References

1. M. HANSEN, "Constitution of Binary Alloys" (McGraw-Hill Book Company, New York, 1958).
2. D. J. MAYKUTH, H. R. OGDEN, and R. I. JAFFEE, *J. Metals* **5** (1953) 231.
3. J. ASKILL, "Tracer Diffusion Data for Metals, Alloys, and Simple Alloys" (Plenum Publishing Co, New York, 1970).

Received 9 October and accepted 16 October 1972

J. KENNEDY
Materials Research Group, Grumman Aerospace Corporation, Bethpage, New York, USA

Improved visibility in crystal pulling

In the field of Czochralski growth of crystals [1], one of the prerequisites for controlled crystal growth is clear visibility of the solid-liquid interface. The technique of liquid encapsulation [2, 3], though primarily designed to prevent loss due to volatilization, has gone some way towards alleviating this problem. However, in the growth of some crystals, for example PbTe and GaAs, some material is still lost during the growth run. This material comes from the seed or from those parts of the crystal which are not covered with encapsulant, from the melt by a path between the encapsulant and the crucible or crystal caused by inadequate wetting by the encapsulant,or by the transport of vapour from the melt in bubbles. This leads to a certain amount of vapour deposition on the cooler parts of the surrounding chamber and window, leading in time to reduced visibility, and even, in the case of some very prolonged runs, a complete loss of visibility.

The problem can be tackled in one of two basic ways; by allowing the volatile material to deposit on the window and then removing it, or by preventing the material from depositing on the window in the first place. Our first approach was to use the former method, and to this end a window-wiping arrangement was devised which would clear the window of deposited material. This is shown in Fig. 1. The device comprises steel wool wrapped around a spring bronze arm, which is clamped to a metal shaft by a metal boss and two holding bolts. The shaft passes through a hole, drilled with a diamond drill, at the centre of a normal $2\frac{1}{2}$ in. silica window, as fitted to the standard RRE puller. It has an O-ring seal fitted on either side of the window, so that the growth chamber can be operated with either a positive or a negative pressure, with respect to the laboratory. A knurled knob is fitted to the outer end of the shaft to facilitate rotation of the wiper. Whenever viewing of the crystal becomes difficult the wiper is rotated, and the window brushed clean by the steel wool. A single rotation is usually sufficient.

The second system was developed to solve the problem of deposited material which is more tenacious, and hence cannot be easily wiped off the window, and also the problem of corrosive vapours, such as the As vapour above GaAs, which might attack the components of the window wiper. This assembly is an adaption of the window arrangements used in the RRE High Pressure Puller Chamber [4]. The window assembly is shown in Fig. 2, and con-

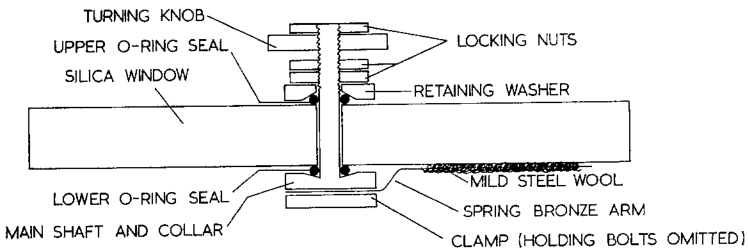

Figure 1 Window wiper assembly.

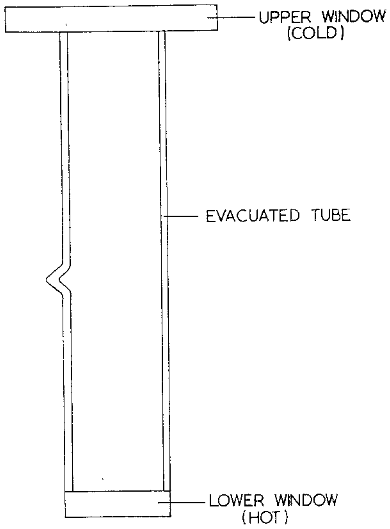

Figure 2 Clear-view window assembly.

sists of a standard silica window, to which a silica tube of smaller diameter has been sealed. The other end of the tube is fitted with a silica window of the same diameter as the tube. The system is then evacuated and sealed off to ensure that at high temperatures there will be no danger of any pressure build-up in the tube. This unit is then fitted into the growth chamber in place of the usual simple window so that the smaller window is near the hot crucible, but is not so near that it interferes with the pulled crystal. The lower window is heated by radiation from the crucible and condensation upon it is thus prevented.

Both window systems have been in general laboratory use for some time, in the growth of PbTe and GaAs, and have proved satisfactory. In general it is possible to use either type of window system, and in these circumstances the window-wiper system is generally better because it has a larger field of vision, is more rugged, and is much easier and cheaper to make. In very corrosive atmospheres the metal components of the system could be replaced by silica components, with some subsequent loss of ruggedness and ease of construction. However, in cases where liquid encapsulation is not used, or there is a possibility of contamination of the melt by material wiped off the window falling back into the melt, the use of the double window assembly is recommended, even though this results in a more restricted field of vision, and the crucible and window positions have to be carefully chosen.

This paper is contributed by permission of the Director, Royal Radar Establishment, and published by permission of the Controller, Her Majesty's Stationery Office.

References

1. J. CZOCHRALSKI, *L Physik Chem* **92** (1917) 219.
2. E. P. A. METZ, R. C. MILLER, and R. MAZELSKY, *J. Appl. Phys.* **33** (1962) 2016.
3. J. B. MULLIN, B. W. STRAUGHAN, and W. S. BRICKELL, *J. Phys. Chem. Solids* **26** (1965) 782.
4. J. B. MULLIN, R. J. HERITAGE, C. H. HOLLIDAY, and B. W. STRAUGHAN, *J. Crystal. Growth.* **4** (1968) 281.

Received 12 October and accepted 24 October 1972

H. C. WEBBER
S. E. R. HISCOCKS
Physics Department,
Royal Radar Establishment,
Great Malvern,
Worcestershire, UK

Luminescence of deformed p-type GaAs

Several papers have been published concerning the influence of crystal defects on the luminescence of GaAs. Casey [1] and also Shaw *et al* [2] used the scanning electron microscope to study the luminescence of n-type crystals doped with Se, Te, and Si. Cathodoluminescence maps were compared with pictures of the etch-pit patterns for the same crystal areas, in an attempt to relate defect structure to the patterns of luminescence. Dislocation etch pits on the etching pictures were found to correspond on the luminescence pattern to a dark spot, usually surrounded by a bright halo of light. Most of the dislocations observed in these studies would have been grown in and it seems possible that the observed effects were due at least in part to the existence of an excess "Cottrell atmosphere" of