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The effect of substrate defects on epitaxial magnetic garnet films

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The stress patterns associated with various defects in Czochralski-grown gadolinium gallium garnet (GGG) crystals have been observed using a polarizing microscope. The effect of these defects on both the surface topography and the magnetic behaviour of epitaxial magnetic garnet films grown on GGG substrates is reported. In particular, iridium inclusions and defects of a filamentary nature affect the surface topography. Other types of defect influence the magnetic behaviour of the films in a manner attributable to a change in the lattice parameter.

1. Introduction

During the past few years, a great deal of the research on magnetic bubble domain devices has dealt with the production of very low defect epitaxial layers, but only a few papers have been concerned with the interaction between substrate defects and the epilayers. The origin and nature of some defects present in Czochralski-grown gadolinium gallium garnet (GGG) and other rare earth gallium garnets have been discussed by Brandle *et al* [1]. Boules of such non-magnetic garnets are sliced into wafers and finely polished for use as substrates in the growth of epitaxial layers. X-ray topography studies [2] have shown the presence of strain associated with defects both in GGG and in the epitaxial layers grown on GGG as a substrate. As a routine assessment technique X-ray topography is a rather lengthy process and a considerable amount of information may be obtained by simply viewing the GGG substrates between crossed polarizers. This paper reports the effect of some substrate defects on the surface topography and magnetic properties of rare earth iron gallium garnet films grown by the liquid phase epitaxial dipping technique [3].

2. Experimental

2.1. Substrate defects

The three main types of stress patterns observed in the polarizing microscope are shown in Figs. 1 to 3. Fig. 1 shows the strain patterns caused by iridium particles and filament like defects. The iridium particles form as inclusions during the growth of the substrate [1] and are either triangular or hexagonal although the strain pattern is 4-fold. As may be seen in Fig. 1, these patterns are apparent as contrast changes in the form of small crosses. The filament like defects

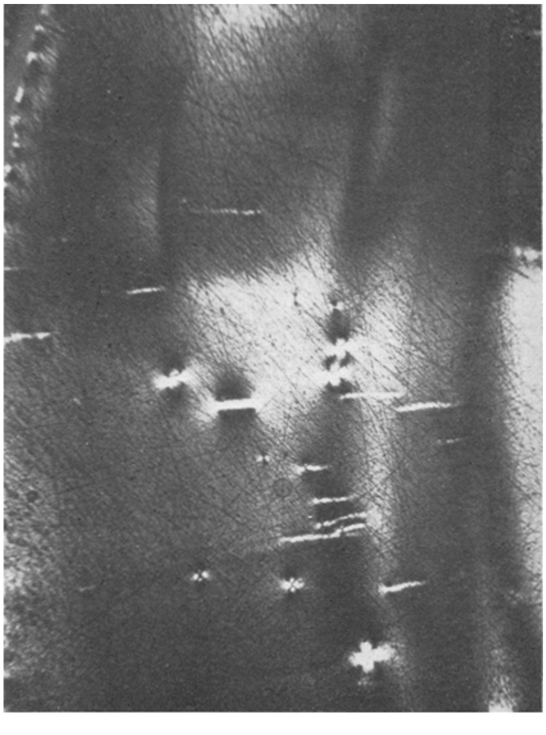

Figure 1 The strain associated with iridium inclusions and filament defects as viewed in polarized light (× 45).

appear as the bright streaks aligned horizontally in Fig. 1. By focusing the microscope through the layer, the filament-like defects are found to be inclined to the (1 1 1) growth axis of the substrate boule. It is thought that the filaments may be caused by gas inclusions during the growth. The dark lines in Fig. 1 are scratches on the back surface of the substrate. A low magnification photograph of a (1 1 1) GGG boule in polarized light shows the presence of a core with 3-fold symmetry (Fig. 2). In one boule which did not contain a central core small faceting marks (such as the bright band at the bottom of Fig. 3) were observed near the edge of polished wafers.

The effect of these four types of substrate defects on epitaxial layers of various rare earth iron gallium garnets grown by the liquid phase epitaxy process [3] is described in the following section.

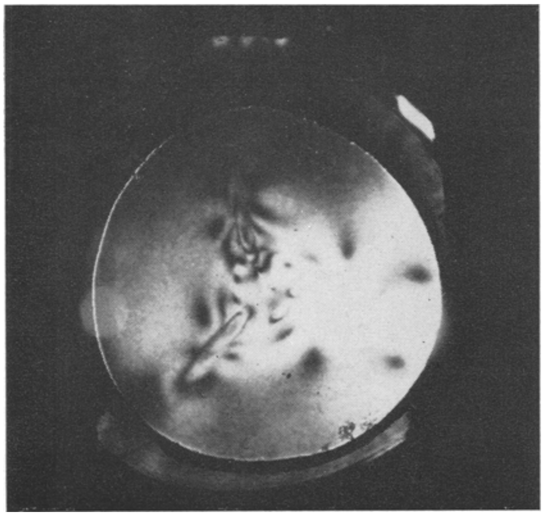

Figure 2 A (1 1 1) boule of GGG viewed in polarized light showing a core with three fold symmetry (× 3).

