Development of High-energy-resolution Display-type Photoelectron Spectrometer for Microanalysis II

Hiroshi Daimon[a], Hiroyuki Matsuda[a], Fumihiko Matsui[a], Laszlo Toth[a], Makoto Morita[a], Satoshi Kitagawa[a], Tomohiro Matsushita[b]

[a]*Nara Institute of Science and Technology (NAIST), 8916-5 Takayama, Ikoma, Nara 630-0192, Japan*
[b]*Japan Synchrotron Radiation Research Institute (JASRI), SPring-8, 1-1-1 Koto, Sayo, Hyogo 679-5198, Japan*

Two-dimensional photoelectron intensity angular distribution (2D-PIAD) at several hundred eV provides fruitful information about atomic structure and electronic structure. Recently, the atomic stereo microscope [1] and the photoelectron holography were developed to measure three-dimensional atomic structure of bulk, surface or around impurity. Efficient measurement of 2D-PIAD can be made by a display-type spherical mirror analyzer [2]. This apparatus can measure angular distributions over the angular cone of ±60° at a time. On the other hand photoelectron emission microscope (PEEM) is remarkably developed recently, which offers much information of small area of surface. Although PEEM can measure 2D-PIAD at around 30 eV, it cannot measure it at several hundred eV because the acceptance

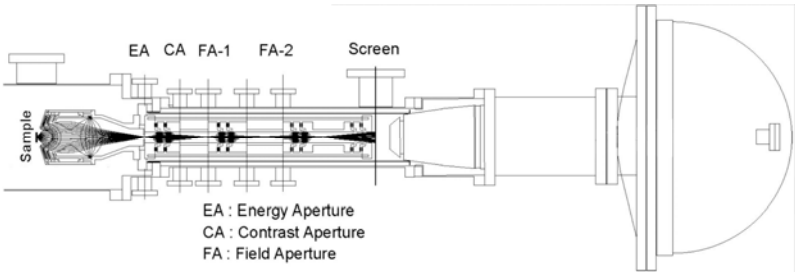

Fig. 1 Display-type Ellipsoidal Mesh Analyzer (DELMA).

angular cone becomes about ±15° at several hundred eV. Then, if an electron spectrometer having both functions of photoelectron microscope and 2D-PIAD, one can open a new research area. Therefore, we have developed a new system containing a wide acceptance angle electron lens (WAAEL) [3], a lens system, and a concentric hemispherical analyzer (CHA) as shown in Fig. 1. WAAEL utilizes an ellipsoid mesh electrode to remove the spherical aberration, and it can accept the electrons in angular cone of ±60°. WAAEL was utilized for hard X-ray photoelectron spectroscopy (HAXPES) to overcome the small photoionization cross-section in the hard- x-ray photon energy region [4]. This apparatus can display a magnified sample image and the angular distribution from a selected area on the screen in Fig. 1 [5]. The lens system controls the image formation (imaging mode and diffraction mode) and by changing the lens voltages and by selecting energy aperture EA, contrast aperture CA, and field aperture FA in Fig. 1. This new spectrometer is called DELMA (Display-type Ellipsoidal Mesh Analyzer) has been tested [6-8] at the free port of BL07LSU in SPring-8, and a new result of poli-Si is shown here.

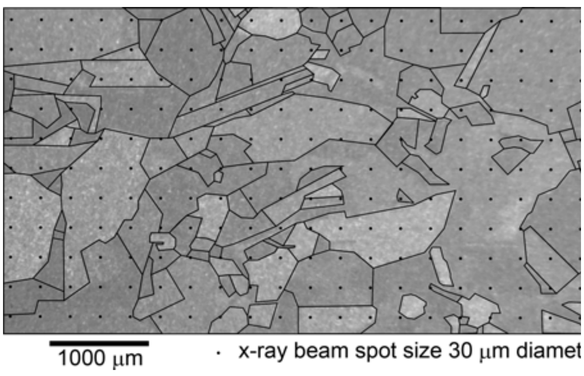

Fig. 2 Optical micrograph of poli-Si.

Figure 2 shows an optical photograph of poli-Si wafer which is utilized to inexpensive solar cell. This wafer was made by cast method. We can see crystal boundaries by the difference of reflectivity. The orientation difference between the neighboring crystals is important for the electric conductivity. Hence the determination of crystal orientation of each crystal is important to improve the efficiency of solar cell.

