bilayers increases. The magneto-optic signal from DIG is large in the blue wavelength region and the Co/Pt overlayer may provide a smooth low-noise surface. Naturally, determining the practicality of such a system would involve optimizing the recording properties by fabrication of discs and detailed SNR measurements.

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