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# Observation of X-rays traveling from end face of organic thin film

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## Introduction

One of the present authors (K. Hayashi) has insisted that the X-ray waveguide phenomenon is useful for the characterization of organic films, because the energies of monochromatic guided X-rays are sensitively varied by the thicknesses and densities of the films. To date, we have determined accurate film structures of paraffin and copper phthalocyanine by observing the guided X-rays in addition to the energy dispersive X-ray reflectivities.[1,2] This structural analysis method is considered to be promising for in-situ measurements during the film growth process. However, white X-rays from X-ray tubes are too weak to allow to be measured in a few seconds. Therefore, intense white X-ray beams such as synchrotron radiation are needed for the in-situ measurements to be made. As a preliminary study, we used white X-rays of synchrotron radiation in Photon Factory and observed X-rays emitted from the end face of copper phthalocyanine (CuPc) film in order to determine the details of the behavior of X-rays traveling in the CuPc layer.

## Experimental

The CuPc film was prepared on a Si (001) wafer by the evaporation method. The X-ray experiment was carried out at BL3C in Photon Factory. The experimental setup adopted here is displayed in Fig. 1. The size of the incident beam was adjusted to be 100 × 100 μm$^2$ by the slit. The X-rays from the end face of the CuPc film passed through two slits and were detected by a pure Ge-type solid state detector (SSD), which was connected to a digital signal processor and personal computer. The grazing incidence angle was fixed at 0.21°, and the X-ray exit angle varied from -0.14° to 0.18° via 0.05° steps. The data collection time for one spectrum was 20 sec. The reflected X-rays were also measured at a symmetrical reflection geometry of $\phi_1 = \phi_2 = 0.21°$.

## Results and Discussion

Figure 1 shows the angular change of the spectrum. The arc indicated by A is the refraction through the Si wafer, because its energy increases with the increasing $\phi_2$, in accordance with Snell's law. Snell's law was expressed as the following equation,

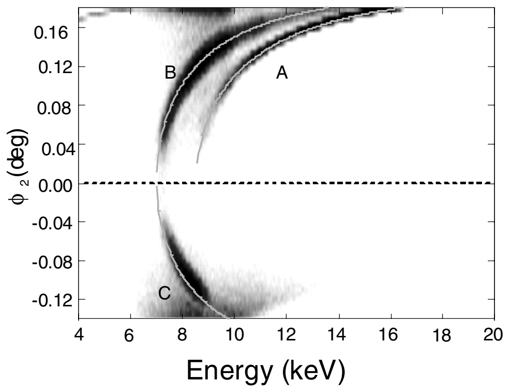


Fig. 1 Intensity distribution of X-rays emitted from the end face of the CuPc layer as a function of X-ray energy and X-ray exit angle $\phi_2$.

$$E_r = hc\sqrt{\frac{e^2 \sum_a N_a f_a}{\pi mc^2(\phi_1^2 - \phi_2^2)}} \qquad (1)$$

where $E_r$ is the energy of the refracted X-rays, $h$ the Planck constant, $c$ the light velocity, $e$ the electron charge, $m$ the electron mass, $f_a$ the real part of the atomic scattering factor of a type a atom, and Na the number of type a atoms per unit volume. Using this equation, the energies of refraction through the Si wafer were calculated with the density of 2.33 g/cm$^3$ (crystalline bulk of Si), and they were plotted in Fig. 3. The calculated energies agree with those of arc A. In addition to arc A, two arcs symmetrical with respect to $\phi_2 = 0.0$ °, which are indicated by B and C, were observed. Since these patterns were not observed for a simple Si wafer, it was considered that they were X-rays traveling in the CuPc layer.

## References

[1] K. Hayashi and J. Kawai, Physica B 283 (2000) 139-142.
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