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Domain Collapse in Grooved Magnetic Garnet Material

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ABSTRACT

Domain collapse fields in grooved garnet material were investigated by experimental observation and numerical simulation. The results indicate that the change in domain collapse field is largely due to magnetostatic effects produced by the groove edge. A simplified model based on the effective field produced at a groove edge, and local changes in the material thickness explains the observed trends very well.

INTRODUCTION

Material grooving has been proposed as a technique for stabilizing magnetic domains in thin films. Vertical Bloch Line data storage devices use material grooving to stabilize a stripe domain, and bias field match the device [1]. We have investigated the effect of material grooving on domain stability in thin film garnet material using simulation and experimental observation. The effect of material grooving can be explained by magnetostatic effects at the groove boundaries

EXPERIMENTAL METHOD

The collapse field of magnetic domains in a thin film of $(YBiGdHoCa)_3(FeGeSi)_5O_{12}$ (material parameters $4\pi M_s$ =-- 472 G, H_k = 1610 Oe, A = 5.18 $\times 10^{-07}$ erg/cm, α = 0.11, characteristic length = 0.282 μm) was determined using optical microscopy and the Faraday effect. An array of grooves was defined with standard photolithography techniques. Selected regions were exposed to an incident beam of Ne ions to locally damage the material. The garnet wafer was then immersed in hot acid to remove the damaged regions of the film. Etch times were based on previous processing efforts. The resulting groove pattern was characterized by a scanning electron microscope to measure the actual groove width and depth. Groove depth (g) varied from 0.2 μm to 0.6 pm, and groove width (w) varied from 1.2 μm to 2.6 pm, The grooves were arranged in a rectangular array with a pitch of either 4 or 8 μm as shown in Fig. 1a.

The domain collapse field was measured by increasing the magnetic field perpendicular to the plane of the material until the domains disappeared from view. Domains were initially nucleated by applying a pulsed magnetic field perpendicular to the film surface. Approximately 5 to 10 bubbles were observed, depending upon the number of grooves in the field of view. Each collapse measurement was performed for a minimum of ten repetitions. To avoid errors relating to the variation of material parameters across the wafer, the ungrooved domain collapse field was measured in the vicinity of each test structure.

NUMERICAL METHODS

Domain collapse field in a grooved region was simulated with a recently developed computer code based on a simplified model of domain structure [2]. In this model the structure of a domain wall is approximated with a simplified analytic form and the wall structure is assumed to be uniform through the material thickness. Although the magnetization structure in the domain wall is known to vary throughout the material thickness, these types of models have been shown to yield accurate results in the linear mobility region. The surface of the wall is approximated with a polygon segment, and a set of equations which describe the evolution of the wall surface have been proposed. The computer simulation code is based on the time evolution of this system of equations.

RESULTS AND DISCUSSION'

Figures 2 and 3 show the change in domain collapse field as a function of groove width for 4 μm and 8 μm pitch groove arrays with groove depths of 570 nm and 408 nm respectively. Simulation results are shown for the corresponding configurations. The simulated results reproduce the observed experimental behavior very well. The general their proximity. The maximum effect occurs between these two limits, as seen in Figs. 2 and 3.

A simplified analytic form for this effect maybe obtained by using an expansion for F(x) about x=O:

$$F(x)\sim x-\frac{2}{\pi}x^{2} \text{ -t (2(X}^{3}\text{)} \qquad (2)$$

Approximating the magnetic field produced by the groove edges with a point wire located at a distance $g/2$ from the material surface, the magnetic field in the center of the groove is given by:

$$\frac{H_z}{4\pi\ M_s} = \frac{\mathbf{2}\, M_s w g}{\pi\ (h^2+w^2)} \qquad (3)$$

The resulting form

$$\frac{H_{co}^{g}-H_{co}}{4\pi\ M_s}=\sqrt{\frac{8}{\pi}}\left(\sqrt{\frac{l}{h}}-\sqrt{\frac{l}{h-g}}\right)+\frac{2wg}{\pi\left(h^2+w^2\right)} \qquad (4)$$

reproduces the general functional form, but over estimates the collapse field difference. The discrepancy results from the magnetic field estimate in the grooved region. The two functions shown in Eq.(4) were used as a basis for a least squares fit to the experimental data. The resulting curves are shown in Figs. 2 and 3.

Fig. 4 shows the change in domain collapse field as a function of groove depth for a constant groove width of ‘2.2 pm. Only four groove depths were experimentally investigated due to the nature of the fabrication process. A similar type of decomposition may be used to interpret the experimental data. In the limit of no material grooving (g+ o) the change in domain collapse field must approach zero, as seen in Fig. 4, because we recover the ungrooved sample. In the opposite limit of very deep grooving ($g \to h$) the collapse field difference must also approach zero. This is not as easily apparent in the experimental data.

