An Unusual Magnetic Domain Structure in a Single Crystal of YIG

Yttrium iron garnet (YIG) is a cubic ferrimagnetic material having a negative first magnetocrystalline anisotropy constant (i.e. ⟨111⟩ easy directions), a room temperature saturation magnetisation of about 1780 G and a Curie temperature of about 280°C. Although YIG is nearly opaque to visible light, it becomes quite transparent at wavelengths beyond 1 μm [1]. A simple technique was described recently [2] which enables the observation of the domain structure to be made *within* quite thick sections of YIG. It was pointed out [2] that by using (i) infra-red microscopy to observe the bulk domain structure and (ii) the well-known magnetic colloid technique (see for example [3]) to observe the surface domain structure, it is possible to assess the correlation between the surface and the bulk structure. The purpose of this letter is to report some preliminary observations of a single crystal of YIG by this approach.

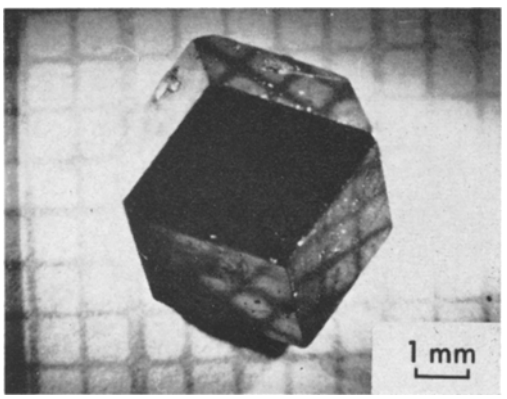

Figure 1

A photograph of the crystal is shown in fig. 1. The crystal was grown from a PbO-PbF_2 solution, slowly cooled from a temperature of 1300°C; it is slightly unusual in that it has no (211) growth faces. The crystal grew on the side of the platinum crucible such that the bottom of the crystal was substantially parallel to the major (110) growth face; the edges of this growth face are ⟨111⟩ easy directions. The as-grown crystal thickness was about 2.3 mm.

The bulk domain structure was badly obscured by features on the bottom of the crystal which had formed by replication of the crucible's grain structure. However, the general impression given was that the bulk domain structure consisted of simple "ribbon" domains [4] running nearly parallel to the [001] axis with the magnetisation in the domains normal to the growth surface. This suggests that the structure was determined by a stress-induced uniaxial anisotropy introduced either (*a*) during cooling following growth [5], or (*b*) during growth itself. The width of the ribbon domains was about 120 μm. The surface domain structure on the growth face (as revealed by colloid) was similar to the bulk structure but the spacing was only 12 μm.

To render the crystal more transparent, a section was cut from the bottom to give a crystal thickness of about 1.7 mm. The cut surface and the growth face were then carefully polished mechanically, using, successively, diamond paste of 3, 1, and $\frac{1}{4}$ μm particle size. Four separate observations of the domain structures were then made, as shown in fig. 2, and are described below.

(*a*) Colloid pattern formed on the growth face (a small polarising field was applied normal to the plane).

(*b*) Bulk domain structure (revealed by infra-red microscopy) with the growth face nearer to the objective lens. Two structures – one fine, the other coarse – are visible. The fine structure is clearly related to the colloid pattern shown in (*a*) and is associated with the surface of the growth face.

(*c*) Domain structure of the polished cut face. This structure was also obtained with the infra-red microscope; the polariser and analyser were crossed (to eliminate the Faraday effect structure) and a quarter-wave plate was inserted between the specimen and the analyser. This technique reveals in-plane magnetic domain structure and depends on the magnetic birefringence of YIG for the effect [4]. The structure revealed by the magnetic birefringence is somewhat indistinct but can be better understood by inspection of (*d*).

