BL08W
(High Energy Inelastic Scattering)

1. Introduction

BL08W is the beamline that can deliver the highest-energy X-rays with only a wiggler source at SPring-8. This beamline is used mostly for Compton scattering experiments and to a lesser extent fluorescence X-ray analyses, particularly for heavy elements. In FY2018, the activities of time-resolved pair distribution function analyses increased because this beamline delivers intense X-rays over 100 keV. Consequently, diffraction experiments can be performed over wide Q-ranges.

This report describes three improvements only related to Compton scattering experiments: (1) updated analysis program for magnetic Compton profiles, (2) development of a high temperature sample holder for Compton scattering, and (3) updated Compton scattering imaging with a pin hole.

2. Update of the analysis program for the magnetic Compton profile.

The analysis program for magnetic Compton profile (MCP), which was coded by Delphi, is provided to users. However, this is becoming difficult since the latest operating system does not support Delphi. Therefore, the program was updated with Python in FY2018. The principal changes are summarized as follows. First, the absorption correction is improved, allowing users to choose the angles of incident and scattering X-rays. Second, the dead time correction can be selected to normalize the area of the Compton profile. Finally, 10 MCPs can be separately obtained from 10 sets of raw data detected by 10 element Ge solid state detectors (Ge-SSDs). Figure 1 shows the control panel of the MCP analysis program. The program is operated with a GUI, considering ease of use by users. Opening the source code to the public allows users to modify the program by themselves.

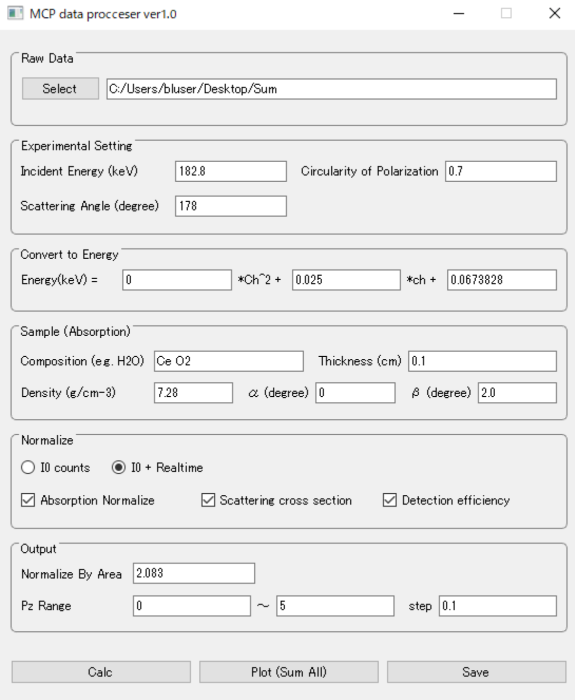

Fig. 1. Control panel of analysis program for MCP.

In addition, the sign of the magnetic Compton scattering (MCS) signals depends on the direction of the magnetization in a sample. The MCP is obtained by subtracting the Compton profiles measured while switching the magnetic directions of the sample. Since the spread of a Compton profile over the X-ray energy depends on the scattering angle, some corrections to raw data are required to obtain a Compton profile. The data processing involves the following:

(a) Energy calibration of Ge-SSDs

Because the energy–channel relationship of Ge-SSDs is linear, the energy calibration is performed by a linear fit to the energy–channel relationship of fluorescent X-rays from a standard sample or a checking source.

(b) Normalization of the Compton profile intensity

MCPs are the difference between Compton profiles obtained by switching the magnetization directions by an angle of 180°. To obtain the MCPs, normalization of the Compton profiles is essential.

(c) Self-absorption correction

Incident X-rays and Compton scattering X-rays are absorbed within the sample. The absorption depends on the sample composition, sample thickness, and X-ray energy.

(d) Scattering cross section correction

The scattering cross section of MCP depends on the energy. This correction is applied to the raw data after a background subtraction.

(e) Detector efficiency correction

The detector (Ge-SSD) efficiency depends on the energy (*e.g.*, 94% at 100 keV and 48% at 180 keV). This correction is applied to raw data after the background subtraction.

(f) Conversion from the energy to the momentum scale

Experimentally, the raw data of the Compton profiles are measured on the energy scale. The conversion from the energy scale to the momentum scale is applied to raw data.

