Characteristics of a Channel Plate as an Image Intensifier for X-ray Topography

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A channel plate has been used for taking X-ray diffraction topographs. A topograph of a Si crystal on a fluorescent screen has been recorded by an optical camera. The spatial resolution of the plate has been found to be at least better than 37 μm. The time for the optical recording of a topograph on this plate proved to be about 10² times shorter than that required by standard topography. The sensitivity of the plate has also been measured for Cr Kα radiation.

Introduction

In order to take X-ray topographs so rapidly that imperfections in crystals may be observed almost in real time, two kinds of techniques have been developed so far: one is to use the intense X-ray source and a vidicon tube with good resolution (Chikawa & Fujimoto, 1968; Chester & Koch, 1969; Rozgonyi, Haszko & Statile, 1970; Chikawa, Fujimoto & Abe, 1972; Chikawa, 1974), and the other is to use a usual source but make the detecting system sensitive with various kinds of image intensifying tubes, where electron scanning is used (Reifsnider & Green, 1968; Lang & Reifsnider, 1969; Meieran, Landre & O'Hara, 1969; Meieran, 1971; Hashizume, Kohra, Yamaguchi & Kinoshita, 1971; Kozaki, Hashizume & Kohra, 1972).

A channel plate may possibly be used for this purpose with certain merits of its own. It needs no electron scanning for itself, is less subject to mechanical shock, its life is long and cost relatively low, and its amplification is fairly large. Besides, the signal-to-noise ratio is so good that the obtained image may show high contrast. Application of a channel plate to X-ray topography was first carried out by Parpia & Tanner (1971); and, partly because the pore size of the channel plate was of the order of 50 μm, the image resolution was not good enough at that time for X-ray topography. At present, however, as a channel plate with a smaller pore size is commercially available, the resolution is expected to be comparable with at least low-resolution X-ray films. The resolution obtained in the present work using a channel plate of 19 μm pitch has been much improved.

Geometry of mounting a channel plate

The channel plate (Model 6025-P20, Galileo Electro-Optics Corp.) used in the present work consists of hexagonally close packed channeltrons of 15 μm inner diameter and 19 μm pitch. Incidentally, the channeltron capillaries are tilted by 5° from the axis normal to the bulk surface of the plate. The diameter of the channel plate is about 2.5 cm and its thickness about 0.5 mm. This channel plate together with a fluorescent screen coated on a fibre optics plate approximately 5 mm thick is fixed in a stainless steel chamber which is kept in dry vacuum of at least 1 x 10⁻⁶ torr, as shown in Fig. 1.

Resolution

The experimental setup to measure resolution and to take a topograph is shown in Fig. 2. In this setup, the topography of a reflexion type was adopted so that the background due to the direct beam would not be high. The specimen crystal was moved as indicated by an arrow in Fig. 2. The fluorescent image can be seen through an attached fibre optics plate. Because the image moving on the fluorescent screen is synthesized on a film in an optical camera, traverse motion is not necessary for the channel plate. Cr Kα radiation of relatively long wavelength has been used because harder radiation may penetrate the channel walls to a greater extent and worsen the resolution, although the walls include 50–60% Pb in weight.

In Fig. 3, three topographs are compared: (a) is a usual direct topograph while (b) and (c) are topographs...
optically taken from the images on the channel plate. Topograph (b) is poor in resolution, while topograph (c) is much better in resolution, being almost as good as that of coarse-grain X-ray film, Fuji X-400 [topograph (a)]. The difference between (b) and (c) is in the value of $D_{gap}$ given in the legend. In the original geometry as supplied, the gap distance between the output of the plate and the fluorescent screen was 2.47 mm. This gap has deliberately been reduced to 0.9 mm in our laboratory. This modification has proved to be very effective in improving the resolution. This improvement may be mainly due to the fact that the electrons emitted from each channel at the last stage of multiplication had been converged by an electrostatic field probably extending deeper into the outlet of each channel. However, the voltage applied to $D_{gap}$ for taking topograph Fig. 3(c) is lower than that for (b). This is due to the fact that the present vacuum system is not powerful enough to avoid any haphazard electrical discharge from the application of too high a voltage. This condition naturally becomes more severe accordingly as $D_{gap}$ is reduced. However, high resolution can be attained by improving the vacuum so that a higher voltage may be applied across this gap.

