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Publication Date
1972-02-01
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February 1972

AEC Contract No. W-7405-eng-48
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OPTICS OF BONSE-HART APPARATUS

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ABSTRACT

We have investigated the beam profiles both at the specimen and detector position in a modern Bonse-Hart small angle scattering apparatus with and without a specimen. A Gaussian intensity distribution in the direct beam was observed both at the specimen and the detector positions at 0 degree 2θ. Photographs taken at different angular positions, starting from 0 degree 2θ are presented which gave a detailed description of the change in beam profile.
The AMR x-ray low angle scattering goniometer used for this experiment consists of two grooved perfect Ge crystals arranged in parallel position with the sample holder placed between them, Fig. 1. The depth of the groove is approximately 1.5 cm. The walls of the crystal grooves are parallel to the (220) planes of Germanium. The x-ray beam is multiply diffracted (six times per crystal) between the walls which results in the effective elimination of the tails of the reflection curve\(^1\). Fig. 2 shows the shape of the rocking curve obtained from the goniometer with a Cu target x-ray tube operated at 40 kv and 20 ma. The second crystal is rotated around the center of the sample by means of a large barrel micrometer calibrated in steps of one second of arc\(^2\). The purpose of this letter is to show how the beam shape changes as the angular position of the second crystal is increased at very small angles where the scattering is mainly due to the entire specimen volume\(^2\), and at larger angles where scattering due to inhomogeneities in the specimen is observed.

Short film exposures of the primary beam were taken at the specimen position and after the second crystal at zero angle as shown in Fig. 3a and 3b respectively. Clearly there is one strong line at the center of each photograph. This is due to the shape of the focal spot of the x-ray tube which was obtained from a pinhole photograph, Fig. 3c. The images are 9.36 mm and 9.5 mm in height, and by simple geometrical calculation, the vertical beam divergence is found to be 4.45 minutes.

The intensity distribution across the equator (perpendicular bisector of the primary beam image) of the films were determined with a microphotometer of scanning area 2mm x 20 microns as shown in Fig. 4a taken at the specimen position. The shape of the curve suggests an approximately
Gaussian distribution of the form \( y = c_1 e^{-cx^2} \). This was checked by making \( \ln I \) versus \( x^2 \) plots. As shown in Fig. 4b, for the specimen position, the detector position and in the small angle scattering region, the linearity of the curves demonstrate that they are all Gaussian and have the same \( c \) value within experimental error.

X-ray photographs were also taken with the detector set at 0, 5, 10, 15, 20, 25, 30 and 40 seconds of arc \( 2\theta \) without a specimen and with different exposure times. As shown in Fig. 5a, the most interesting feature is the apparent decrease in beam height with increase in \( 2\theta \). This was found to be due to the fact that intensity distribution along its height is not constant, but is greater in the central portion than at the top and bottom as is clearly evident in the beam shape at zero degree \( 2\theta \).

A simple analysis suggest that with gradual increase of \( 2\theta \), the top and bottom portions of the incident beam fail to satisfy the exact Bragg condition and are strongly attenuated. In order to confirm this, two lead pieces were attached to the specimen holder to allow only the strongest central portions of the beam to pass into the second crystal. The experiment was repeated with different exposure times at the same angles as those used in Fig. 5a. It can be seen in Fig. 5b that the beam height remains the same at all angular settings.

Small angle diffraction photographs, using a glassy carbon specimen were taken at 160 sec and 200 secs of arc \( 2\theta \) respectively as shown in Fig. 3d and 3e. The background intensity at those angles is practically negligible. The beam profile is similar to the shape at zero degree \( 2\theta \). That is, there is a Gaussian intensity distribution in this small angle scattering region as shown in Fig. 4b where the slope is indistinguishable.
from that obtained without a specimen. Furthermore there is no reduction in beam height irrespective of scattering angle.

In conclusion, we have shown that the beam height at the detector position decreases rapidly when no specimen is present but reaches a limiting height within about 25 seconds of arc and this is due to non-uniform intensity distribution along the beam height. However this has no effect on the beam height when small angle scattering from a specimen is being recorded. Comparison of the slopes of the plots of the ln (intensity) versus $x^2$ for the specimen, detector at zero angle and at 160 seconds of arc showed that they were identical within experimental error ($\pm 5\%$). Thus it appears that the divergence of the x-ray beam for this experimental arrangement is extremely small and can be disregarded in any calculations. The data also show that in any convolution calculations the assumption that the beam profile is Gaussian is well justified.

In experiments wherein counting rates versus $\theta$ were made, it was found that the half width was approximately 5 second of arc which supports the contention of Koffman that an angular resolution of 10 seconds of arc can be achieved. However, his assumption that $i(y)$ is constant is shown to be incorrect. Furthermore, as pointed out by Rothwell and borne out by experiments done in this laboratory the assumption that infinite slit height conditions are attained is also incorrect. This will be discussed upon completion of work now in progress.

ACKNOWLEDGMENTS

The support of this work by the United States Atomic Energy Commission through the Inorganic Materials Research Division of the Lawrence Radiation Laboratory, is gratefully acknowledged.
REFERENCES


FIGURE CAPTIONS

1. Multiple reflections of x-ray within the grooves cut into Ge crystals.

2. Rocking curve after 12 reflections from Ge crystals without any specimen.

3. (a) Beam profile at the specimen position.
   (b) Beam profile at the detector position at zero angle of arc 2θ.
   (c) Pinhole photograph of the x-ray source.
   (d) Photograph in small angle scattering region 160° of arc 2θ with glassy carbon specimen.
   (e) Photograph in small angle scattering region 200° of arc 2θ with glassy carbon specimen

4. a. Intensity distribution across the equator (perpendicular binector of the primary beam image) of the film,
   b. Plot of Ln I vs x² for the (a) specimen position, (b) detector position and (c) small angle scattering region.

5. X-ray photographs in ultra-small angular region
   (a) Without specimen,
   (b) Without specimen taking only strongest central portion of the beam.
Fig. 2.
Fig. 3.

XBB 722-1362

Fig. 3.
Fig. 4(a)

XBL 722-6053
Fig. 4(b).
Fig. 5.
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