CONCLUSIONS

The results indicate that the variation of the domain collapse due to grooving in garnet material is well explained by magnetostatics and the local reduction of material thickness. The simulation results provide a useful tool for predicting the upper limit of domain stability in grooved regions. The variation of domain collapse due to material grooving is one aspect of a larger investigation. A simplified model which describes the entire domain stability range in grooved regions is needed for the general problem of bias field matching. Additional work is needed to investigate the effects of further material processing on domain stability margins.

ACKNOWLEDGMENTS

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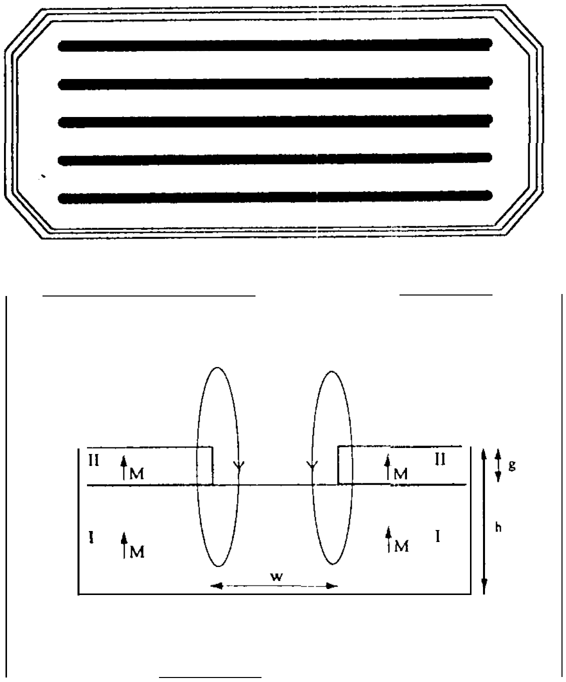

Figure 1 (a) Mask used to define groove array for investigation. (b) Material cross section in the vicinity of the groove.

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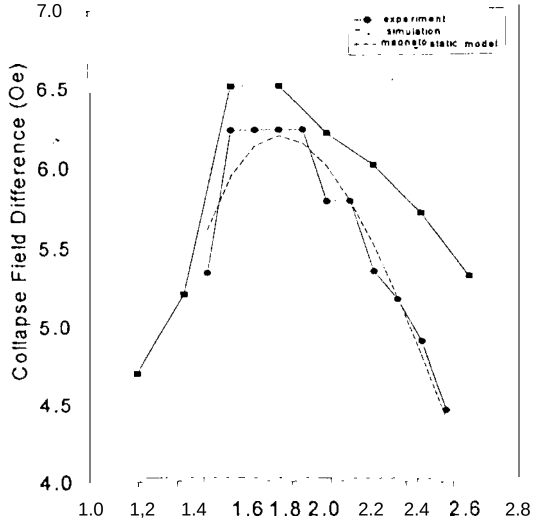

Figure 2. Change in domain collapse field in a 8 μm pitch groove array with groove depth 580 nm.

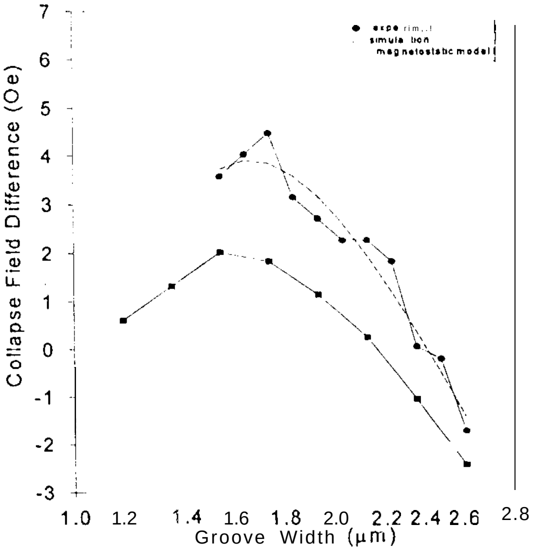

Figure 3 Change in domain collapse field in an **8 μm** pitch groove array with groove depth 408 nm.

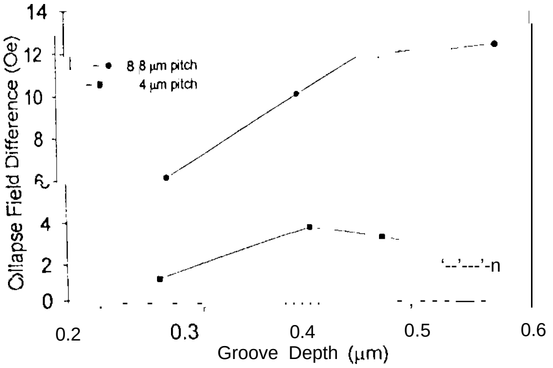

Figure 4. Variation of collapse field difference With groove depth at a constant groove width of **4.4μm.**

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