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The spatial variation of coercivity on patterned magneto-optical (MO) materials has been studied with a Kerr microscope. Our results show that the coercivity values on arrays made by holes are larger than those observed on the land regions. In contrast with nonpatterned MO media, which present a sharp Gaussian-like distribution, the coercivity distribution in the patterned material is much wider and shows an exponential-type distribution. This article maps the spatial variation of the coercivity on patterned magnetic materials with a spatial resolution of 0.1×0.1 μm^2. © *2003 American Institute of Physics.* [DOI: 10.1063/1.1555368]

A major concern usually found to characterize the magneto-optical write and erase processes is the coercivity of the thin film material. Technically, the coercivity H_c in a hysteresis loop is defined as the value of the applied field at which the total magnetization becomes zero. Coercivity, however, is an ill-defined concept which may be useful in the phenomenology of bulk reversal, but its relevance to the phenomena occurring on the spatial and temporal scales of magnetic recording must be seriously questioned.[1] It is fair to say that the existing theories of coercivity[2-4] are generally unable of handling problems associated with spatial variation of coercivity. Moreover, our previous studies indicated that the coercivity of patterned magneto-optical (MO) thin film media is quite different from the nonpatterned samples.[5-7] In addition, we found that the coercivity in the arrays made by holes is quite different from the value found in the land area. We believe that the natural vehicle for conducting the experimental investigation in this area is to map the coercivity variation on the sample surface.

We used a Kerr microscope which has been equipped with an electromagnet, capable of producing a 5 kOe magnetic field, and a CCD camera with a resolution of 300 k pixels. This device grabs the continuous domain-reversal images (30 frames/s) under a series of magnetic fields that are applied perpendicularly to the film plane. We then plot the gray-scale levels of the domain images *versus* the applied field (H_a), and obtain the microhysteresis loops and coercivity values for each single 0.1×0.1 μm^2 area.[8] Figures 1(a) and 1(b) show six of the measured microhysteresis loops and the mapping coercivity distribution, respectively, obtained from 90 000 hysteresis loops for a $Dy_{20}(FeCo)_{80}$ thin film sample with 30 nm in thickness. The sample was made by depositing the DyFeCo film onto a patterned SiN-coated silicon substrate. This film was patterned by the electron beam lithography technique.[9] The upper-left-hand side of Fig. 1(a) is the nonpatterned region, while the lower-right-hand side is the 0.5 $\mu m \times 0.5$ μm square-patterned region with the hole depth of 13 nm. The separation of the square holes is 0.5 μm apart. The coercivity difference between the square arrays of the patterned surface and the nonpatterned area can be clearly identified. The color bar on the right-hand side of Fig. 1(b) indicates the coercivity strength. The blue color depicts the lowest magnetic field strength, while the red color represents the highest strength. From this color bar, we can see that the coercivity on the patterned area (from 1400 to 1900 Oe) is larger than that on the nonpatterned area (from 1200 to 1400 Oe). In addition, the high coercivity spots outside the patterned area are due to the high anisotropy defects, produced from inhomogeneous of the film, hinder the easy motion of domain walls.

In order to investigate the coercivity variations due to the effect of patterned substrates for a magnetic thin film

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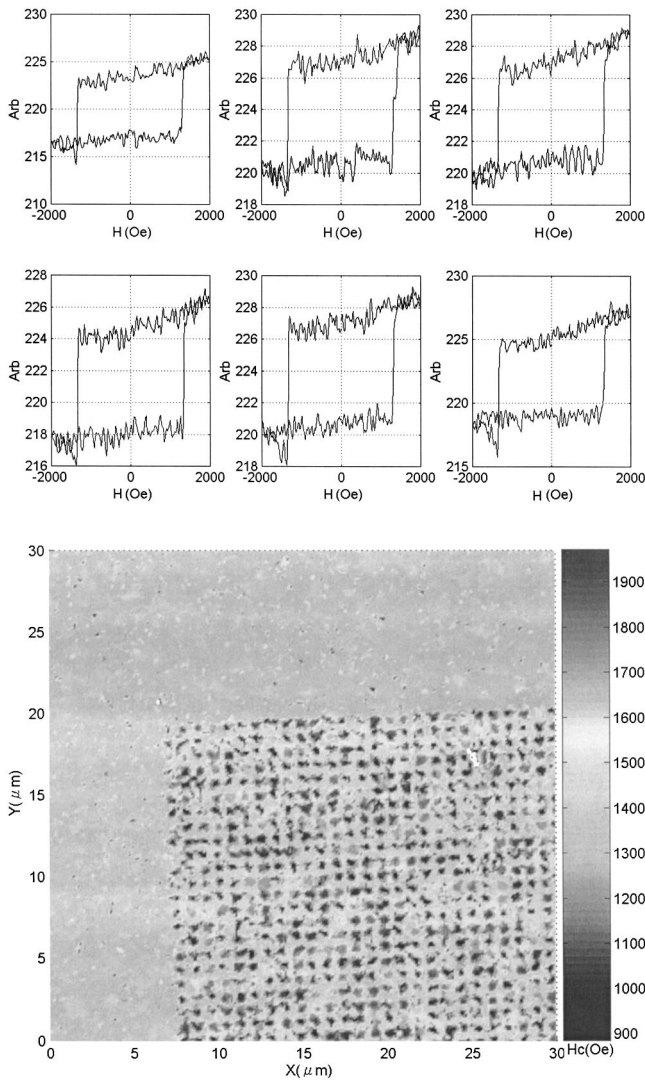[a)]Electronic mail: wuth@pine.yuntech.edu.tw

