Cellular hole growth of faceted crystals

We have made observations of the growth of silicon in Al–Si–Cu melts of approximate composition 10% Si and 30% Cu by weight, and have noted the formation of cellular holes in the crystals. This is a form of instability in which the crystal surface advances from cell boundaries, so that hollows result, while in the normally observed cellular growth mode, particularly for silicon [1], the surface grows from pyramidal promontories. We shall briefly describe experiments, and give a short description of the mechanism.

The experiments were made on Al–Si–Cu alloys of composition 10% Si and 30% Cu by weight. The alloys were prepared from superpurity (99.999%) Al, semiconductor grade Si and electrolytic copper. Melting was performed in MgO crucibles in a vacuum furnace. After homogenising at 750° C, the crucible and contents were cooled at 50° C min^{-1}.

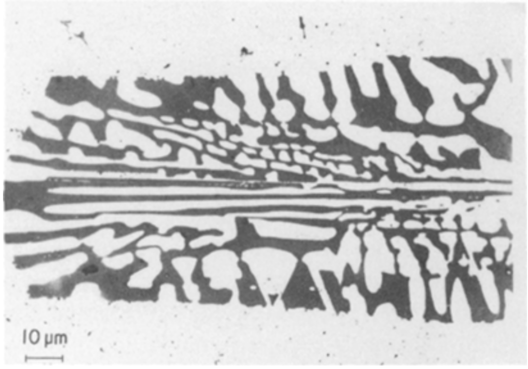

Figure 1 Cross-section of cellular hole silicon crystal.

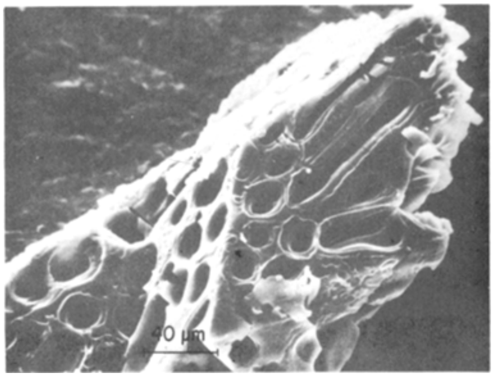

Figure 2 Cellular hole silicon crystal (SEM).

Metallographic sections were taken and Fig. 1 shows the cross-section of a typical primary silicon crystal. Fig. 2 shows a scanning electron micrograph of an extracted silicon crystal.

The mode of growth of the crystal as cellular holes is observed to occur as follows. In primary silicon growth in Al–Si alloys, steps on the crystal surface become unstable and form protuberances which branch in growth [2], Fig. 3. In the presence of Cu, the branching phenomenon becomes more pronounced and the steps on the silicon surface are no longer planar. These instabilities join up to form a network of ridges which enclose holes. Fig. 4 shows such a network on a crystal surface while Fig. 5 shows an enlarged view of the surface of the crystal of Fig. 2 in which both initial ridges and the finally resulting holes are seen.

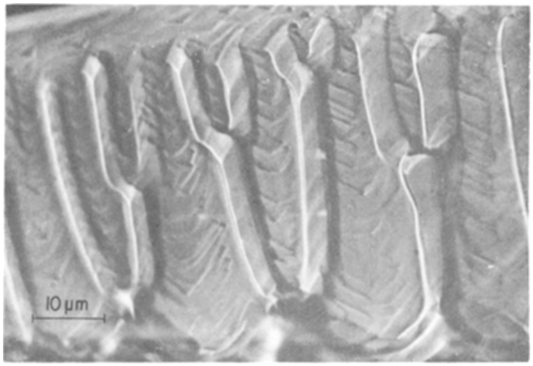

Figure 3 Instability of steps on silicon crystal in Al–Si alloy (13% Si) [2]. Optical micrograph.

