A New Method of Observing Compton and Other Incoherent X-Ray Scattering in Crystals

If a narrow cylindrical beam of copper K + white radiation is allowed to impinge on an iron foil of suitable thickness, placed in contact with a mosaic-type diamond (the foil being between the X-ray source and the diamond), an excellent divergent-beam pattern due to fluorescent iron K radiation can be obtained, superimposed on the Laue pattern of the diamond[1,2].

Even when the foil is removed, however, a weak divergent-beam pattern is still observed on sufficiently well-exposed Laue photographs, but it now corresponds to that expected for copper K wide-angle radiation. It was at first thought that this indicated the presence of copper as an impurity in the crystal, in sufficient quantity for a high proportion of fluorescent copper K radiation to be generated. This initial hypothesis was disproved by the following considerations and experiments.

(*a*) The effect is found for clear, colourless diamonds which would not be expected to contain copper as an impurity.

(*b*) Copper is a more unusual impurity than iron even in the opaque, coloured Belgian Congo diamonds which showed the copper K spontaneous pattern most clearly; yet, with an incident pencil of copper K radiation, for which the iron K fluorescence might be expected to be far more intense than any copper K fluorescence, no iron K spontaneous pattern was found.

(*c*) To check this reasoning, a spectrographic analysis of two Belgian Congo diamonds showing the effect was kindly undertaken by Miss Czapska, of Hilger and Watts, Ltd. This showed the presence of iron and silicon, but not of copper.

(*d*) A Laue photograph taken with cobalt K + white radiation showed a weak superimposed divergent-beam pattern due to cobalt K wide-angle radiation only.

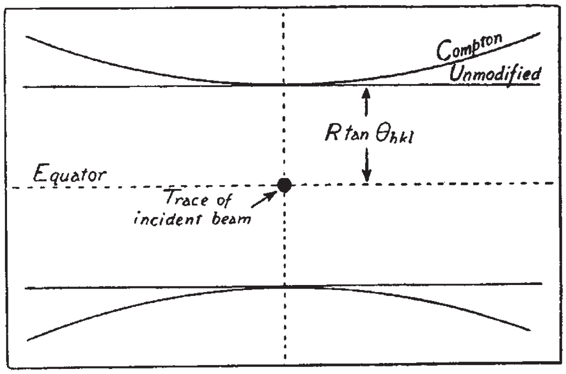
(*e*) Similar spontaneous wide-angle patterns were found for a mosaic benzophenone crystal using copper K and cobalt K incident beams respectively; and for a graphite crystal, using copper K radiation, when the incident beam was parallel to the basal plane.

Since the source of wide-angle radiation is within the crystal, and is not fluorescent radiation but of a kind similar to that in the incident beam, it must be either Compton scattering or imperfection scattering (including thermal scattering) or both.

This is confirmed by the observation that in the neighbourhood of the undeviated incident beam only reflexion conics, and no absorption conics, are recorded; which means, in effect, that the wide-angle source of radiation within the crystal has zero or low intensity near the incident beam direction, as would be expected for all such secondary radiation, but not for fluorescent radiation, or for low-angle scattering of any kind.

Owing to the difficulty of obtaining a pattern sufficiently intense for precise measurements of high-angle conics, it has not so far proved possible to distinguish between the effects due to the two types of incoherent scattering.

In principle, however, this could be done. In Compton scattering the wave-length of the scattered radiation is altered by up to 6 per cent, according to the incident radiation and the angle of scattering,



Appearance of the hkl conic on a cylindrical film of radius R, when the planes (hkl) are perpendicular to the axis of the film. The curvature of the Compton conic is greatly exaggerated

whereas for imperfection scattering the wave-length change is only about 10^{-3} per cent. If the crystal is set with a plane (hkl) accurately perpendicular to the axis of a cylindrical camera, the divergent beam conics due to this plane will appear symmetrically on each side of the equator. If the pattern is due to the comparatively unmodified radiation, the conics will be a pair of lines parallel to the equator of the film; if it is due to Compton scattering the lines will diverge (appreciably for high-angle conics) as the angle of deviation from the incident beam increases (see diagram). Deviations from parallelism due to unwanted curvature of the film, etc., could be corrected for automatically by superimposing on the pattern a rotation photograph taken in the same orientation. In certain circumstances the mth-order conic will coincide with the nth rotation layer line, and any high-angle deviation could be observed. (For example, the deviation would be of the order of 2 mm. in the separation of the 220 copper $K\alpha$ conics for an angle of scattering of 140° for diamond with [110] parallel to the camera axis, using a cylindrical film of diameter 6·0 cm.).

The method is one which, if difficulties of technique are overcome, may be expected to give information about the relative amounts of Compton and imperfection scattering in various directions.

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H. J. Grenville-Wells

University College,
London, W.C.1.
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[1] Grenville-Wells, H. J., thesis, London (1951).
[2] Lonsdale, K., *Phil. Trans. Roy. Soc.*, A, **240**, 219 (1947).

Intensity Variation in Sunspots

The most conspicuous and readily observed feature of a normal sunspot is a dark central umbra surrounded by a less dark penumbral fringe which, under good seeing conditions, appears to be composed of converging filaments directed radially inwards. Secchi[1] concluded from his visual observations that the penumbra is brighter at its inner edge, that is, towards the periphery of the umbra and darker at its outer edge. This feature is clearly shown in his drawings of sunspots.

Measurements of the variation of total energy across a sunspot with a thermocouple led Pettit and