5 IMSS Instrument R&D Team

The IMSS Instrument R&D team has been developing new detector systems for material science and biology since May 2010. Here we introduce R&D projects ongoing in the Photon Factory and the results obtained in FY2013.

5-1 X-Ray Imaging Using Synchrotron Radiation for Studies on Hierarchic Structure and Dynamics in Materials

A new project for developing a high-performance Silicon-On-Insulator (SOI) area detector is just starting for studies on hierarchic structure and dynamics in new materials. SOI technology is suitable for developing a good pixelated monolithic detector for X-ray imaging experiments using synchrotron radiation. The SOI device has no mechanical bump bonding and so a smaller pixel size can be achieved. A large gain and low-noise operation can be expected because the parasitic capacitances of sensing nodes are very small. The new SOI detector with a high space resolution of 30×30 μm^2 pixel will be valuable for investigating new ferroelectric materials for electronics applications. Utilizing the fine pixels of the new detector, we aim to determine the precise positions of hydrogen atoms, which are related to the mechanism of the large polarization of a ferroelectric, found in an organic complex. We also aim to determine the time response of the domain structure in such a sample to the application of an external electric field by using the 1 kHz to 1 MHz framing rate of a new detector system, as shown in Fig. 1. To study non-crystallized bio-molecules and structural changes of cell membranes, the fine pixels and high frame rate of the SOI detector will be effective for grazing-incidence small-angle X-ray scattering (GI-SAXS) measurement. The detector's high sensitivity to soft X-rays of around 2 keV is also attractive for studies using X-ray absorption of phosphor or sulfur. GI-SAXS measurements will be conducted with the new SOI area detector at BL-15A.

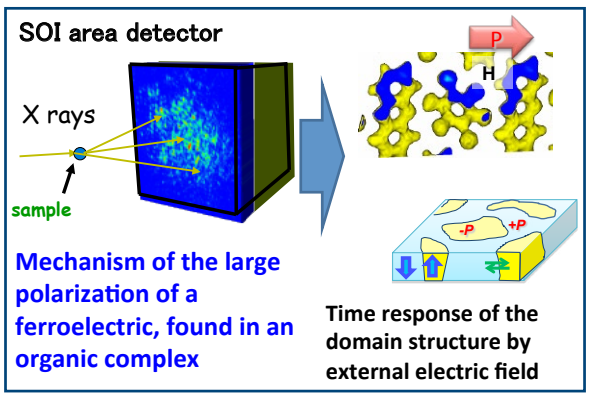

Figure 1: X-ray imaging using SOI area detector for studies on hierarchic structure and dynamics in materials.

5-2 Ultra-Fast Signal Processing System for a Si-APD Array X-Ray Detector

The project team has been developing an X-ray detector system using a 64-pixel Si-APD linear array (pixel size: 100 μm × 200 μm) and pulse counting electronics for multi-channel scaling (MCS). In FY2013, the team applied the detector system to nuclear resonant scattering experiments on ^{57}Fe (first excited level: 14.4 keV, half-life: 98 ns) using synchrotron radiation. The experiment was carried out at beamline BL09XU of SPring-8. A sample including ^{57}Fe and the detector were arranged along the incident beam axis for nuclear forward scattering. The detector counted the resonant γ-ray photons emitted from hyperfine splitting levels which were generated by surrounding electronic states. By using this system with MCS, information on material properties of the sample was successfully obtained from data recorded at each pixel of the detector as the time distribution of the γ-ray counts using 1 ns sampling.

5-3 Auger-Electron Detector System for Depth-Resolved X-Ray Magnetic Circular Dichroism (XMCD)

The group working for beamline BL-16A has been preparing a multi-anode MCP detector system, which has an angle-resolution and a fast digital data read-out of 30 channels, instead of the system consisting of a CCD and a fluorescence screen. In 10-Hz polarization switching of the insertion devices installed in BL-16A, the new MCP system improved the S/N ratio and the dynamic range of output counts in XMCD measurements. In FY2013, tests of data acquisition at a count rate of more than 10^7 s^{-1} per channel were conducted using an improved frontend board.