(g) Normalization of the magnetic Compton profile

The integrated area contribution of the MCP is proportional to the magnitude of the spin moment in the sample. To normalize the MCP, a standard sample such as Fe, Ni, or Co whose spin moment is already known, is measured for the normalization of MCP.

3. Development of high-temperature measurements for Compton scattering experiments

Various experimental conditions are important for materials science. Temperature is one influential condition. Currently, the temperature range for Compton scattering experiments at BL08W is limited between 10 K and room temperature using a GM refrigerator. In FY2018, a sample holder for high-temperature measurements using a ceramic heater was developed. Figure 2 show the sample holder for MCS. This holder allows MCS experiments up to 500 °C to be conducted. This heating system is also available for other Compton scattering experiments by changing the sample stage and heater holder.

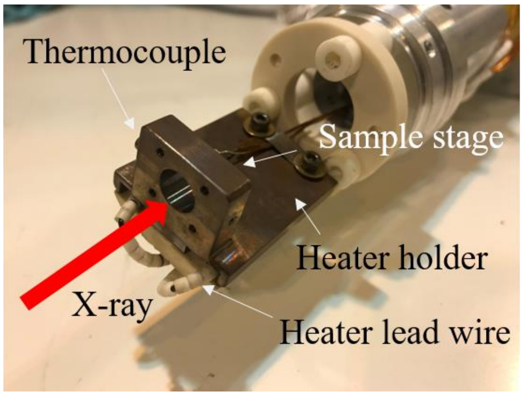

Fig. 2. High-temperature holder for MCP.

4. Update of Compton scattering imaging using a pinhole

The intensity and energy-distribution in Compton scattering both depend on the sample composition because each component in a Compton profile corresponds to the wavefunctions of the electrons in the samples. Therefore, the internal structure can be imaged by mapping the intensities accompanying the Compton profiles from the positions in a sample.

Compton scattering imaging (CSI) at BL08W has some advantages over other imaging techniques. First, an X-ray detector can be placed in any direction. Second, CSI is highly sensitive to light-element materials. Third, the intense, high-energy X-rays (*i.e.,* 115 keV) available at BL08W possess a high transmittance even to a large object. Finally, CSI allows direct 2D imaging in a plane-by-plane arrangement using a pinhole.

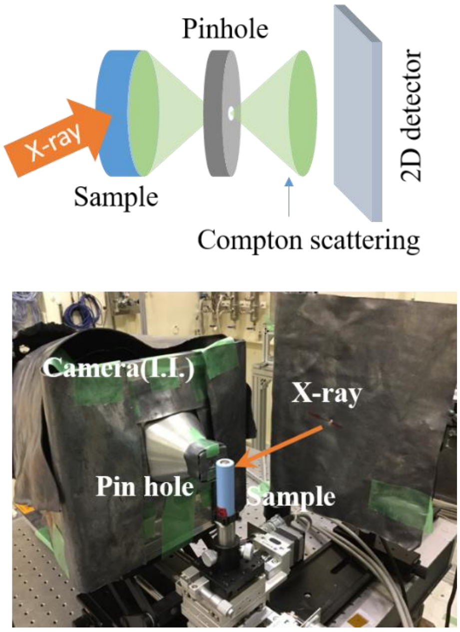

Fig. 3. CSI setup for a plane-by-plane arrangement.

Figure 3 shows the experimental setup for a plane-by-plane measurement. The spatial resolution depends on the pinhole size. In FY2018, a pinhole with a diameter of 100 μm was developed. This pinhole is made of tungsten and is tapered so as not to transmit extra X-rays as background. An image intensifier is employed as a position sensitive detector. A lithium ion polymer battery was measured to demonstrate the CSI experiment (Fig. 4). A clear contrast image of the electrodes inside the battery was successfully obtained.

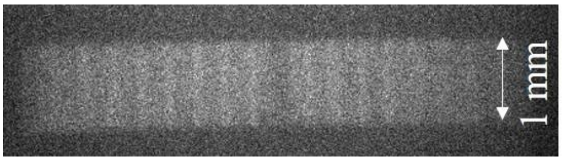

Fig. 4. CSI of a lithium ion polymer battery. Recorded vertical length of this CSI is 1 mm due to the vertical beam size.

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