leakages in the apparatus. At the end of an hour, the impregnation is complete for specimens of about one to two cubic centimeters.

After impregnation, the die assembly is dismantled. Because the rubber bag may pinch along the plunger-cyclinder interfaces, the plungers may have to be pushed out forcibly by using a smaller diameter plunger. The bag commonly breaks during the extraction process and care must be exercised to avoid excessive skin contacts with the resin. All die parts should be cleaned immediately with acetone or ethyl methyl ketone before polymerization sets in. The specimen is removed from the bag, the excess epoxy wiped off, and the specimen placed upon a suitable substrate to cure for the time and temperature specified by the manufacturer of the resin. In the case of Epon 828, overnight curing at about 60° is sufficient. If the nature of the materials being impregnated permits, another curing for several hours at about 100–120° serves to harden the resin still more. However, direct polymerization at the higher temperature mentioned results in excessive internal strain in the mount. If the specimen is to be cut later by precision sawing it is advantageous prior to epoxy polymerization, to place the specimen upon a slip of plywood or other suitable substrate which will later permit clamping in the feed mechanism. Small specimens of hyaloclastites and manganese nodules mentioned above were found to be completely impregnated, enabling slices as thin as a few millimeters to be cut on a precision saw. While this method cannot succeed in impregnating extremely dense aggregates of clay minerals, it can fill the very fine cracks formed in such aggregates during drying, thus creating a sort of breccia less liable to disintegrate during subsequent surface preparation.

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KINETIC CONSIDERATIONS IN THE GENESIS OF GROWTH TWINNING: A DISCUSSION

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Donnelly (1967) criticizes current theories of growth twinning with emphasis on the energetics involved because of the kinetic nature of the phenomenon. It is concluded that the energy differences between the twinned and the untwinned states may be of minor importance, and that growth twins may result because of the more favourable facial arrangement obtained by the twinned configuration. However, similar considerations were put forward by Billig (1954) who showed that the twinning of germanium crystals grown from the melt is not due to a haphazard event and occurs if the actual growth direction deviates appreciably from the preferred growth direction. Similar views are also held by Bolling, Tiller and Rutter (1956) and Turovskii and Lainer (1964).

Although it may be generally true that kinetic factors dominate during crystal growth, energy factors are still important in the nucleation of crystals. The formation of twinned crystals may sometimes be traced back to the nucleation stage. Fullman's (1957) analyses of the equilibrium form of crystalline bodies indicate that a twin may be more stable than the single equilibrium-shaped crystal if the sum of the twin boundary and the surface energy of the twin is less than the minimal surface energy of the single crystal. Twinning, therefore, not necessarily results in a higher total energy (Donnelly 1967, p. 2), and the observation that some minerals are nearly always twinned becomes more understandable. Sears (1963) suggested that zinc oxide fourlings nucleated as fourfold twins because of the Fullman effect or by nonclassical nucleation mechanisms. It seems probable that mimetic twins may originate from nuclei containing the twin elements. An interesting discussion on the origin of twinned nuclei of bromellite (BeO) has recently been presented by Newkirk and Smith (1965).

Donnelly refers to the fact that twinned crystals are commonly much larger than the accompanying untwinned crystals. Such twins may be more than 10 times as large as the untwinned ones. If a new facial orientation was the only advantage gained by the twinning, twinned crystals should not be much larger than twice the size of a single crystal. Growth may be stimulated by an outcropping twin plane for two reasons. Screw dislocations on the twin plane may cause the crystal to grow by an increased rate in the direction of the Burger vector as shown by Newkirk and Smith (1965). Growth acceleration may also occur without the need for dislocations when reentrant angles are present. The reentrant angle at the composition plane of the twin is a favourable nucleation site provided that the energy of the twin boundary is small compared to the surface energy (as for example at coherent twin boundaries). It has been argued that the very presence of a reentrant angle in twins having grooves which are not self-perpetuating is an evidence against the effectiveness of the reentrant angle in promoting growth (in some crystals the presence of two twin planes are necessary to produce a self-perpetuating system of grooves), and Donnelly suggests that the increased energy at the twin plane obstructs growth in the grooves. However, numerous cases of twin-stimulated growth in nature have been recognized and it may suffice to refer to papers by Tertsch (1926), Frank (1949) and Grigor'ev (1965). The significance of the reentrant angle in the growth kinetics of twinned crystals was already known to Becke (1889) and was again stressed by Stranski (1949) and Frank (1949). The "twin-plane reentrant edge mechanism" is now a well established technique in the controlled growth of ribbon-shaped semiconductors (Faust and John 1964).

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KINETIC CONSIDERATIONS IN THE GENESIS OF GROWTH TWINNING: A REPLY

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Carstens' discussion (1967) of my recent paper on growth twinning (Donnelly, 1967) provides some additional references, largely from the field of metallurgy, including several which I had not seen. I am particularly grateful to him for pointing out that observations of germanium crystals grown from the melt have led to considerations of the importance of orientation of the crystal lattice with respect to the external physical and chemical environment. These considerations, although based on a one-dimensional growth phenomenon, in a highly anisotropic medium are very similar to my own conclusions involving multi-directional growth in an isotropic medium.

However, consideration of some of the other points raised by Carstens