High-coercive garnet films for thermo-magnetic recording

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Abstract. The possibility of using high-coercive garnet films for thermo-magnetic recording is related with the presence of the metastable domain structure, which arises due to a significant mismatch of the lattice parameters of the film and the substrate. In the work the connection between facet crystal structure of elastically strained ferrite garnets films and the domain structure in them is established by methods of phase contrast and polarization microscopy.

1. Introduction

Uniaxial anisotropy high-coercive garnet films are an optimal media for thermo-magnetic recording by laser beams or contact printing. For example, contact printing magneto-optic films were used for criminalistics examinations of magnetic recordings [1]. For these purposes the films had a low Curie temperature ($T_C < 100 \, ^\circ C$). The effective technological way to increase coercivity $H_c$ is to make strains by increasing mismatch $\Delta a = (a_f - a_s)$ between crystalline lattices of film $a_f$ and substrate $a_s$. Stresses are proportional to the mismatch and networks of misfit dislocations are formed usually to relief them. As in the case of polycrystalline films obtained by the deposition of the aerosol, the crystal structure of the films due to a strongly inhomogeneous internal stresses [2]. Strain-induced morphology has a great influence on parameters of mono-crystalline garnet films, grown by means of liquid phase epitaxy.

2. High-Coercive Garnet Films

2.1. Synthesis of High-Coercive Garnet Films

Garnet films (Bi,Sm,Lu)₃(Fe,Al,Ga)₅O₁₂ synthesized by liquid phase epitaxy, using isothermal dipping technique. As substrate monocrystalline wafers were taken Gd₃Ga₅O₁₂ (GGG) with a lattice parameter 12.383 Å and (111) crystallographic orientation. Mismatch of film-substrate crystal constants are positive $\Delta a = 0.04-0.12$ Å. After mechanical polishing by diamond abrasives (with optical surface quality) and ion-beam etching the thickness of garnet films is 1-2 microns. As a rule, this processing increases garnet films coercivity $H_c$ [1,3]. As a result, the grown films are $H_c = 80-550$ Oe, angle of Faraday rotation $\theta = 2-2.3^\circ/\mu m$ ($\lambda = 532$ nm), $4\pi M_s > 1.0$ kGs, $h = 4-5 \, \mu m$ and $T_C = 60-210 \, ^\circ C$. Uniaxial anisotropy field $H_k = 1.3-1.7$ kOe.

2.2. Magnetic and Morphological Properties of the Films

The initial morphology of films with a great $\Delta a$, which is due to the occurrence of the facet structure, is shown in Figure 1 (a, b). Relief of the surface and internal stresses in the films particularly well...
revealed in the interferometer of Interfako microscope. All of the samples are characterized by block structure. It forms a mosaic. The size of its elements is about 1-5 microns. Block sizes reveal dependence on mismatch of film-substrate crystal constants Δa. In the films with smaller mismatch, the block size is less. These blocks are regions of relatively free from dislocations. The boundaries of the blocks consist of dislocation clusters. Typical film relief after epitaxy caused by the intersection dislocations with surface.

Figure 1 The facet structure of the films with Δa=0.074 Å (a) and Δa=0.103 Å (b). The block size is 2 (a) and 5 (b) microns (Nomarskii differential-interference contrast).

Figure 2 shows the magneto-optical images of two types of domain structures (DS), which are observed in such films. Domain structure on Figure 2 (a) obtained after demagnetization of the film by an alternating magnetic field. This domain structure is stable. It retains its form during remagnetization. Domain structure on Figure 2 (b) obtained by the method of thermo-demagnetization, during the heating above Tc. Such domain structure is metastable, it turns into a stable DS during remagnetization. Fractal analysis was used for a description of the type of domain structure. It is found that the fractal dimension of the meta-stable domain structure is higher (D=1.7) than the dimension of the stable domain structure (D=1.3). Both images are retaining a hexagonal symmetry, which is conditioned by cubic anisotropy in (111) plane.

Figure 2 Stable (a) and meta-stable (b) domain structures.
2.3. Dislocations in the Films

It has been established that a network of misfit dislocations is located above the interface of substrate-film and its position is dependent on the value $\Delta a$ [3]. This means that pseudomorphic layer, where the elastic stresses are mainly concentrated, has a definite value of thickness $h_p$. At large mismatches the line of appearance of the first dislocations above the interface tends to decrease $h_p$. Selective etching has been used to identify the detection of defects in ferrite garnet films. Interface (ends of the film) and wedges are etched. Wedges were obtained by a special polishing, as a result of which the film thickness ranged from $h$ to 0. The samples were studied using differential interference contrast (Figure 3) and scanning electron microscopy (Figure 4). Etch pits reveal the existence of dislocations near the interface (boundary) film-substrate, that observed that both the film-substrate interface and the wedges. The distribution of density over the thickness of the films was evaluated by observing dislocations in differential-interference microscope wedges in monochromatic light on the location of the interference fringes of equal thickness. The greater the mismatch, it corresponds to the lower height of appearance of the first the dislocation above the interface. In the image of the wedge Figure 3 it's clear the first dislocation in the film with constant mismatch film-substrate 0,045 Å appear with the achievement of the epitaxial layer thickness of about 0.2 microns. Half of the average dislocation density is located at a distance higher than 0.6 microns above the interface. The maximum density of dislocations is focused on the film surface.

![Figure 3](image1.png)

**Figure 3** The distribution of dislocations in etched wedge of garnet film. Interference stripes of equal thickness (590 nm). (Differential-interference contrast)

Importantly, the images and the ends of wedges after the selective etching of films misfit dislocations are not located directly on the interface of substrate-film.

![Figure 4](image2.png)

**Figure 4** Garnet films after selective etching in HNO3: surface (a,b). (SEM).
Figure 5 Garnet films after selective etching in HNO3: 45° views (a) (SEM). View of the film-substrate interface (b) (Nomarskii differential-interference contrast).

The relief of surface the film-substrate interface is visible when using differential interference contrast. On Figure 5 dark spots are etching pits of misfit dislocations, located above the film-substrate interface. The so-called "tracery creek" formed by a grid of screw dislocations is located still higher.

2.4. The relationship of the form of domain structure with morphological features

The research using methods of phase contrast and polarization microscopy has detected the relationship of the form of domain structure with morphological features faceted garnet films. We used a standard polarizing microscope equipped with a surveillance system by phase contrast (having a revolving holder with phase plate). When the polarizer is off, we can see the internal structure of a transparent film of garnet (called facets). At the included polarizer, the image of the internal structure is superimposed with image of the domain structure (Figure 6).

Figure 6 The domain structure observed by phase contrast at the included polarizer. The structural elements are in the form of grains. The grain size of 1.5 microns. The period of the domain structure of 6 microns.

The combination of these two methods of obtaining of contrast shows that the domain walls extend along the lines of equal brightness and encircle elements faceted structure of the film. Since the accumulations of dislocations are local weakly magnetic zones of the film, it is clear that domain walls will be distributed along their geometric borders.
3. Conclusion
In the high-coercivity ferrite garnet films with a large lattice mismatch film-substrate observed two types of domain structure - stable and metastable. It was found that the fractal dimension of a stable domain structure is lower than the metastable. It is shown that correlation of the domain structure of faceted crystal structure of the films due to lattice mismatch film-substrate.

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