XMCD MEASUREMENTS BY HELICITY MODULATION TECHNIQUE

Polarization properties may be one of the most promising items in the third generation SR. In particular, the polarization tunability is crucial for the measurement of magnetic effects through magneto-optical activity. Such measurement is attained by a combination of a linear undulator and a phase retarder, capable of controlling both linear and circular polarization states.

Diamond crystal functions as the phase retarder to convert linearly polarized X-rays, originally emitted from the undulator, to the circularly polarized state. Furthermore, it can alternate quickly between plus and minus helicities with almost circular polarization. In the energy range of hard X-rays, a diamond phase plate is suitable for modulating the photon helicity because of the high perfect-crystallinity and high transmittance. A helicity modulation technique has been successfully developed using the phase retarder with a synthetic diamond installed on **BL39XU** [1]. The efficiency of this technique has been demonstrated by a remarkable improvement in the accuracy of the X-ray magnetic circular dichroism (XMCD) at the Fe K-edge in Fe ferromagnetic compounds.

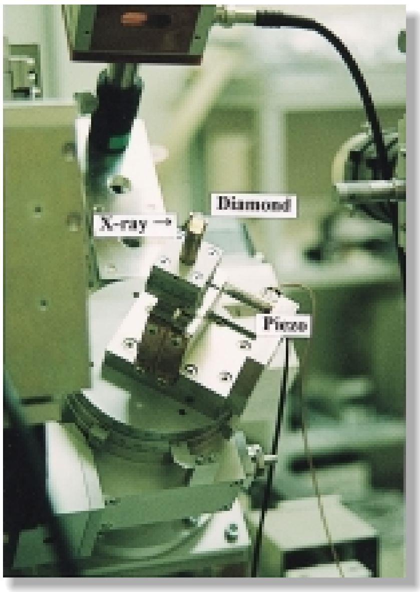

Fig.1: Assembly of the phase retarder. The diamond phase plate is fixed in a piezo-driven stage mounted on a 2-circle goniometer.

A diamond (111) slab 0.5 mm thick is used in the Laue geometry with 220 symmetric reflection plane tilted by 45° from the polarization plane of the incident beam. The phase plate can be operated by a piezo-driven oscillation stage. Figure 1 shows the phase retarder assembly.

Fast switching of the photon helicity is effectuated by flipping between plus and minus offset angles around the Bragg condition, previously determined from polarization measurements of the transmitted beam. The X-ray intensity as a function of the offset angle is shown in Figure 2. The photon helicity was alternately tuned at 40 Hz. The absorption

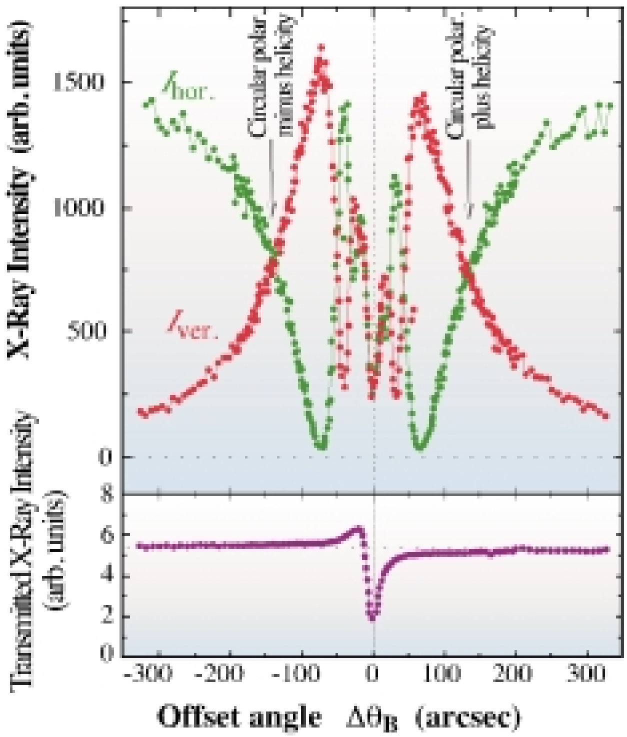

Fig. 2: Measured variations of X-ray intensities versus the offset angle with respect to the Bragg angle in the energy range of 8 keV. The vertical component is equal to the horizontal one at ±140 arcseconds, where the polarization state of the transmitted X-ray is converted into circular polarization. The phase retarder can also function as a λ/2-phase plate, that is, the polarization plane is rotated from horizontal to vertical at around ±70 arcseconds.

