THERMOMAGNETIC RECORDING IN AMORPHOUS TbFeCo FILMS ON PATTERNED SUBSTRATES

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Abstract - Magnetization reversal and thermomagnetic recording in amorphous TbFeCo films on patterned glass substrates were studied. Two types of patterns were examined: 1x1 μm^2 raised and lowered square patches. Pinning of the domain walls at the side-walls of the patches was observed. Thermomagnetic recording experiments confirm the ability of patterned substrates to confine recorded domains within boundaries defined by the side-walls.

1. Introduction

Achievement of higher information density in magneto-optical (MO) recording requires the use of a light source with a shorter wavelength and utilization of methods allowing writing and reading domains smaller than the focused spot. Confinement of the recorded domains in MO film by patterning of the disk substrate is promising for this application [1-3]. Patterning of the glass substrate in the form of shallow patches produces periodic variations of the film coercivity, possibly caused by a tilt of the easy axis or by a change of film thickness on the side-walls of the patches [4]. The patch borders pin the domain walls during thermomagnetic writing, thus providing confinement of the domains.

In the present work we study domain structures in amorphous TbFeCo films deposited onto patterned Corning 7059 glass substrates. Thermomagnetic recording has been performed on these samples, confirming the ability of the underlying structure to confine the written domains.

2. Experimental

Patterned Corning 7059 glass substrates were fabricated using a photolithographic method. Square 1x1 μm^2 patches, having a height (or depth) of 10 or 20 nm, were produced by argon etching through a photoresist mask [1,3]. The result of this etching is shown in the atomic force micrographs of Fig.1. The lowered patches shown in Fig. 1(a) are obtained using the same procedure but the exposed photoresist was underdeveloped. Figure 1(b) shows the raised patches obtained by the method described in [3] when the exposed photoresist was overdeveloped.

The thin film structure deposited on the patterned substrate was as follows: glass/SiN(10nm)/TbFeCo(50nm)/SiN(80 nm). The MO layer itself was an amorphous Tb-rich TbFeCo film having a saturation moment M_s=190 emu/cc and a coercivity H_c=3 kOe at T=300 K

The magneto-optic loops of the samples were obtained in a loop tracer in fields up to 20 kOe [5]. Domain structures were observed in a polarized light microscope using 100x oil immersion lens. The observations were recorded with a TV camera and a PC-based frame grabber that allowed image processing for noise reduction [6]. A single-pole, conical-tip electromagnet, having a maximum field capability of 5 kOe, was mounted under the microscope's XY stage to provide the necessary fields

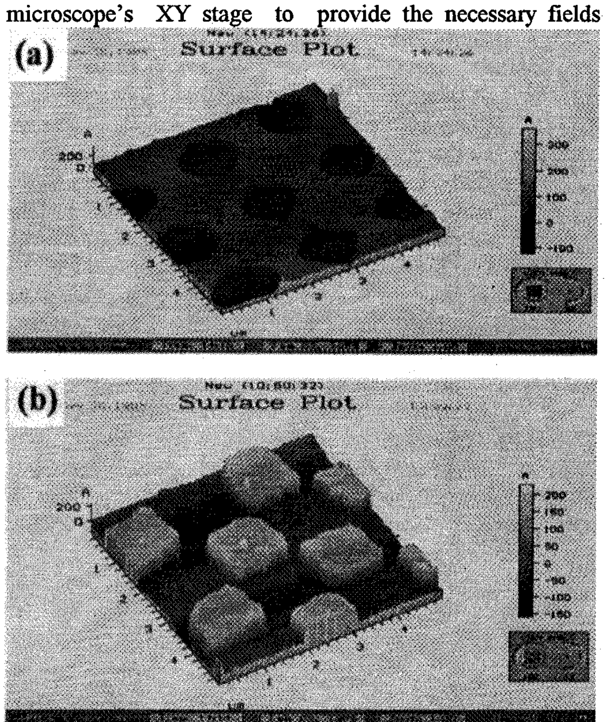

Fig.1 AFM picture of 1x1 μm^2 patches on a Corning 7059 glass substrate obtained by a photolithographic method and using argon-ion milling. (a) Lowered patches having a depth of 10 nm. (b) Raised patches having a height of 20 nm.

for domain growth, as well as a bias field for thermomagnetic recording. The microscope was equipped with a semiconductor laser diode for domain writing and erasure experiments.

