One-Dimensional Microstrip Germanium Detector

In order to understand the sophisticated electronic structure of a given substance, it is valuable to study the momentum distribution of electrons existing in the substance. Since Compton-scattering using an SR X-ray beam in the high energy region offers direct access to this important physical quantity, it has been used as an elegant and straightforward method in material science by Professor N. Sakai of the Himeji Institute of Technology (HIT) and his group at the high energy inelastic scattering beamline (**BL08W**) of the SPring-8 facility.

A high-energy X-ray beam is generated using a wiggler and monochromatized with a double-bent monochrometer. The experimental setup at this beamline is depicted in Fig. 1. Fixed-angle Compton-scattered X-rays are, in general, energy-dispersive due to the Doppler effect induced by moving electrons. In the present experimental setup, the X-rays scattered by the sample will be spread in one dimension using three precisely-aligned analyzer crystals. Scattered X-rays having the same energy will converge on a focal plane at a position depending upon their energy. By scanning the focal plane with a conventional germanium detector having an appropriate slit system, the intensity of the Compton-scattered X-rays could be obtained as a function of the their energies. This relationship is referred to as the Compton Profile of the sample. However, this scanning approach is highly time-consuming. Even with an X-ray beam intensity as high as that realized at the SPring-8 facility, it would take a month to reach the 0.1% level of statistical accuracy in an observed Compton profile, which is the level necessary to accurately explore electronic structures.

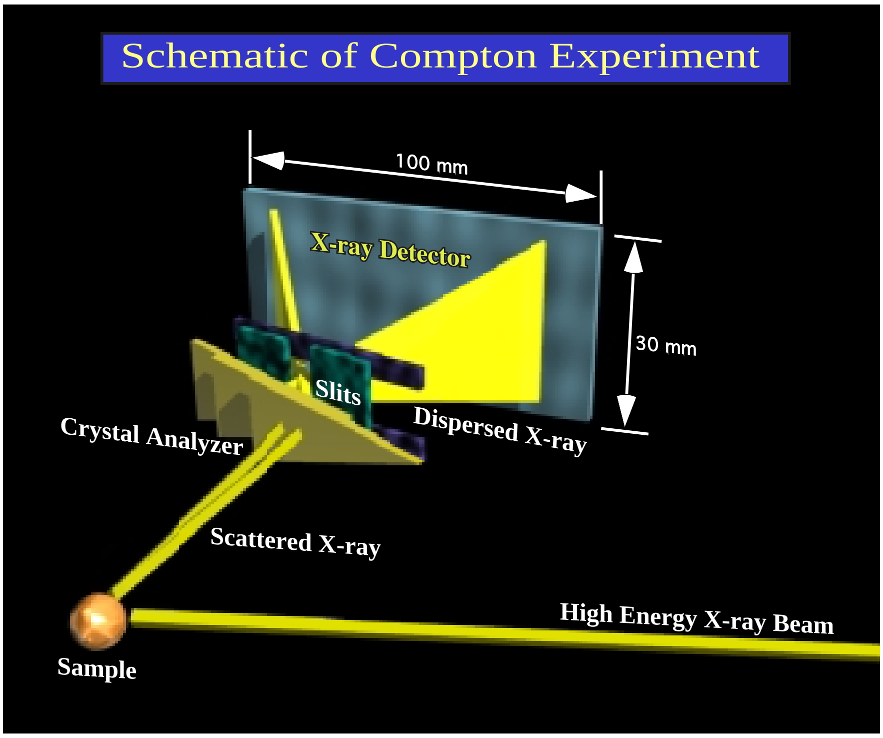

Fig. 1. Schematic of Compton-scattering experiment carried out at beamline BL08W.

An R&D project has been begun by Professor N. Sakai and Mr. N. Hiraoka of HIT in collaboration with Drs. M. Suzuki, H. Toyokawa, Y. Sakurai, M. Mizumaki, and M. Ito of JASRI to develop a one-dimensional position-sensitive X-ray detector, with which Compton profiles could be effectively and reliably measured in much shorter period of time. Since the Compton spectrometer composed of the analyzer crystals has been designed to attain an overall momentum resolution of 0.1 atomic units to meet the scientific needs of the beamline, the spatial resolution of the one-dimensional position-sensitive detector should also match this resolution, corresponding to a spatial resolution of 350 μm with the current spectrometer configuration.

Semi-conductor X-ray detectors made of germanium crystals with microstrip electrodes are the most technologically advanced candidates for use as one-dimensional position-sensitive X-ray detectors. The performance of microstrip germanium detectors is decreased, however, at X-ray energies above 100 keV. The interaction between the X-rays and the germanium crystal in this energy region may be topologically complicated, and the transportation of the charge carriers generated in the crystal may be subject to diffusion. Two prototype germanium detectors contained small numbers of strips with pitches of 200 μm or 350 μm were made in order to evaluate performance in the energy region of interest in areas including energy resolution, spatial resolution, and detection efficiency (Fig. 2). During 1999, these prototypes have been experimentally investigated using γ-ray radioisotopes, an X-ray generator, and the synchrotron radiation X-ray beam at beamline BL08W. Computer simulations based on EGS4-lscat have also been applied to the prototypes to see whether or not they behave as predicted by standard models.

Fig. 2. Prototype microstrip germanium detector with a strip pitch of 350 μm.

Although the experimentally-confirmed behaviour of the prototype with a strip pitch of 200 μm was not well reproduced in the computer simulation, probably due to an enhanced hole diffusion process, the behaviour of the 350 μm-pitched prototype was found to be in good agreement with the simulation, attaining a spatial resolution as high as 350 μm, an energy resolution better than 1.4%, and an overall detection efficiency higher than 50% at an X-ray energy of 80 keV. The successful verification of the 350 μm microstrip germanium detector has allowed the project to move into the next stage, in which a new prototype with 128 total strips and advanced readout electronics will be constructed based on VLSI technology.

Masayo Suzuki
SPring-8 / JASRI

E-mail: msyszk@spring8.or.jp

Reference

[1] SPring-8 Annual Report 1998, "SPring-8 Detector project 1998", to be published.