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Imperfections in Yttrium Iron Garnet Crystals

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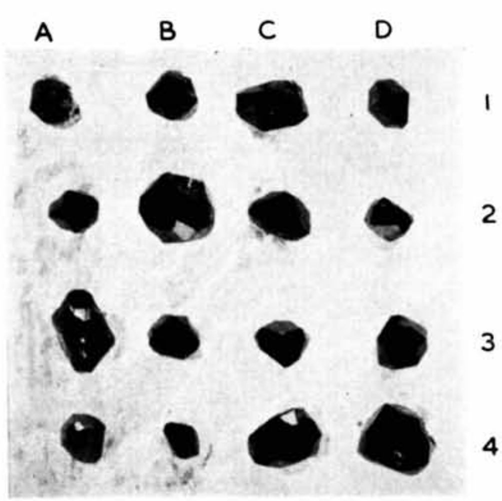
Yttrium iron garnet crystals grown by the fluxed-melt technique from lead oxide often contain inclusions of lead-rich phases. In large crystals these inclusions are oriented and regular. Photographs of crystal sections show them to be associated with an initial dendritic stage of growth. Limitations of the growth technique are discussed.

The ferrimagnetic garnets have been studied with considerable interest as narrow resonance materials for use at microwave frequencies. Single crystals of yttrium iron garnet, $Y_3Fe_5O_{12}$, have been grown from solution in lead oxide by a technique devised by Neilson (1958); some of typical habit are shown in Fig. 1(*a*). Although crystals up to 1 cm. in length have been obtained, they often contain gross internal imperfections which seriously impair their properties. Radiographic examination has been used to select crystals for fabrication into the thin discs required for microwave purposes.

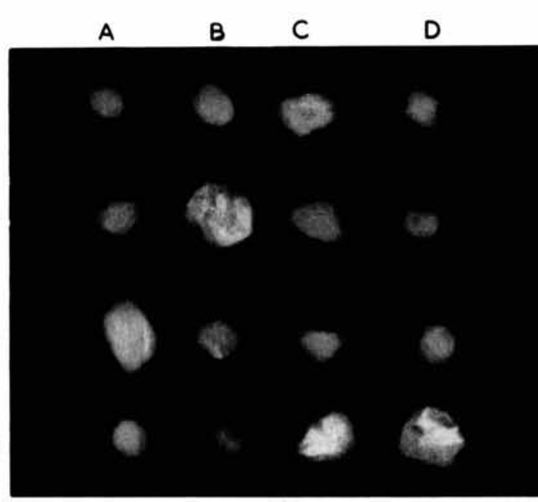
A radiograph was taken of a batch of these crystals lightly fixed to a paper sheet and labelled so that the most perfect crystals could be identified and selected. The uneven thickness of the crystals as grown did not materially detract from the value of this procedure, since the inclusions present were in all cases relatively opaque to X-rays. A radiograph negative of this batch of crystals is shown in Fig. 1(*b*) in which the inclusions appear as white marks. For example, the crystals *A*3, *C*4 and *D*4, etc. have good external appearance but are of poor internal quality, while crystals *A*1, *B*1, *C*2 etc. have no serious defects.

Regular oriented inclusions have frequently been observed, particularly in large crystals. A photograph of a section from a crystal with such a pattern is shown in Fig. 2 together with the corresponding radiograph. These photographs clearly demonstrate that inclusions of this type have arisen because of an initial dendritic growth stage; subsequently the terminations of the dendritic branches have joined together, giving an externally perfect crystal but with considerable amounts of the melt trapped in the interstices. This effect has also been noted in water-soluble crystals (Buckley, 1951) and in barium titanate crystals grown from solution in potassium fluoride.

It is probable that this is not the only mechanism for the formation of inclusions in garnet crystals. The crystals grow in an environment limited by (*a*) the proximity of other crystals, particularly ferroplumbite which crystallized before the garnet phase; and (*b*) the lack of agitation which would otherwise tend to remove foreign matter from the growing surfaces as in



(*a*)



(*b*)

Fig. 1. Batch of yttrium iron garnet crystals (*a*) with corresponding radiograph (*b*) in which the inclusions appear as white markings (see text). (Magnification about 3 times.)

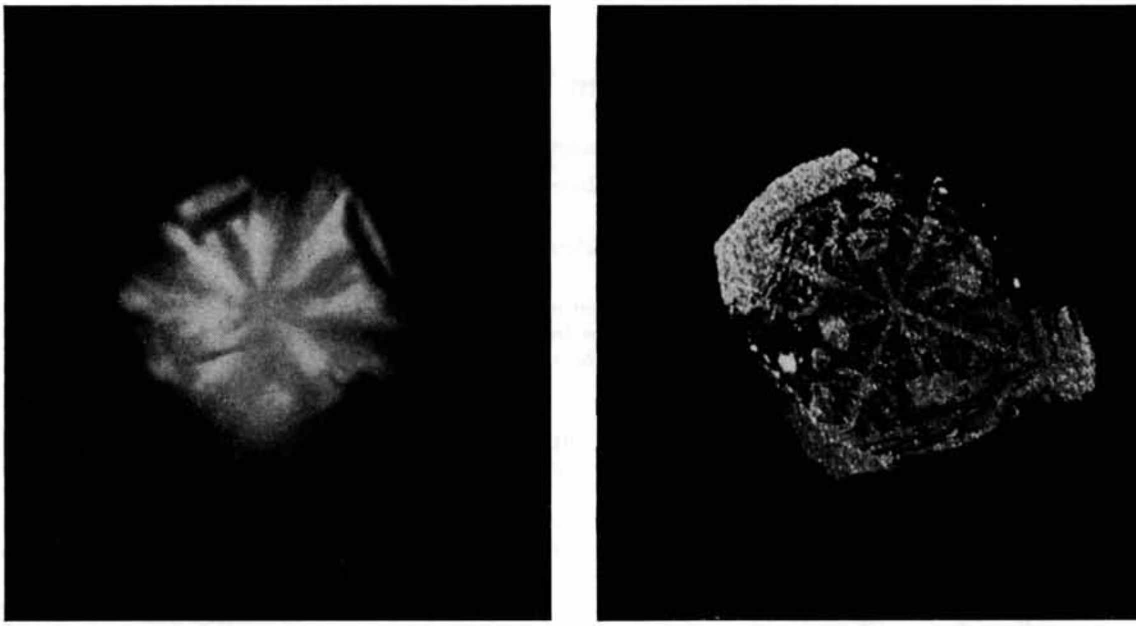


Fig. 2. Radiograph (left) and photograph (right) of a crystal showing internal dendritic structure. (Magnified.)

more controllable growth techniques. Small crystals, which are less likely to be affected by restrictions during growth, are usually more perfect both internally and externally than large crystals.

It is clear that the initial growth period for garnet is very critical, and even under the conditions of slow cooling used (ca. 1° per hour) dendritic growth can occur. These observations suggest that this is the result if the scavenging action, due to the initial crystallization of ferroplumbite limiting the nucleation sites available for garnet growth, is too effective. The introduction of garnet seed crystals into the melt at the appropriate point in the cooling schedule should improve the quality of crystals produced, but severe practical difficulties are involved.

The fluxed-melt technique evidently has limitations with regard to both size and quality of the crystals grown. Although some improvement in both respects may be expected from refinements or modifications of the technique, it would be preferable to adopt a more controllable growth process for the production of yttrium iron garnet crystals.

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References

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