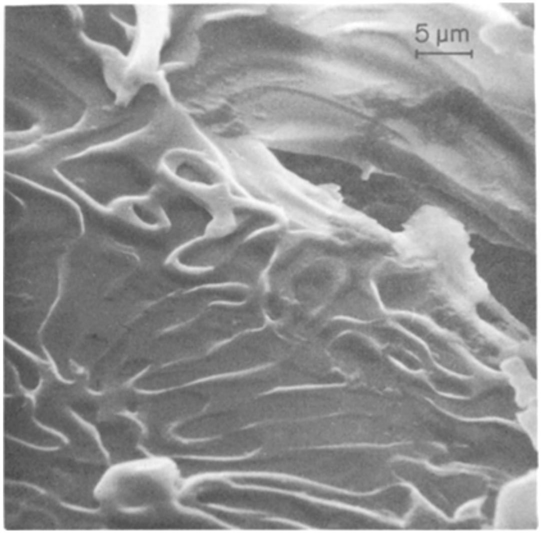

Figure 4 Formation of steps on silicon crystal in Al–Si–Cu alloy.

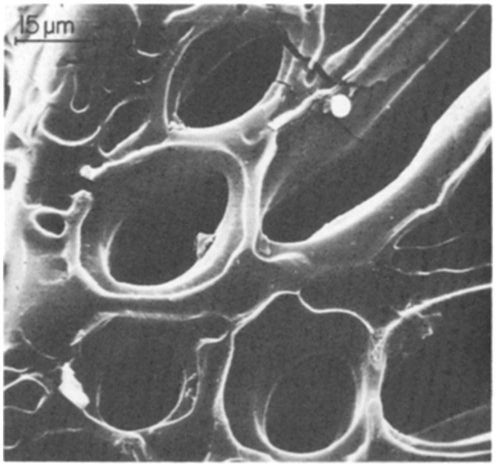

Figure 5 Detail of surface of crystal shown in Fig. 2.

This behaviour is the opposite of normally observed cellular growth. In the present case, the instability is in the form of an array of ridges formed from steps on the surface. These enclose holes in a close-packed arrangement. The crystal grows from the ridges, developing the cellular hole structure.

We have made extensive observations of this behaviour under different conditions and shall report on this in full in a further contribution. We shall also discuss the factors determining step or surface instability. The former leads to hole formation while the latter leads to pyramids [1]. We shall also relate this to the type of solute and impurities in solution.

References

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Received 30 April
and accepted 28 May 1976

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Sintering kinetics of pure and $CdCl_2$–doped NaCl in air

During densification of particle compacts there are so many complex changes that it appears almost impossible to develop a unifying theory of sintering [1]. Since sintering a porous compact is essentially a process of redistributing the mass, there has been considerable interest in the transport processes involved and much of the available evidence comes from the sintering behaviour of model systems.

Early studies on the sintering of NaCl using model systems showed that the particles bonded without an increase in the denisty of the mass [2, 3]. On the basis of limited results it was concluded that the rate-controlling mechanism of mass transport during sintering of NaCl is by evaporation–condensation [2], and these conclusions were confirmed [3], although a different model was used to explain the results. Mass transport by evaporation–condensation cannot cause a density increase during sintering [4] and it appeared that densification of NaCl was not possible. However, Morgan *et al.* [5] showed that substantial densification of NaCl compacts did occur, provided the particle size was small enough. They also showed that 0.1 mol % $CsNO_3$ co-precipitated with NaCl, decreased the amount of shrinkage compared to pure NaCl. Ammar and Budworth [6] established that densification of NaCl particles occurred if, (1) the particle size is small enough ($< 150\,\mu m$ diameter), (2) the sintering temperature is high enough, and (3) the green density is low enough. Although evaporation–condensation does occur during sintering of NaCl it is clear that some other mass transport process is operating to cause densification. The present work investigates the densification kinetics of NaCl, and the effect of small quantities of $CdCl_2$ on the sintering behaviour.

All samples of NaCl were from one batch of