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LAMELLAR STRUCTURE IN A TYPE I DIAMOND*

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A lamellar structure parallel to octahedron planes is not unusual in diamonds. Such structure becomes visible between crossed polars when the diamond is observed along a [110] direction.

A very pale-yellow diamond crystal, apparently free of birefringence, was selected for stress-optical study. A rectangular parallelopiped was cut in such a way as to be bounded by two dodecahedral planes and one cube plane. The excellence of the natural octahedral faces was such that the optical goniometer could be used to determine the orientation. The largest orientation error of any of the planes is 6 minutes of arc. The dimensions of the diamond sample are $2.6\times3.6\times4.6$ mm. After the diamond was cut, it was found to show very low double refraction.

Figure 1 shows three views of the crystal between crossed polars. In each view, the vibration directions of the polars are parallel to the edges of the crystal. The interference colors are all first order gray. The birefringence of the lamellae is about 2×10^{-5}. A central nucleus shows a

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birefringence of 2.5×10^{-4}. The sharp edges of the nucleus are parallel to {111} planes or edge [112] or nearly parallel to {112} or edge [111] or nearly parallel to {221} or edge [114]. With careful adjustment of the illumination, a Becke line can just be detected at the {112} (or [111]) boundary. The lamellae are to a large extent alternately length slow and length fast. The vibration directions within the lamellae are parallel to {111} at midpoint, and in most of the lamellae they make an angle of about 40° to the {111} planes at the extremities. Such a distribution of vibration directions gives rise to the broad extinction cross. Other extinction bands reveal a more complex distribution of vibration directions. The lamellae in adjacent sectors meet in sharply defined but rather irregular surfaces roughly parallel to cube planes. Some of the dark areas near the nucleus appear optically isotropic.

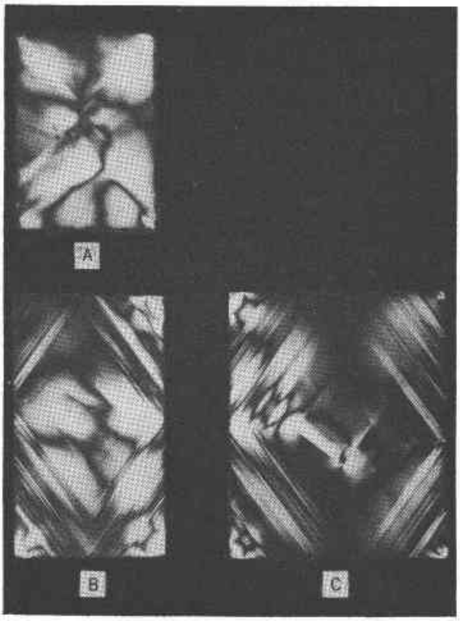

FIG. 1. Birefringence patterns in type I diamond. Crossed linear polars. Vibration directions are parallel to edges of crystal. A(001), B(110), C(110). The dimensions are 2.6×3.6×4.6 mm.

When the crystal is viewed normal to the cube facet (Fig. 1A), the birefringent areas are seen to be roughly divided into four sectors. Extinction bands are irregularly distributed. There is little if any evidence of lamellar structure in this orientation.

Twinning is practically absent. The grinding rate of the crystal as observed during the preparation of the specimen gave no indication of twinning. The grinding behavior probably is the most sensitive test for twinning in diamond. Under favorable conditions, if 1% of the area being cut were twinned, the twinning could be easily detected. Theoretically if a tenth of a per cent of the cut surface were twinned, it should be possible to detect the twinning from the grinding behavior. No twinning was recognized.

As a further check, a number of Laue photographs were taken. While these failed to reveal twinning, it was noted that the scattering power for x-rays is not uniformly distributed over the volume of the crystal. It was possible to correlate the intensity of scattering with the strength of double refraction. The nucleus and the corners of the crystal show the greater scattering power. Microdensitometer traverses along the Laue spots show that the regions of greatest double refraction scatter x-rays about twice as strongly as the optically isotropic portions. An attempt was made to obtain an x-ray topograph from the (220) reflection with copper radiation, as described by Wooster (1945). The thickness of the crystal and other experimental factors did not permit the resolution of the desired features, so reliance had to be placed on the energy distribution in the Laue spots. Ultra-violet and infra-red absorption spectra were studied for the entire crystal as well as for selected areas of the crystal. The absorption characteristics of all parts of the crystal are typical of type I diamonds. The crystal is opaque for wavelengths below 315 mμ, and the absorption bands in the 7–9 μ region, characteristic of type II diamonds, are absent.

In ultra-violet radiation from a mercury lamp, no fluorescence can be visually detected. However, a rather weak blue fluorescence is excited by x-radiation from a copper tube. It can be demonstrated that the most strongly fluorescent portions of the crystal are the regions of strongest double refraction. The lamellar distribution of the fluorescence is not so well developed as is the lamellar birefringence. The fluorescence is always greatest on the side of the diamond nearest the x-ray source, because of the absorption of x-rays by the diamond. Photographs of the fluorescence were taken, but the low contrast makes half tone reproduction impractical.

It was noted that as the crystal was compressed on a cube plane, the lamellar birefringence tended to disappear, even at the fairly low stress of a few hundred kilograms/cm.^{2}. It may be that the increased optical homogeneity is more apparent than real. Both the x-ray diffraction and the fluorescence studies were repeated with the diamond under stresses up to nearly 1000 kg./cm.^{2}. No difference, either in the diffraction pattern or in the fluorescence, was detected. Another similar diamond (uncut) was stressed non-uniformly until it showed tenth order interference for sodium light. The local maximum stress was then 20,000 kg./cm.^{2} (280,000 lbs/inch^2), at which stress the diamond failed along a cleavage plane at an opaque inclusion. No change in either the x-ray pattern or the distribution of fluorescence was induced by such stress. No hysteresis effects, optical or otherwise, were noted after the stress was removed.

The correlation of birefringence, x-ray scattering and fluorescence in diamond has previously been observed by Raman and his colleagues (1944, 1949).

The data suggest that the diamond crystal used grew under periodically varying conditions which resulted in a cyclical variation of minor constituents. It seems reasonable that the variation in composition is due to the substitution of some element other than nitrogen, since no variation in ultra-violet or infra-red absorption of the kind recently correlated with nitrogen content by Kaiser and Bond (1959) has been observed for various regions of the crystal.

While the birefringence of the nucleus is too large to be explained by nitrogen substitution, the birefringence of the lamellae if due to nitrogen substitution would indicate a variation of nitrogen content in adjacent lamellae of at least 3.5×10^{20} atoms/cm.^{3}.

In order to explain fully the strain which gives rise to the birefringent lamellae, the accompanying crystal imperfection, the distribution of fluorescence, together with the uniformity of the ultra-violet and infrared absorption, it is believed that other atoms than nitrogen must be present in different amounts in adjacent lamellae.

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