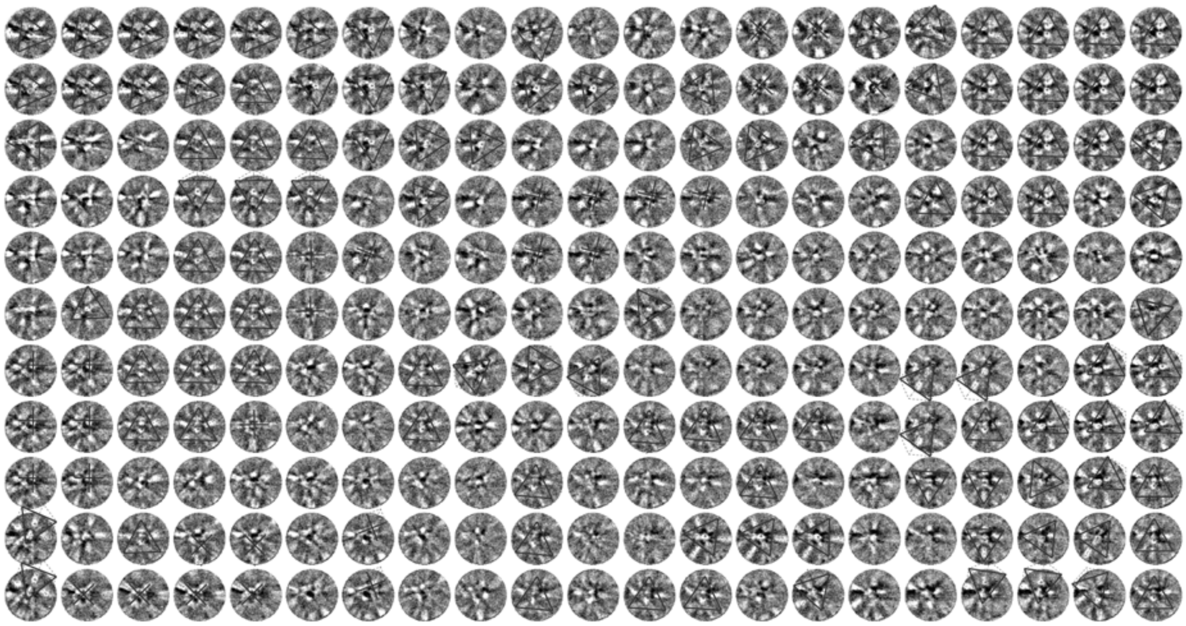

Fig. 3 Small area photoelectron diffraction patterns from 231 points on poli-Si surface.

Sample was annealed at 800 ℃ to remove surface oxide. Photons of 803 eV are focused to 30 μm on the surface. Figure 3 shows small area Si 2p photoelectron diffraction patterns from poli-Si surface. Totally 231 points were measured in 3mm×6mm region by 30 μm step. These 231 points correspond to the dots in Fig. 2. The center of each pattern corresponds to surface normal direction and peripheral is ±50°. It was found that the most abundant orientation was [111] and the second is [001] as shown in Fig. 4. This analysis of crystal orientation can also be made by using EBSD (electron back scattering diffraction) method, but the present method not only reveal structural information but also produce electronic information because this method is based on photoelectron spectroscopy. In this way we succeeded in obtaining photoelectron diffraction pattern from small area.

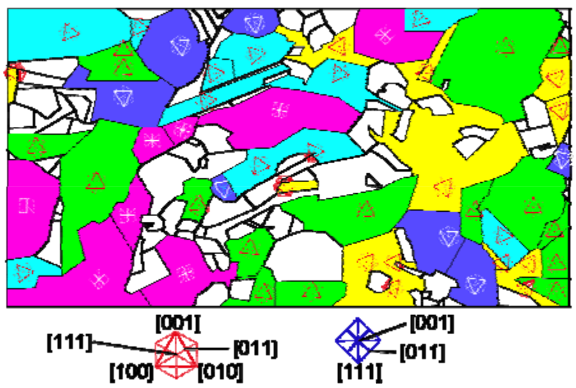

Fig. 4 Orientation of each crystal.

References

[1] H. Daimon: Phys. Rev. Lett. 86, 2034 (2001).
[2] H. Daimon: Rev. Sci. Instrum. 59, 545 (1988).
[3] H. Matsuda et al.: Phys. Rev. E 71, 066503 (2005); Phys. Rev. E 74, 036501 (2006); Phys. Rev. E 75, 046402 (2007).
[4] M. Kobata, et al.: Anal. Sci. 26, 227 (2010).
[5] H. Daimon, H. Matsuda, L. Toth and F. Matsui: Surf. Sci. 601, 4748 (2007).
[6] K. Goto, et al., e-J. Surf. Sci. Nanotech. 9, 311 (2011).
[7] L. Toth, et al., Nucl. Inst. Meth. Phys. Research Sec. A 648, S58 (2011).
[8] L. Toth, et al., Nucl. Inst. Meth. Phys. Research Sec. A 661, (1) 98 (2012).