(*d*) Colloid pattern formed on the polished cut face; the outline around the pattern shows the shape of the cut face. The domain structure is very nickel-like with the magnetisation lying along directions parallel to the edges of the crystal. This structure is determined by the intrinsic magneto-crystalline anisotropy of the crystal and is not influenced by the large uniaxial anisotropy which dominates the domain structure of the rest of the crystal; it is also worth noting that mechanical polishing has not strained this surface.

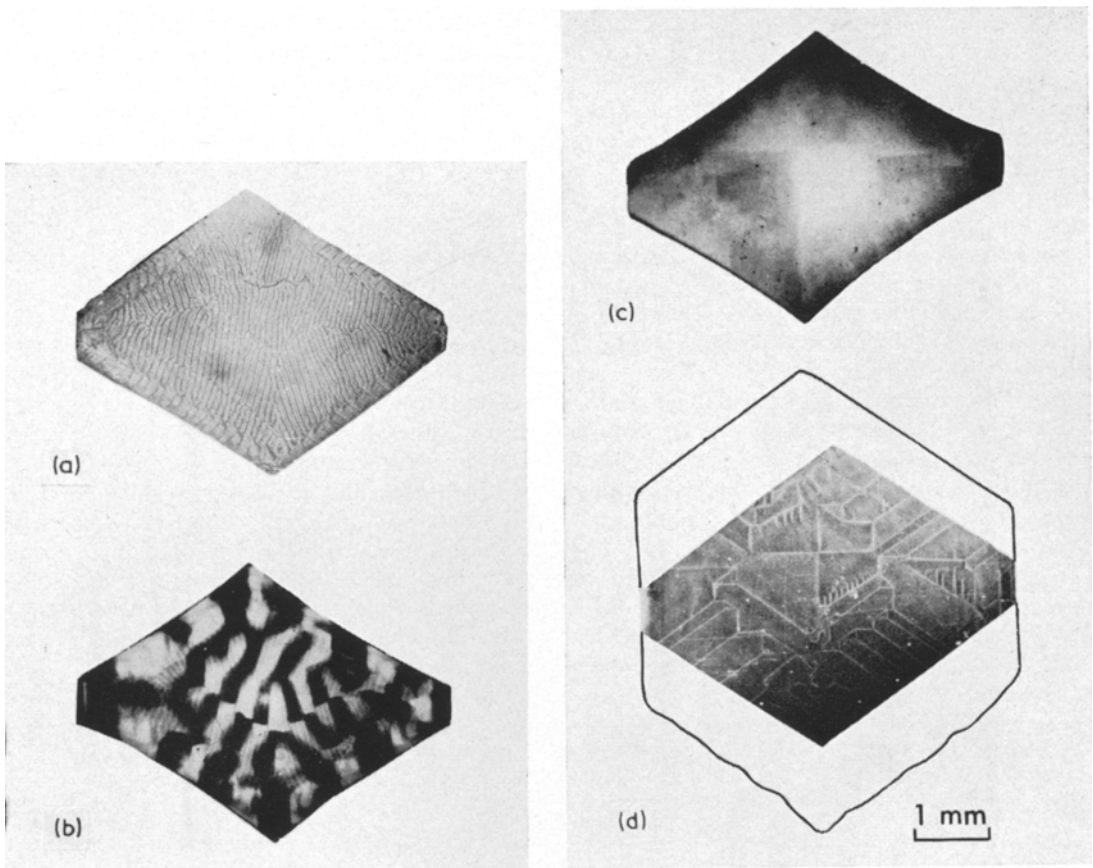

Figure 2

Summarising these results: the polished growth-face of the crystal has an out-of-plane magnetisation domain structure determined by an induced uniaxial anisotropy. The bulk of the crystal has a coarse structure, also determined by a uniaxial anisotropy. The polished cut-surface of the crystal has an in-plane structure which is determined by the magnetocrystalline anisotropy of the material and which is not influenced by the uniaxial anisotropy affecting the structure of the rest of the crystal.

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