In order to compare the spatial resolution more precisely, transmission X-ray images of copper meshes were made on the channel plate with the narrower $D_{gap}$ value, and recorded by an optical camera as shown in Fig. 4. A uniform incident beam used in this case has been obtained by the 311 Bragg reflection from a perfect Si crystal plate traversed as in Fig. 2. Although the photographic reproduction is not clear enough for it to be seen, even the finest mesh can be recognized on the original film. Therefore, the resolution can be claimed to be at least better than 37 $\mu$m, probably about 30 $\mu$m. By the way, it is noted here that a channel plate with channeltrons of less than 10 $\mu$m can technically be made (Owen, 1975). This may better the resolution by a factor of 1.5 in future under the same geometrical conditions.

**Sensitivity**

The section pattern corresponding to a part of a topograph, Fig. 3(c), was used for estimating the sensitivity of the present channel plate. The output current from the plate has been measured by a picoammeter, and this value, after conversion into numbers of electrons per unit area and unit time, has been

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Fig. 2. The experimental setup for taking an X-ray topograph.

Fig. 3. Three X-ray topographs of a Si plate taken with the 311 reflection by the use of Cr Kz. (a) Fuji X-400. (b) Channel plate + tri-X; $D_{gap} = 2.47$ mm; $F: 11$; 20 s, $E_{c-p} = 860$ V and $E_p = 4900$ V. (c) Channel plate + tri-X; $D_{gap} = 0.9$ mm, $F: 2.8$; 8 min, $E_{c-p} = 790$ V and $E_p = 3750$ V. The X-ray unit (Rigaku Microflex) was operated at 50 kV, 1.3 mA with the effective focus of 60 x 60 $\mu$m. Bigger black spots in topographs are holes in the thin plate, while smaller ones are dislocation clusters (Yoshimatsu, 1963).
plotted against the applied voltage as shown in Fig. 5. From this result, the current in time average has been estimated to be about $3.5 \times 10^{-16}$ A/channel. Then the conversion factor from Cr Kα X-ray photons to electrons at the entrance of the plate was experimentally estimated as follows: the number of photons reaching the plate per second was measured by a scintillation counter, then the number of output electrons was measured through output current as mentioned in the above, and the amplification factor indicated by the manufacturer was used. Thus the conversion factor has been estimated to be one electron per about four X-ray photons.

When the channel plate with the smaller $D_{gap}$ is used in the above-mentioned improved vacuum, a topograph can be taken during the time as short as used for Fig. 3(b) and with resolution as good as shown in Fig. 3(c). On the other hand, according to the information from Suzuki (1975), the value of current per channel enables us to carry out the real-time observation for the section pattern of Fig. 3(c), when the plate is incorporated in an electron beam scanning tube and its output charge is accumulated for about 100 s.

Therefore, the real-time observation of section patterns is almost possible when the plate is kept under a good vacuum in the scanning tube. The feasibility of the traverse pattern observation by use of a memory tube or of a wide parallel beam, and of other applications can be estimated.

As already described, the above-mentioned channel plate is useful in image intensification without too much loss in resolution. Moreover, if a channel plate of chevron type, namely two plates in tandem, is used, then the gain is as high as $5 \times 10^7$ instead of $10^3$ to $10^4$ for a single plate. Although worsening the spatial resolution by a factor of about two, it may be possible to make the real-time observation more easily with a light vidicon tube.

![Fig. 5. The dependence of the number of electrons emitted from the channeltron capillaries on the voltage applied to the channel plate.](image)

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### References