FIG. 1. (a) Six of the measured microhysteresis loops; (b) coercivity distribution for a patterned $Dy_{20}(FeCo)_{80}$ thin film.

material, we compare the results with another composition. We have produced the films with and without a patterned SiN-coated silicon substrate. Figure 2(a) shows the coercivity distribution on the surface of a nonpatterned $Dy_{21}(FeCo)_{79}$ sample (with 50 nm in thickness) obtained from 90 000 microhysteresis loops. It can be seen that the magnetic domain wall motion started via a defect (low coercivity) site, as the arrow indicates on the blue spot. In addition, other light blue color portrays the other defects. Most of the color in yellow shows that the average values of coercivity is in this range. That also can be seen from Fig. 2(b), which shows the statistic numbers of various coercivity strengths. This reveals that the coercivity value behaves as a Gaussian-like spectrum, and that most of the coercivity value concentrates in 3950 Oe. Moreover, we can reconstruct the a hysteresis loop from Fig. 2(b) by plotting the number of coercivity values versus the coercivity value, as shown in Fig. 2(c). We can see from the dashed-line hysteresis loop of Fig. 2(c) that the averaged coercivity value obtained from the loop is about 3949 Oe, which is consistent with the peak value of the Gaussian-like spectrum in Fig. 2(b).
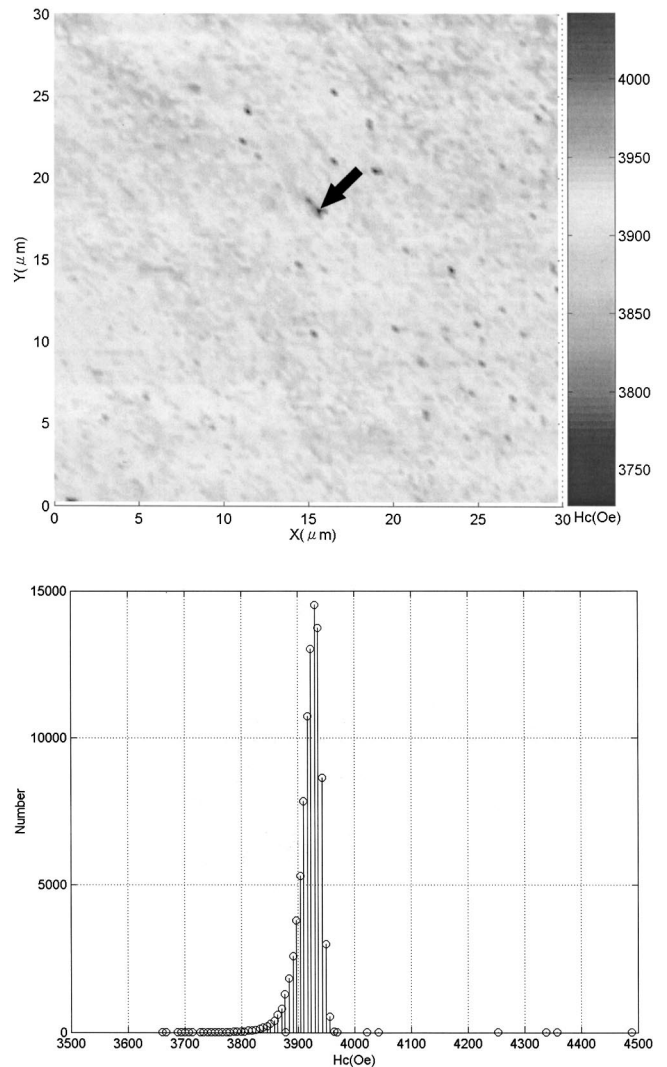

FIG. 2. (a) Coercivity distribution on the surface for a nonpatterned $Dy_{21}(FeCo)_{79}$ sample; (b) statistical numbers of various coercivity strengths; (c) averaged hysteresis loop for a patterned (solid line) and a nonpatterned (dash line) sample.