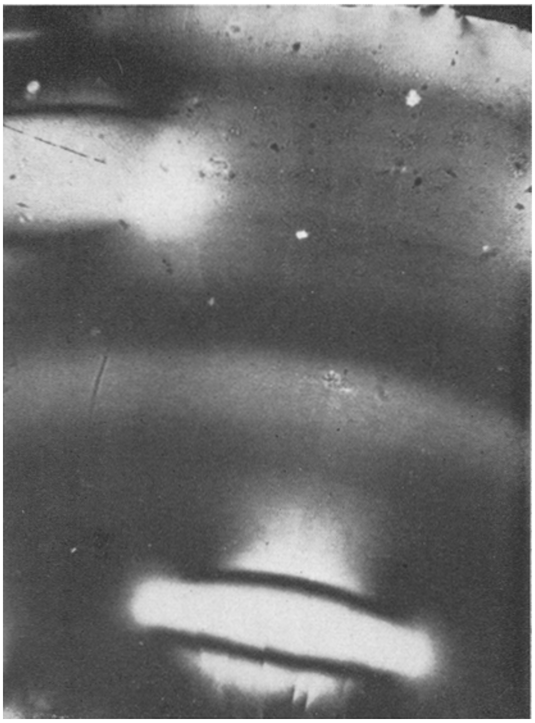

Figure 3 A faceting mark observed in polarized light in a polished slice of GGG which is substantially core-free (× 45).

2.2. Defects in the epitaxial layers

The photograph in Fig. 4 was taken using a combination of reflected and transmitted light and shows the defects which are present in the film surface at a point above the intersection of a filament defect (the light region) with the substrate surface. Using the scanning electron microscope it has been shown that some of the substrate defects cause a series of pits in the film (Fig. 5). The film defects caused by iridium particles near to the substrate surface are remarkably similar to those resulting from

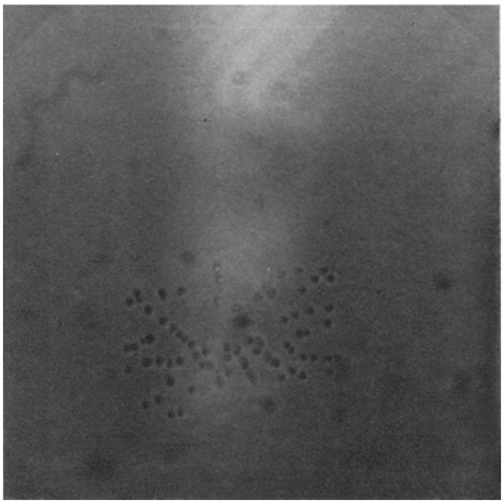

Figure 4 A filament defect and the resulting topography of the epitaxial layer of $Y_3Fe_5O_{12}$ on GGG (× 400).

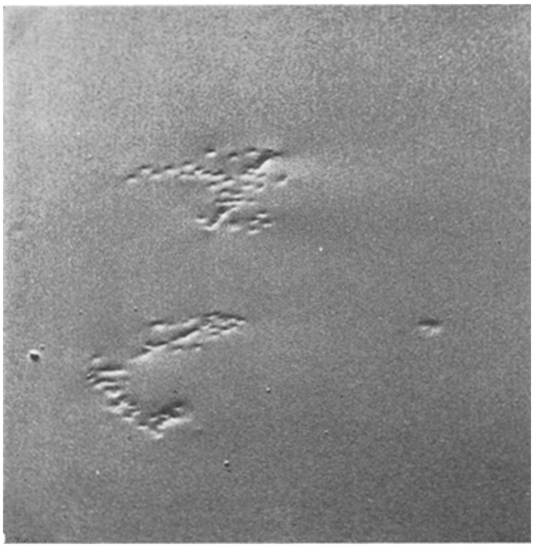

Figure 5 A scanning electron micrograph of the pits in the epitaxial layer of $Y_3Fe_5O_{12}$ above a substrate defect such as an iridium inclusion ($\times$ 500).

filamentary defects. In the case of the pitting caused by the iridium particles, observations suggest a general tendency for the pits to be arranged with 3-fold or 6-fold symmetry. The relationship between the observed 4-fold stress pattern due to an iridium particle (Fig. 1) and the resulting 3-fold or 6-fold symmetry of the pits is not fully understood.