3. Results and discussion

Figure 2 shows domain structures developing in the patterned sample with lowered patches (Fig. 1(a)) under a bias magnetic field. At first the magnetic reversal occurs due to nucleation followed by wall motion in the connected areas of the sample, namely in the region between the patches (see Fig. 2(a)). At a certain magnetic field strength the entire region between patches becomes saturated, while within the patches magnetization remains unreversed (see Fig. 2(b)). The side-walls prevent the magnetic domain wall from entering the patches. At higher magnetic fields the domains defined by the patches begin to collapse either due to domain wall penetration through the side-walls or due to nucleation of reverse domains within the patches (see Fig. 2(c)). The Kerr loop for the same sample shown in Fig. 2(d) shows all the peculiarities of magnetization reversal in this sample. The sharp drop in the Kerr signal in the vicinity of 2.4 kOe corresponds to magnetization reversal in the regions between the patches. Between 2.5 kOe and 5 kOe the Kerr signal continuously approaches the saturation value, indicating the collapse of the various domains within the patches.

Samples with raised patches (see Fig. 1(b)) show very similar magnetic behavior. Again nucleation and domain wall motion occur first in the connected areas between the patches. After that the magnetization reversal occurs within the patches. A difference exists however in the magnetic field strength that causes reversal within the patches. Figure 3 shows a Kerr loop measured on the patterned sample with raised patches having a height of 10 nm. The sharp drop in the Kerr signal in the vicinity of 2.3 kOe again corresponds to magnetization reversal in the areas between the patches. Between 2.5 kOe and 4 kOe very few patches reverse, leaving all the remaining magnetization reversal to occur between 4 kOe and 7 kOe.

The stronger field needed for domain collapse within the raised patches can originate from steeper side-walls of these compared to lowered patches. Another possible source of the difference is the different nucleation/wall motion coercivities of the TbFeCo film on the etched and unetched regions of the substrates [3].

Figure 4 shows results of thermomagnetic recording on patterned samples. A 780 nm laser beam was directed through a 1.25 NA immersion oil objective to the individual patches and, with the aid of an externally applied magnetic field, effected the writing/erasing of domains. In Fig. 4(a) 200 ns, 10 mW laser pulses produced erasure of selected domains from the sample shown in Fig. 2(b). In Fig. 4(b) the domains were written on the patches of an initially saturated sample under a reverse field of 1.3 kOe. The figure shows good confinement of domains within individual patches.

Figure 5 shows the noise spectra measured in a dynamic tester [7] on the sample with raised 1x1 μm^2 patches having a height of 10 nm. The sample was magnetically saturated before the measurement. The peaks at 2.5 MHz, 5.0 MHz, and 7.5 MHz correspond to the various harmonics of the 2 μm-period pattern on the substrate at V = 5 m/s. Shown below the signal measured on the patterned region is the signal from a flat region of the same sample. Note that additional wide-band noise introduced by the

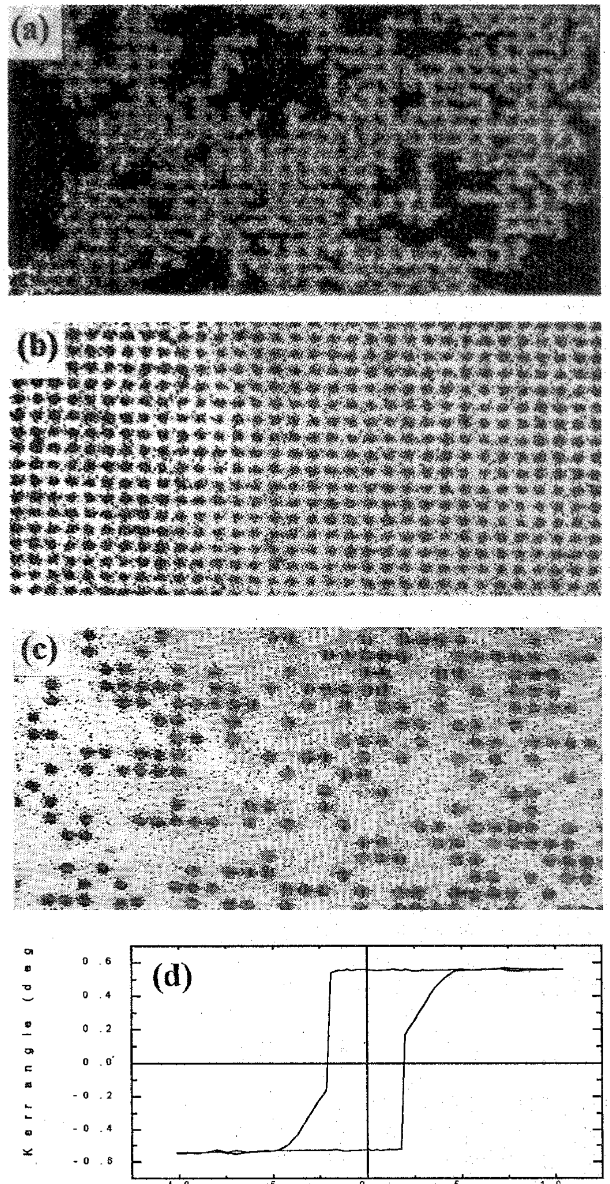

Fig. 2 Domain structure developing under a bias magnetic field, H_b, in a TbFeCo film deposited onto a patterned substrate having 1x1 μm^2 patches with a depth of 10 nm. (a) H_b = 2.4 kOe. (b) H_b = 3.5 kOe. (c) H_b = 4.5 kOe. The Kerr loop of the sample is shown in (d).

