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X-ray optics for observing dark-field and bright-field refraction-contrast images

Keiichi HIRANO*, Anton MAKSIMENKO, Hiroshi SUGIYAMA and Masami ANDO
KEK-PF, Tsukuba, Ibaraki 305-0801, Japan

Introduction

Because X-ray refraction-contrast imaging by means of a crystal analyzer has a much higher sensitivity to light elements (Z<17) than conventional X-ray imaging techniques based on absorption, it is very useful for observing the inner structures of biological and polymeric objects. Here we report on a new X-ray optics using a Bragg-transmission analyzer for observing both dark-field and bright-field refraction-contrast images [1].

Experimental and results

Our optics consists of a collimator and an analyzer in the Bragg geometry as shown in Fig. 1. Both optical elements are prepared from perfect crystals, such as silicon, germanium and diamond, and installed in a nondispersive scheme. The first crystal collimates and expands the X-rays, producing a pseudo-plane wave that passes through the sample. The phase shift acquired by the X-ray beam upon passing through the sample depends on the thickness of the sample and the number of electrons per unit volume. The phase gradient represents local changes in the direction of the beam, which are resolved by the analyzer. The transmitted X-rays through the analyzer are recorded on an X-ray film. When the analyzer is tuned at an angle inside the Darwin's region, non-refracted X-rays are completely reflected and only refracted X-rays have a chance to pass through the analyzer, leading to the formation of clear dark-field images. On the other hand, when the analyzer is tuned in the vicinity of, but outside, the Darwin's region, both the refracted and non-refracted X-rays pass through the analyzer, leading to the formation of bright-field images. We can thus observe both dark-field and bright-field images by changing the angle of the analyzer. We can also observe absorption-contrast images at angles away from the Bragg condition.

This X-ray optics was tested at a vertical-wiggler beamline, BL-14B. The wavelength of the incident beam was tuned to 0.073 *nm* by the beamline monochromator. The collimator was adjusted at the asymmetric 220 diffraction condition ($b = 0.047$). The analyzer of 400 μm thickness was adjusted close to the symmetric 220 diffraction condition. At first, we measured the rocking curve of the analyzer, and then recorded the transmitted X-rays through the analyzer on an X-ray film at each offset angle, $\Delta\theta$. The observed area was $9\,mm \times 6\,mm$ in size, and the exposure time was a few seconds. Figure 2 shows the dark-field image observed at $\Delta\theta = 1.8''$ (within the Darwin's region). We could observe both dark-field and bright-field images successfully [1].

Reference

[1] K. Hirano et al., Jpn. J. Appl. Phys. **41**, L595 (2002).

*keiichi.hirano@kek.jp

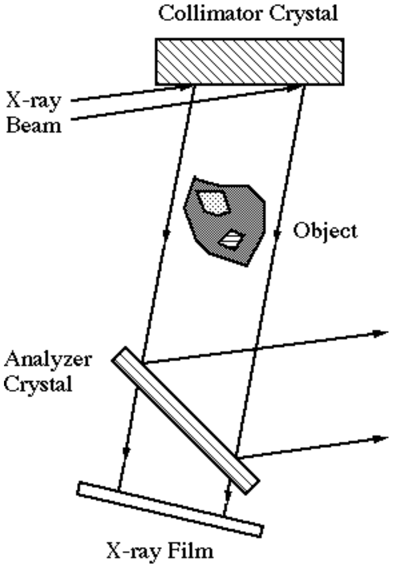

Fig. 1 Experimental setup

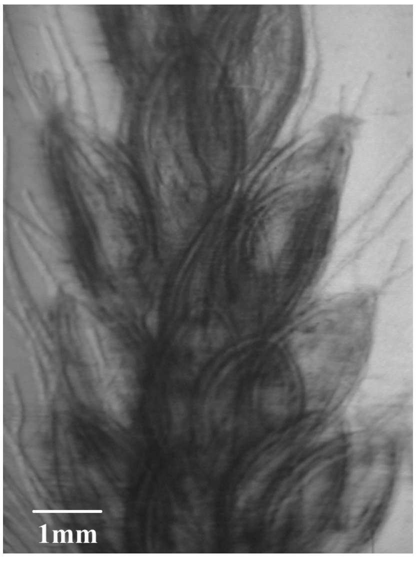

Fig. 2 X-ray refraction-contrast dark-filed image of