The behaviour of the magnetic domain pattern in the epitaxial deposit under the influence of a bias field has also been found to depend on the substrate defects. The effect of the core on the magnetic domains in the epilayers is not usually apparent until precise measurements are made. Measurements of the film thickness and stripe domain width inside and outside the core in a typical film with $q = H_K/4\pi M_S$ of 5, shows that the intrinsic material length, l, changes by nearly 14%. Bubble collapse field determinations inside and outside the core in the same film showed that the magnetization was unaffected by the core and could not explain the variation in the observed values of l. If the film is assumed to have a purely stress induced anisotropy and the stress arises from the difference between the film and substrate lattice parameters (the mismatch), then the above figures suggest a mismatch variation of approximately 25%. The film under discussion has an average mismatch of about 0.004Å which together with the reported variation of the substrate lattice parameter across the core of 0.001Å [4, 5] agrees with the above predictions. The homogeneous background coercivity has been measured magneto-optically using an a.c. bias field excitation. Measurements inside and outside the core have shown a variation of approximately 30%, the higher value occurring in the more strained region inside the core. If the film composition is changed so that q is near to unity, the effect of the core is far more apparent as shown in Fig. 6. It can be seen that the domain configuration changes across the well defined core boundary and, outside the core (the region in the bottom right of Fig. 6), the film is actually single domain.

No variation in l or in the background coercivity has been measured across the small faceting marks shown in Fig. 3. However, the stress birefringence in the substrate near a faceting mark can lead to complete contrast reversals (Fig. 7) which can complicate any quantitative magneto-optic measurements.

3. Conclusions

Two types of substrate defects have been shown to cause film defects in the form of groups of small hollows. These hollows have a typical dimension of 2 μm. The film defects can, in a severe case, cause domain wall pinning. The core present in some GGG substrates has been shown to change the magnetic film parameters in a way which is

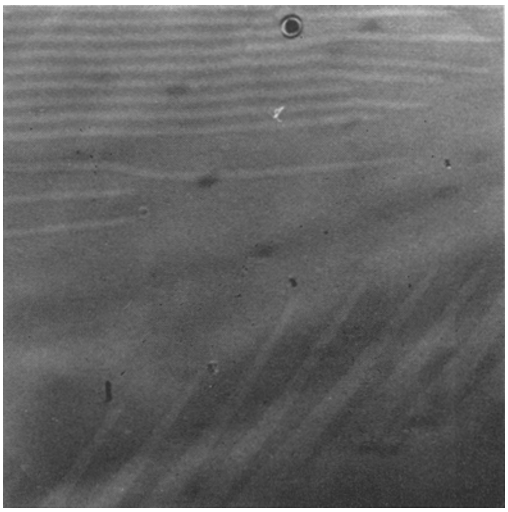

Figure 6 The effect of the substrate core on a film of $(YGd)_3(GaFe)_5O_{12}$ which is only just capable of supporting bubbles ($\times$ 220).

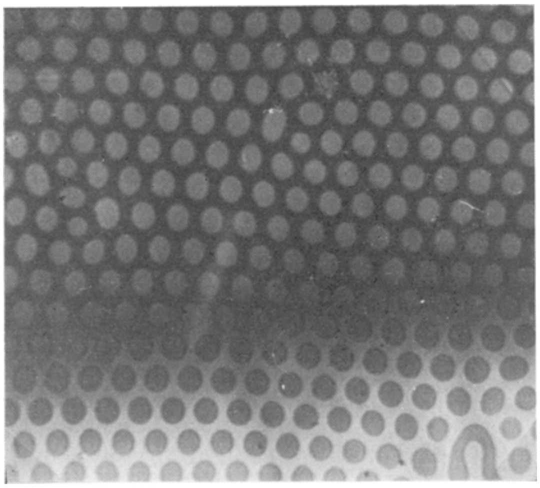

Figure 7 The effect on a magnetic domain pattern of the stress birefringence across a faceting mark in the substrate for an epitaxial film of $(EuEr)_3(GaFe)_5O_{12}$ (× 220).

directly attributable to a change in lattice constant of the substrate.

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References

1. C. D. BRANDLE, D. C. MILLER and J. W. NIELSEN, *J. Crystal Growth* **12** (1972) 195.
2. H. L. GLASS, *Mat. Res. Bull.* **7** (1972) 385.
3. H. J. LEVINSTEIN, S. LICHT, R. W. LANDORF, and S. L. BLANK, *Appl. Phys. Letts.* **19** (1971) 486.
4. B. COCKAYNE, J. M. ROSLINGTON, and A. W. VERE, *J. Mater. Sci.* **8** (1973) 382.
5. H. L. GLASS and T. N. HAMILTON, *Mat. Res. Bull.* **7** (1972) 761.

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