coefficient was monitored through a logarithmic converter circuit, and the XMCD signal was directly measured by a lock-in amplifier referring to the frequency of helicity alternation under a fixed magnetic field of 0.6 T.

Figure 3 shows an XMCD spectrum at the Fe *K* edge in ferromagnetic Fe_4N. The spectrum indicates that the experimental error is reduced to less than 10^{-4} and that a high signal-to-noise ratio can be obtained in the entire energy range measured. It took only about 60 min to record the spectrum. This was sufficient to ensure a high statistical accuracy. Hence, the measurement time can be reduced by an order of magnitude in comparison with the conventional method. Some fine structures are clearly resolved around the absorption edge, which is characterized by a positive and acute peak observed at just the threshold. Accordingly, this spectrum may be interpreted in the context of covalency due to charge transfer from the ligand atoms.

The helicity-modulation technique is also applicable to XMCD measurements under extreme condition (*e.g.*, high magnetic field, high pressure, low temperature, etc). In such cases, feeble magnetic effects accompanied by secondary processes of photoexcitation will be observed with high accuracy. This is suitable for recording natural circular dichroism and also linear dichroism as well. Consequently, this technique should open up new fields in the study of XMCD.

Hiroshi Maruyama
Okayama University

E-mail: maruyama@mag.okayama-u.ac.jp

References

[1] M. Suzuki *et al., Jpn. J. Appl. Phys.* **37** (1998) L1488.

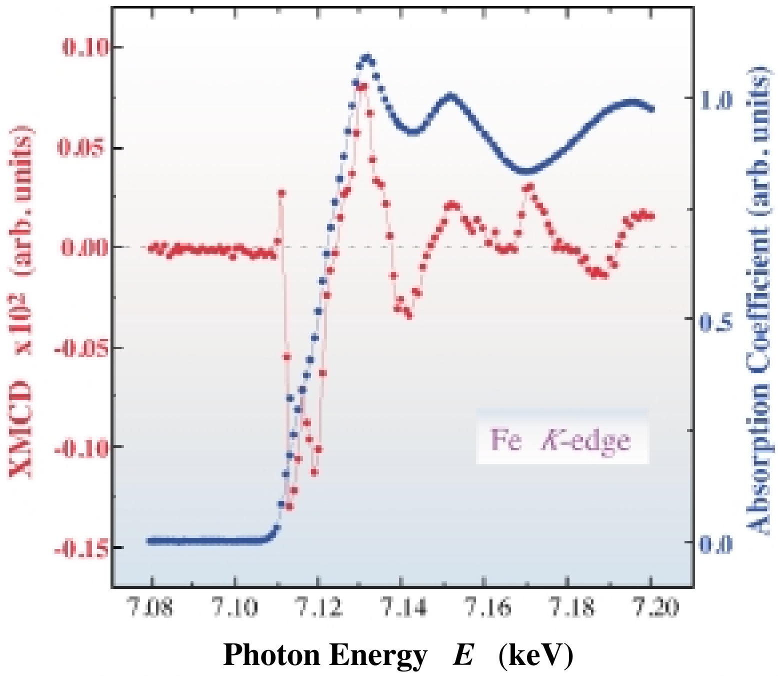

Fig. 3: XMCD spectrum at the Fe K edge in Fe_4N recorded by the helicity-modulation technique. The normalized XANES spectrum is also displayed.