LETTERS TO THE EDITORS

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Spiral Growth on Carborundum Crystal Faces

IN 1949 Frank[1,2] pointed out the possibility that growth of crystals at low supersaturations, essential for good crystals, could take place because of the formation of dislocations in the crystal so that any real crystal should have a number of dislocations with a screw component, terminating on the face. When growth takes place on these exposed molecular terraces, the edges of these layers develop into spirals centred on the dislocation.

Griffin[3] has observed these 'monomolecular' layers on the (1010) face of a beryl crystal, and has shown by multiple-beam interferometry that the height of these steps is less than 34 A., that is, less than four unit cells of the crystal. It was inferred that these steps are only one unit cell high.

In the present investigation, numerous 'growth spirals' have been observed on the faces of carborundum and measured with the aid of phase-contrast microscopy and multiple-beam interferometry.

Carborundum[4] occurs in at least eight known types, one of which is cubic, whereas the rest are either hexagonal or rhombohedral and have identical layers but differ in their arrangement and are uniquely distinguished by the number of layers in the unit cell. The crystals studied here are of type I (rhombohedral, fifteen layers, with lattice parameter c = 37·7 A.), and type II (hexagonal, six layers, c = 15·1 A.).

These spirals were studied by coating the crystal faces with a thin film of silver of reflectivity nearly 90 per cent, deposited by thermal evaporation, and then examining these faces in reflexion.

Theory shows that for growth taking place from vapour, the ledge extending from the point of emergence of the dislocation to the crystal boundary has a rate of advance independent of the crystallographic orientation, thus forming a simple Archimedean spiral which can be calculated and from which the constant of spacing between turns can be predicted. These predictions have been completely confirmed numerically by the circular spirals shown in Fig. 1.

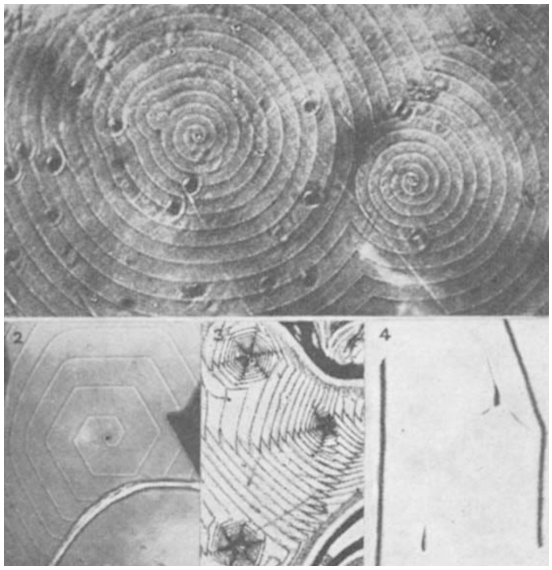
The dependence of the rate of advance of a growth front on the orientation of the step line should impose a characteristic distortion of the growth of spirals, exhibiting the crystal symmetry. In accordance with this, Fig. 2 shows a hexagonal spiral (crystal type II). The straight edges correspond to a sharp minimum in the growth-rate as a function of orientation.

The complex growth patterns predicted for two or more screw dislocations ending on a crystal face and depending on the property of growth fronts which annihilate each other where the two edges meet are illustrated in Fig. 1. Thus for two screw dislocations of opposite hand, with the unfolding of the two spirals the ledges starting from one terminate on the other, generating closed loops.

Various other growth patterns for two, three and larger numbers of dislocations ending on crystal faces of type I and type II have been photographed and explained.

Interlacing of hexagonal spirals observed on a crystal face of type II is illustrated in Fig. 3.

The observed density of dislocations varies widely on different specimens, ranging from a few to a maxi-



mum of $\sim 10^4$ per sq. cm. On any crystal they are predominantly of one hand.

The calculated radius of the critical nucleus is 2 μ and the supersaturation 0·2 per cent.

To measure the step height of these spirals, multiple-beam interference (Tolansky[5]) has been employed. Fig. 4 shows the Fizeau fringes for λ 5,461, passing over a circular spiral, in which the height can be accurately measured; and as the number of turns is readily visible, the height of each single step can be deduced with precision. Analogous measurements have been made also with fringes of equal chromatic order. The step heights on a type II crystal measured from two different spirals are respectively 15·2 A. and 15·1 A., with a maximum uncertainty of 2 A. It is already known from X-ray analysis that, for type II, c = 15·1 A. Thus it has been proved here that the step is a single unit-cell high.

The observation of spiral markings on carborundum has already been reported[6]. The observed shapes of these spirals are in accordance with the predictions of theory, and their step height is equal to that of a unit cell, showing that these are growth spirals originating from screw dislocations.

A more detailed account of this work has been communicated elsewhere. I am grateful to Prof. S. Tolansky for his interest and encouragement in the course of this work, and to the British Council for the award of a scholarship.

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THE theory of crystal growth based on dislocation theory as formulated by F. C. Frank[1] predicts the presence of growth features in the form of very flat, spirally terraced hills on the crystal face which is perpendicular to a screw dislocation line.