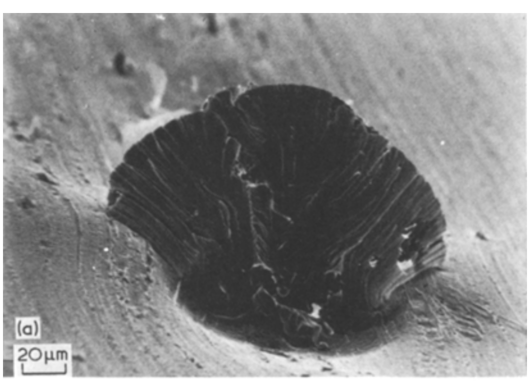
## *The internal structure of diamond cavities in rigid PVC*

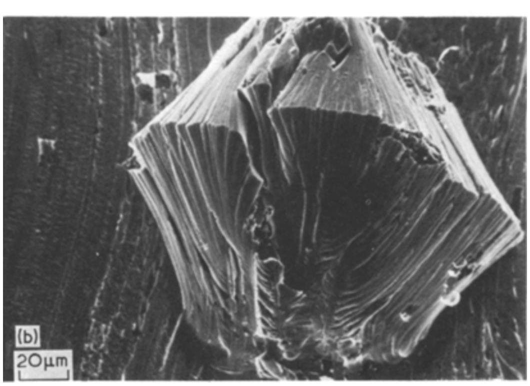
In a recent paper [1] we described the strain fields around diamond cavities in rigid PVC. The study concentrated on diamonds which had penetrated the thickness of the specimen so that the analysis was essentially two-dimensional. However, the elongation-to-break of a tensile specimen depends on the lifetime of the diamonds growing in the drawn material. Since a diamond is generally only part-through for the majority of its lifetime, the internal morphology is obviously of some interest.

It was decided to investigate this morphology by taking negative replicas of the surfaces of tensile PVC specimens containing diamonds. The specimens used were conventional dumb-bell specimens (narrow section 60 mm × 12.7 mm) cut from 1 mm thick sheet and extended in an Instron at 0.2 cm min$^{-1}$. The PVC sheet was compression-moulded from granules of a commercial mass polymer (Breon) stabilized with 3% organotin stabilizer (Irgastab). Each sheet was pressed at 200° C for 30 sec using a pressure of 9 MPa. Before being extended, defects were placed in the specimens to promote the growth of diamonds. This was done either by stamping emery paper onto the surface or by touching at various points with a scalpel. After the diamonds had grown appreciably the specimen was removed and the surface replicated.

First the specimens were coated with a thin layer of gold in a vacuum evaporator. A layer of copper, around 1 mm thick, was then electroplated onto the gold film. When the PVC was prised away, a negative gold-coated copper replica remained. The replica was then examined in the scanning electron microscope. Replication obviously could not be performed on specimens under load so that some relaxation takes place. However, the general morphology remains unaltered and the shape of the cavity perpendicular to the tensile axis should not alter dramatically.

Fig. 1 shows three views of the same diamond cavity. The most striking feature is the multiplicity of crack fronts. All the diamonds examined in this way show the splitting of the crack front into many partial fronts. This phenomenon has been shown to occur when a crack is subjected to a combination of mode I (in-plane tension) and mode II (anti-plane shear), opening displacements [2]. However, in that case the splitting is due to the inability of the crack to rotate past a critical angle and the partial fronts grow on successively higher planes [3]. Here there is no obvious source of anti-plane shear displacements and the partial fronts are arranged in a more haphazard manner. The partial fronts are present



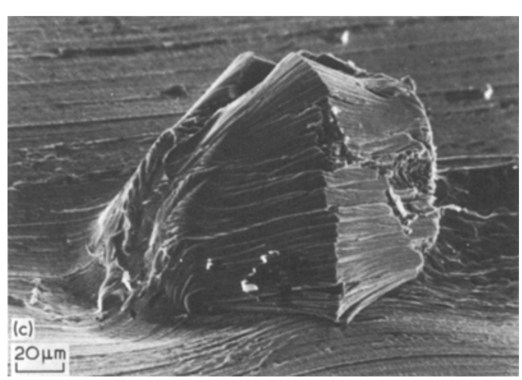




*Figure 1* The negative replica of a diamond cavity viewed (a) along the tensile axis, (b) in the crack plane normal to the specimen surface, (c) in the crack plane parallel to the specimen surface.

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on the smallest diamonds and consequently it is suggested that initiation occurs from various discrete points on the original defect, and in subsequent growth the cracks coalesce but the original crack fronts remain separated. As the cavity continues to grow the partial fronts can lose their identity. When this occurs parabolas are formed on the fracture surface (Fig. 2). The parabolas lie in the reverse orientation to those normally observed on fracture surfaces.

With this technique details of the order of 0.1 $\mu$m can be resolved but, as reported previously [1], no cavitation or any other significant features could be observed at the tip of the diamond.

It is obvious from Fig. 1 that the surface of the PVC in the vicinity of the diamond is far from planar. The surface bulges above and below the mid-section of the diamond and depressions exist around the tips of the diamond. These undulations are possibly enhanced by the relaxation after unloading, but normal incidence microscopy shows that the undulations are present under load. When the diamonds penetrate the thickness of the specimen, the undulations are still evident, which suggests that the two-dimensional strain analysis presented previously [1] may be an over-simplification. However, the depth of the undulations is small compared with the thickness of the specimen and the general conclusions drawn are still valid.

Present studies involve determining the growth rates of diamonds in various glassy polymers. Whilst the growth rates of diamonds which have penetrated the thickness are relatively easy to evaluate, part-through diamonds present greater problems. From the replicated diamonds it is apparent that the ratio of the length of the crack front to the tip-to-tip distance along the surface is near 1.6 for a wide range of diamond sizes. The area of the crack plane occupied by the diamond is, therefore, roughly semi-circular and the increase in crack area can now be estimated from the tip-to-tip distance.

The internal morphology of the diamonds is not as clearly revealed by direct observation in the SEM, and the dimensions of the cavity can only be obtained with difficulty. This simple replication technique also has the advantage that in using a metallic material, beam damage at high magnifications is avoided.

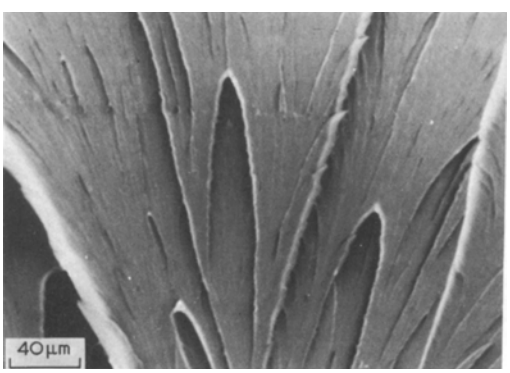


*Figure 2* Parabolas on the growth surface of a diamond. Crack growth is from bottom to top of the micrograph.

## References


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