Remarks on Diamond Crystal Counters

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IN a recent interesting publication, Friedman, Birks, and Gauvin[1] have indicated that "gamma-ray counting" diamonds are of the ultraviolet transparent variety, Type II, in the notation of Robertson, Fox, and Martin.[2] Attention may profitably be called to the considerable research performed in recent years on the ultraviolet and infra-red absorption, photo-conductivity, luminescence, birefringence, and x-ray studies of a large number of diamonds. This work has been published by C. V. Raman and his school and is collected in two symposia on the "Structure and Properties of Diamond."[3]

Many facts are reported in these extensive studies, some of which may have direct bearing on the work of Friedman, *et al.* Raman's group has found that Type II ultraviolet and infra-red transparent, highly photo-conductive diamonds show a laminated structure. The other diamond variant, Type I, is ultraviolet opaque and exhibits a uniform isotropic structure on macroscopic examination, although often it is spotted with random inclusions of laminated or Type II material. The x-ray studies of Krishnan[4] and Ramachandran[5] indicate that the ultraviolet opaque material (Type I) is probably a microcrystalline mosaic structure consisting of two similar forms of diamond (see below).

If we assume that Type I is a mosaic and Type II a laminated structure, it may be possible to understand why the Type I, ultraviolet opaque diamond will not count as well as the Type II, ultraviolet transparent variety. For the ability of a material to count depends, among other things, on the range of an electron freed by an ionizing particle in the diamond. It may be expected, although such has not yet been proved, that the range of a secondary electron will be terminated at the boundary of a lamination. In Type II material, the range may be large, particularly if the electric field is parallel to the laminations. Such diamonds can count, and indeed all the better, if the electric field direction is parallel to the laminations. On the other hand, in a mosaic structure, it is likely that electron traps exist at the boundaries of the microcrystals and, hence, that the range is very small. On this theory, it may then be expected that with present amplifier technique, Type I diamonds, having mosaic structure, will not count individual gamma-rays or beta-particles. At best they should show only feeble pulses above amplifier noise. However, pulses due to alpha-particles, protons, or deuterons of energy larger than a few Mev, may be visible over the noise since such heavy ionizing particles will give up all their energy to the crystal, even in very small diamonds. Such is not the case with beta-particles or Compton electrons whose range is larger than the crystal thickness. In Type I diamonds it may be possible to observe integrated effects under strong irradiation by many beta-particles or gamma-quanta.

From the above discussion it appears possible that a change of pulse size per unit electric field intensity may accompany a reorientation of the diamond with respect to the electric field in a "good" specimen of the Type II or gamma-ray counting diamond. By "good" is meant a diamond showing preferably only one set of parallel laminations. A diamond with several crisscrossing sets of laminations should not show such an effect to any marked degree. The laminations in Type II diamonds are not, in general, perpendicular to the face of a cleavage plate. The laminae seem to have thicknesses between 10 and 100 microns.[6]

It may be that the differences between Curtiss' diamond and NRL diamonds[1] are caused by an orientation effect, but it is more probable that the various diamonds studied by Friedman, *et al.* are different mixtures of Types I and II material. Perfect examples of Types I and II seem to be rare. On the other hand, mixtures occur together quite often.[5] This point should be emphasized. Such mixtures can be partially ultraviolet transparent.

The experimental results of Raman's group also suggest that the best gamma-ray counting diamonds should be non-luminescent under ultraviolet excitation and colored when examined in visible light between crossed Nicols. Poorer counting diamonds should show blue luminescence, or possibly yellow or greenish luminescence, and little or no birefringence. Such criteria may be useful in sorting diamonds as crystal counters. Probably such rules will not be found to hold rigidly because mixed samples are so common. A rough criterion might be that diamonds which luminesce brightly will be poor counters or will not count at all.

It was kindly pointed out to the author by Professor Frederick Seitz that the difference in properties between Types I and II might be due to impurities. This view has been considered by Raman[7] and is thought not to be the differentiating principle between Types I and II diamonds. It is interesting that the reorientation test, proposed above, may satisfactorily provide a decision between these two views and, in fact, a test of the theory presented here.

Raman[7] has proposed a theory for the structure of diamond which indicates the existence of two similar tetrahedral forms of diamond (Type I) and two distinct octahedral forms (Type II). The latter two, although distinct, coexist side by side in a strained laminar condition. Thus, according to this theory, there appear to be four types of diamond. It is quite probable that further research on diamond crystal counters will provide new tests or verifications of Raman's theory.

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