It is clear from the present work that observation of CL can provide an additional and valuable technique for the investigation of glass-ceramic microstructures. In this study the CL observed was confined to lithium disilicate crystals. However, this had the advantage of enabling these crystals to be readily distinguished from the crystalline silica phase. With an improved system for detection and analysis of the radiation emitted, it may be possible to extend the technique to selectively reveal the morphology of the silica crystals and of other crystal types in different glass-ceramic compositions. As the micrographs indicate, CL enables micrographs showing good contrast to be obtained without the necessity for etching of the glass-ceramic surface. The latter could cause modifications of the microstructure and clearly this is undesirable.

We conclude that the technique of using CL gives additional valuable information in the investigation of polished glass-ceramic surfaces and also has a considerable potential for characterizing the fracture surfaces of multiphase materials based on elements of low atomic number.

Acknowledgements
The authors would like to thank Mr G. Smith for invaluable assistance with the electron microscope. Gratitude is also expressed to the SRC for financial support.

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Received 26 November
and accepted 27 November 1973

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Possible use of glass-ceramics containing a crystalline ferrimagnetic phase as memory material

Several publications have now appeared in the technical press describing the magnetic properties of glass-ceramics containing crystalline ferrites [1-10]. A number of ferrite and glass forming systems have been investigated and in several of these publications the magnetic properties of lithium ferrite glass-ceramic have been studied. Lithium ferrite, $LiFe_5O_8$, is a magnetic material of commercial interest and is employed as a basis for square *B-H* loop material which can be used for the manufacture of memory element toroids and which displays stable magnetic properties over a wide range of operating temperature. A necessary condition for a material to be considered for application as memory material is that the material should display a high degree of loop squareness. This is particularly important when the elements are assembled into a 3D organization where the δ noise arising from the $\frac{1}{2}$ select currents passing through cores on the same x and y lines as the core being interrogated must be minimized. The purpose of this note is to point out that glass-ceramics containing crystalline ferrite are not, in general, suitable as square loop material.

A glass-ceramic containing crystalline ferrite can be considered to act as an assembly of ferrite particles held together by a glass binder. The degree of squareness attainable with a glass-ceramic is limited to a value below that of the pure ferrite due to the presence of the non-magnetic glass binder which causes the glass-ceramic to be subject to an internal demagnetizing field. This field has the effect of altering the shape of the loop and reducing the squareness. The internal demagnetizing field, H_{int}, is given by

$$H_{int} = -NM$$

where N is a constant depending on the volumetric fraction of glass in the glass-ceramic and M is the magnetization. It is possible to make an estimate of the size of the demagnetizing field from data on $Na_{\frac{1}{2}}Zn_{\frac{1}{2}}Fe_2O_4$ published by Smit and Wijn [11]. Assuming that in the absence of internal demagnetization the material displays a square *B-H* loop, we find that *NM* is approximately 3 Oe at a volumetric fraction of glass of 15%. The effect that a demagnetizing field of this magnitude has on the shape of an actual *B-H* loop depends on the coercivity of the glass-ceramic. If the material is magnetically hard with a large coercivity the effect will be small whereas at low coercivity a pronounced change in the shape of the loop will occur. In practice, drive current constraints lead to the use of low coercivities between approximately 0.5 and 5 Oe in devices and, therefore, this degree of demagnetization would be very significant on such material. The shape of the loop will accordingly be altered in such a manner that both the squareness and the remanence will be reduced from the values they would have taken in the absence of internal demagnetization.

It does not appear feasible to attempt to overcome this problem by increasing the percentage crystallinity to very high values since then two practical factors have to be taken into consideration. Firstly, an adequate amount of glassy phase must be present in order to form the material into the required shape. Secondly, at high iron concentrations uncontrolled devitrification is known to occur [12] and as the percentage crystallinity is increased it will be more difficult to obtain the required grain size distribution by means of the heat-treatment schedule.

Experimentally, lithium ferrite glass-ceramics have been found to have a non-square *B-H* loop. In particular, Weaver and Field [10] found a remanent ratio of 0.4 and a coercivity of 160 Oe in one of their heat-treated samples. The fact that the coercivity increased on heat-treatment to reach the relatively high value of 160 Oe is strong indication that as the grain size increased on heat-treatment, the grains ultimately behaved as single domain particles with magnetocrystalline anisotropy the dominant anisotropy. For comparison K_1/M_S a measure of the intrinsic coercive force for such an assembly is approximately 270 Oe, where K_1 is the magnetocrystalline anisotropy and M_S is the saturation magnetization. The remanent ratio of an array of single domain particles has been calculated by Gans [13] who found a value of 0.87. The fact that a value of 0.4 is found experimentally can be attributed mainly to internal demagnetization.

Acknowledgement

The author wishes to thank Messrs Pilkington Brothers and Dr D. S. Oliver, Director Group Research and Development, for permission to publish this letter.

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Received 6 December
and accepted 31 December 1973

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