patches is about 3 dB. This noise is believed to have arisen from the induced roughness on the substrate by the photolithographic process, and by the scattering of light from the sharp edges of the pattern. Improvements in the patterning process and reduction of the patch height are expected to reduce this component of the media noise. The various harmonics of the pattern itself would not have appeared in the differential channel output, if the scattering of light at the side-walls of the raised/lowered squares did

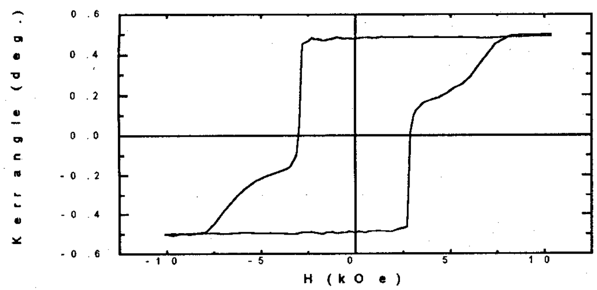

Fig. 3 Kerr loop measured in TbFeCo film on the patterned substrate with raised patches having a height of 10 nm.

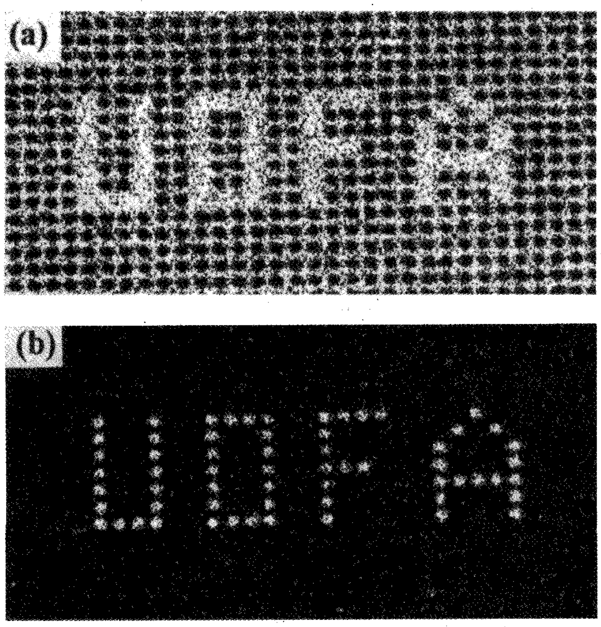

Fig. 4 (a) Domains erased at H_b = 1 kOe by 200 ns, 10 mW laser pulses from a sample having 10 nm-deep, 1x1 μm^2 patches. (b) Domains written on 1x1 μm^2 patches having a height of 20 nm at H_b = 1.3 kOe using 200 ns, 10 mW laser pulses.

not cause any depolarization. Again, improvements are needed in the patterning process to eliminate the appearance of the substrate pattern in the differential MO signal. If these harmonics can be made narrow and if their levels can be brought below the normally accepted levels of cross-talk from adjacent tracks, then it is possible to live with the disturbance that they cause on the read signal.

4. Conclusions

Pinning of domain walls in TbFeCo thin films by the side-walls of square patches on patterned glass substrates has been observed. The pinning is observed in both cases of raised and lowered patches, although in the case of raised patches the pinning appears to be stronger. Confinement of thermomagnetically written domains within the patches was

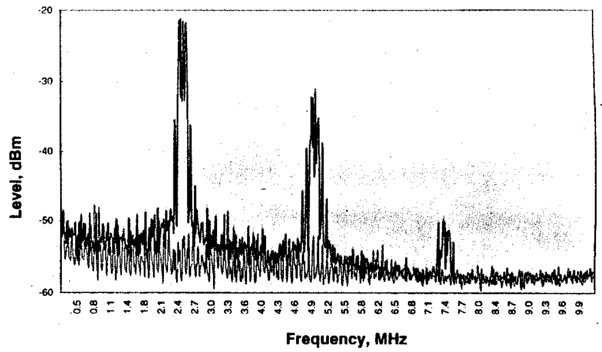

Fig. 5 Noise spectra measured on the flat region (lower trace) and patterned region of the same sample (upper trace) with raised patches having a height of 10 nm. The sample was fully saturated by a strong magnetic field prior to these measurements. The sample's linear velocity was 5 m/s.

demonstrated. Dynamic measurements of noise on "erased" samples indicate that the additional noise introduced by the patterning of substrates must be reduced if the technique is to have a future in MO recording applications.

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