PHOTO-ELASTICITY OF DIAMOND

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1. Introduction

All the three photo-elastic constants of diamond were first determined by the author (1947) from measurements on the relative and absolute changes of refractive index in specimens subjected to a linear compressive stress. Unfortunately, an error had crept into the measurements whereby the sign of the constants were reversed (West and Makas, 1948; Burstein and Smith, 1948 *b*). It was therefore considered worthwhile to repeat the measurements and obtain fresh values for the piezo- and elasto-optic constants of diamond. The same three specimens of diamond (*viz.*, N.C. 73, N.C. 60 and N.C. 85) from the collection of Sir C. V. Raman, as were used in the original determination, were employed for the present study also. The method used was also essentially the same. It was found that the vertical and horizontal directions had been interchanged by mistake in all the previous measurements. Consequently the piezo-optic constants $(q_{11}-q_{12})$ and q_{44} have nearly the same magnitudes as found earlier, but both are negative and not positive. Further it is found that the individual values of q_{11} and q_{12} have to be revised.

2. Measurements of Relative Retardations

As was mentioned in the earlier paper by the author (1947), measurements made with a Babinet compensator for different directions of compression and observation with three specimens yield the values of three linear functions of $(q_{11}-q_{12})$ and q_{44}, denoted respectively by q_1 and q_3 for brevity. The mean values of these three functions found in the present study are

$$(q_1 + 2q_3)/3 = -4\cdot 27 \times 10^{-14} \text{ cm.}^2 \text{ dyne}^{-1}$$
$$(q_1 + 5q_3)/6 = -3\cdot 53 \times 10^{-14} \quad ,,$$
$$q_3 = -2\cdot 79 \times 10^{-14} \quad ,,$$

The best values of q_1 and q_3 deduced from these are

$$q_1 = -7\cdot 2 \times 10^{-14},\; q_3 = -2\cdot 8 \times 10^{-14} \text{ cm.}^2 \text{ dyne}^{-1}$$

Since only $q_1/3$ and $q_1/6$ occur in these functions, it is clear that there is a greater uncertainty in the value of q_1 than in that of q_3. If a crystal could be found with its length along [100] then q_1 can be measured directly.

From the above, the elasto-optic constants are

$$p_{11} - p_{12} = -0\cdot 40,\ p_{44} = -0\cdot 12.$$

The above constants are probably correct to 5%.

3. Measurement of Absolute Path Differences

The interference method used earlier was adopted now also, but the fringes obtained with the silvered crystal were not photographed, but were observed directly with a micrometer eye-piece. The diameters of the rings were measured with the eye-piece and in this way a large number of readings could be obtained. The changes in path for the vertically and horizontally polarised rays were obtained by graphical interpolation and found to be $-0\cdot 053\ \lambda$ and $+0\cdot 052\ \lambda$ respectively for a load of 5 kg. with the mercury 5461 radiation. The increase in thickness calculated from the elastic constants of Bhagavantam and Bhimasenachar (1946) was 94 Å, so that the changes in path for the two rays were − 381 Å and + 193 Å respectively. The difference is thus 574 Å and as calculated from q_1 and q_2 it is 583 Å, which are in good agreement. These measurements give

$$(q_{11} + q_{12} + q_{44})/2 = -2\cdot 80 \times 10^{-14}$$

$$(q_{11} + 5q_{12} - q_{44})/6 = +1\cdot 42 \times 10^{-14}$$

which together with $(q_{11} - q_{12}) = -7\cdot 2 \times 10^{-14}$

lead to the following values:

$$q_{11} - 5\cdot 0_5 \times 10^{-14}\ \text{cm.}^2\ \text{dyne}^{-1}$$

$$q_{12} = +2\cdot 1_5 \times 10^{-14}\quad ,,$$

$$q_{44} = -2\cdot 8 \times 10^{-14}\quad ,,$$

From these, using the elastic constants, we get

$$p_{11} = -0\cdot 31,\ p_{12} = +0\cdot 09,\ p_{44} = -0\cdot 12$$

The absolute values of q_{11} and q_{12} as also those of p_{11} and p_{12} are expected to be accurate to 10%.

4. Discussion of the Results

The present values differ from those previously reported in that the signs of both $(q_{11} - q_{12})$ and q_{44} and the corresponding elasto-optic constants are negative. This means that diamond behaves as a negative uniaxial crystal for unidirectional pressures along the cubic and octahedral axes and as a negative biaxial crystal for stresses along the [110] or any other direction. It does not however follow that the sign of $(dn/d\rho)$ is opposite to that reported earlier. This is because the absolute values of p_{11} and p_{12} are different.

Actually it is found that $dn/d\rho$ is negative, since $(p_{11} + 2p_{12})/3 = -0\cdot04$ and $\rho dn/d\rho$ has the value $-0\cdot28$. Such a negative value for $dn/d\rho$ is to be expected since other highly covalent crystals like MgO (Burstein and Smith, 1948 *a*) have negative $dn/d\rho$. Thus the value of λ in the equation (Mueller, 1935)

$$\rho \frac{dn}{d\rho} = (1 - \lambda) \frac{(n^2 - 1)(n^2 + 2)}{6n}$$

is $1\cdot10$, as compared with $\sim 1\cdot4$ for MgO.

R. S. Krishnan (1947), who obtained the Brillouin components in the scattering of light in diamond, found that the relative intensity of the longitudinal and transverse components did not agree with the value calculated from the theory of Leontowitsch and Mandelstamm, (1932) using the author's previously reported photo-elastic constants. This discrepancy, however, disappears with the present data. According to Leontowitsch and Mandelstamm's theory, the average intensities of the longitudinal and transverse components would be in the ratio of

$$\frac{2(p_{12}^2 + p_{44}^2)}{c_{11} + c_{12} + 2c_{44}} : \frac{p_{44}^2}{c_{44}}.$$

With the present values of p_{12} and p_{44} this comes out as $2\cdot04 : 3\cdot35$, so that there is no glaring discrepancy between theory and experiments, as was present previously, the transverse component being the brighter of the two.

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Summary

The photo-elastic constants of diamonds have been redetermined and are found to be $q_{11} = -5\cdot0_5$, $q_{12} = +2\cdot1_5$, $q_{44} = -2\cdot8 \times 10^{-14}$ cm.^{2} dyne^{-1} and $p_{11} = -0\cdot31$, $p_{12} = +0\cdot09$, $p_{44} = -0\cdot12$. These lead to a decrease in refractive index when diamond is subjected to a hydrostatic pressure.

References

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