Polarization analysis

X-ray polarization is nothing but a correction factor for crystal structure analysis. In some cases, however, polarization of the scattered X-ray includes significant information about electronic degrees of freedom, that is, charge, spin and orbital [1, 2]. To perform linear polarization analysis, a crystal polarizer is widely used in X-ray diffraction experiments [3].

Crystal polarizer

Monochromatic light is 100 % polarized upon reflection at Brewster's angle. In case of X-rays, reflection occurs at certain angles of incidence; this is known as Bragg's law. Therefore, the crystal polarizer must meet the conditions of Brewster's law and Bragg's law, simultaneously. In this practice, Cu 333 reflection is utilized for a crystal polarizer, which restricts the wavelength to 0.984 Å. Since the scattering amplitude parallel to the scattering plane of the crystal polarizer is suppressed, the scattered x-rays are 100 % linearly polarized perpendicular to the scattering plane.

Polarization analyzer

To measure the polarization state of the scattered beam, a crystal polarizer is installed in front of a detector. By rotating a crystal polarizer about the scattered beam, arbitrary linear combinations of the ***x*** and ***y*** components (see Fig. 1) can be selected by varying the rotating angle ϕ_P. The intensity may now be written as

$$\begin{aligned} I(\phi_P) &\propto \left|E_x \cos\phi_P + E_y \sin\phi_P\right|^2 \\ &= I_0\left[\frac{E_x^2+E_y^2}{E_x^2+E_y^2} + \frac{E_x^2-E_y^2}{E_x^2+E_y^2}\cos 2\phi_P + \frac{\mathrm{Re}\left[E_x E_y\right]}{E_x^2+E_y^2}\sin 2\phi_P\right], \\ &= I_0\left[1 + P_\zeta \cos 2\phi_P + P_\xi \sin 2\phi_P\right] \end{aligned}$$

where I_0 is the total intensity, and $P_i\,(i=\xi,\zeta)$ are the normalized Stokes parameters[4]. Consequently, one can determine the polarization state of the scattered beam by measuring the dependence of intensity on the rotation angle ϕ_P. Rocking a crystal polarizer is also necessary for obtaining correct integrated intensities, because the divergence of the scattered beam is not isotropic.

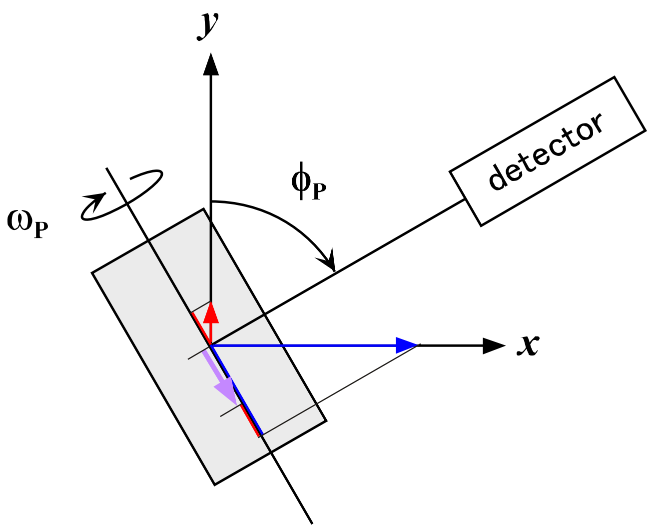

Fig. 1 Selection of linear polarization upon crystal polarizer.

Practical work

Let’s determine the polarization state of the direct beam from the monochrometor.

References

[1] F. de Bergevin and M. Brunel, Acta Cryst. A**37**, 314 (1981).

[2] Y. Murakami *et al*., Phys. Rev. Lett. **80**, 1932 (1998).

[3] Doon Gibbs *et al.*, Rev. Sci. Instrum. **60**, 1655 (1989).

[4] M. Blume and Doon Gibbs, Phys. Rev. B **37**, 1779 (1988).