The same magnetic thin-film sample with patterned SiN-coated silicon substrate was made by a photolithography technique. Figure 3(a) shows the topography image of a patterned substrate sample, as obtained by a Digital Instruments
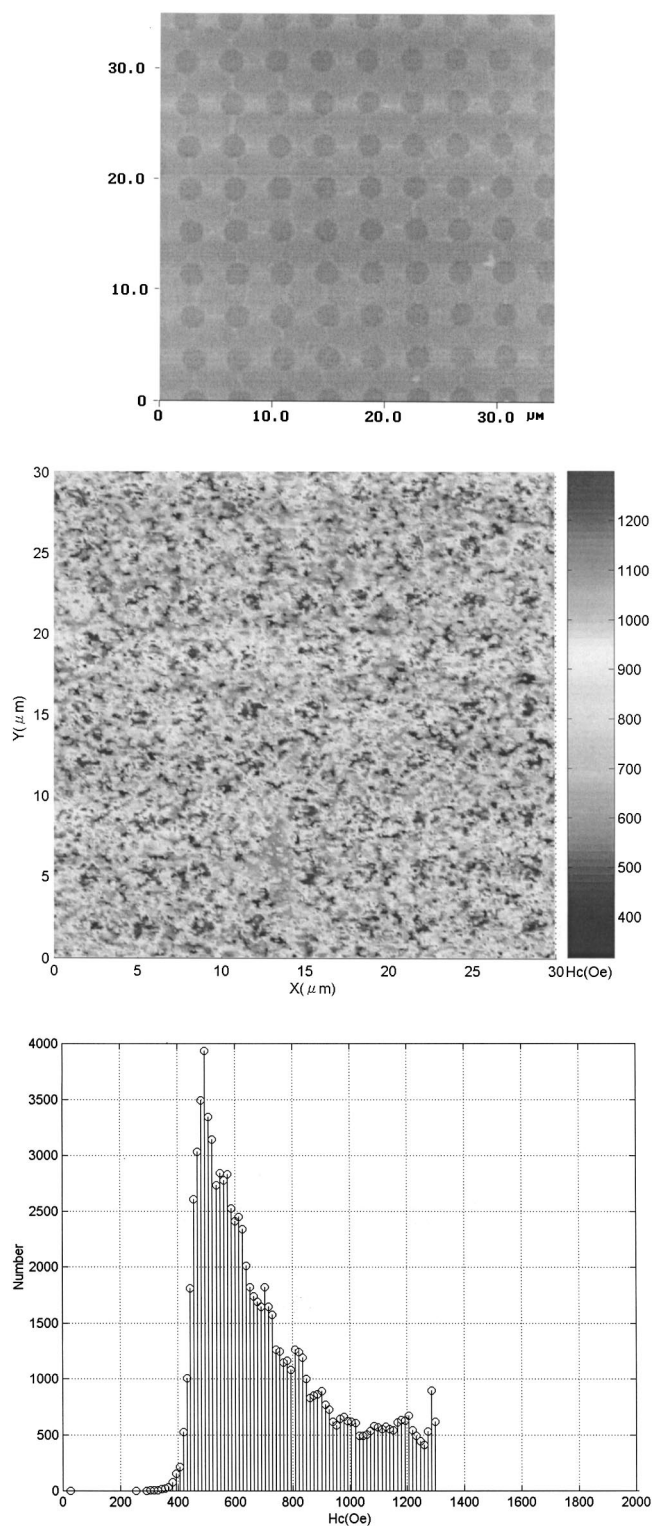
FIG. 3. (a) Topography image from a patterned substrate sample; (b) coercivity distribution on the surface for a patterned $Dy_{21}(FeCo)_{79}$ sample; (c) statistical numbers of various coercivity strengths.

AFM working in a tapping mode. The sample composition and thickness are the same as the previous one, except that this new sample is patterned with arrays of circular holes, each one with a hole depth of 13 nm and a circular diameter

of 2 μm. Figure 3(b) displays the coercivity distribution on the surface of the patterned thin film. The coercivity difference between the arrays of circular holes and the land regions on the patterned surface can be clearly identified. Inside the regions of arrays of holes, as the color bar portrays, the coercivity is within the range of 900–1300 Oe, while on the land regions the coercivity range is between 400 and 900 Oe. The coercivity of patterned magnetic thin film decreases, and the coercivity in the regions of arrays of holes is higher than that on the land area. Indeed, patterned thin film can be treated as an interacting system of flat disks (hole regions) and the continuous thin film with the nonmagnetic inclusion (land regions). The reduction of the coercivity in the land area can be easily understood from the inclusion theory,[10] which states that $H_{cl} = H_c - \gamma n r / 2 M_s$. Here, γ is the wall energy, M_s is the magnetization of the magnetic thin film, n is the number density of the circular pinning site, and r is the radius of the circular pinning. The possible explanation for the ragged circle distribution in the hole area is the ragged bottom surface inside the hole and the mutual interaction between the hole regions and the land area.

The spectrum for the statistical numbers of coercivity is shown in Fig. 3(c). Compared with Fig. 2(b), the spectrum in the patterned thin film is much wider than the one obtained for the nonpatterned thin film. This can be understood from the mutual interaction of the holes and the land area. The spectrum is composed of two distributions, namely, the left spectrum that comes from the land region, and the right spectrum that results from the hole arrays. In addition, the total number of coercivity values in the region of arrays of holes is about one-third of that obtained for the land region, which is consistent with the geometric area ratio between hole arrays and land regions.

Once again, we can reconstruct the hysteresis loop from Fig. 3(c) by plotting the statistical number of coercivity values *versus* the coercivity value, as shows in the solid-line hysteresis loop of Fig. 2(c). It can be seen from the solid-line loop that the coercivity is about 700 Oe, which is consistent with the peak value of the coercivity distribution in Fig. 3(c).

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