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

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Recently, the atomic stereo microscope[1] and the photoelectron holography were developed to measure three-dimensional atomic structure of bulk, surface or around impurity. These experimental methods utilize two-dimensional photoelectron intensity angular distribution (2D-PIAD) at several hundred eV. When a commercial concentric hemispherical analyzer (CHA) is utilized, it is necessary to measure 2D-PIAD by sweeping the orientation of the sample, because the commercial CHA can accept the electron only in a small cone of about 10°×1°. Therefore, long measurement time is required. One breakthrough to this problem is a display-type spherical mirror analyzer[2]. This apparatus can measure angular distributions over the angular cone of ±60° at a time.

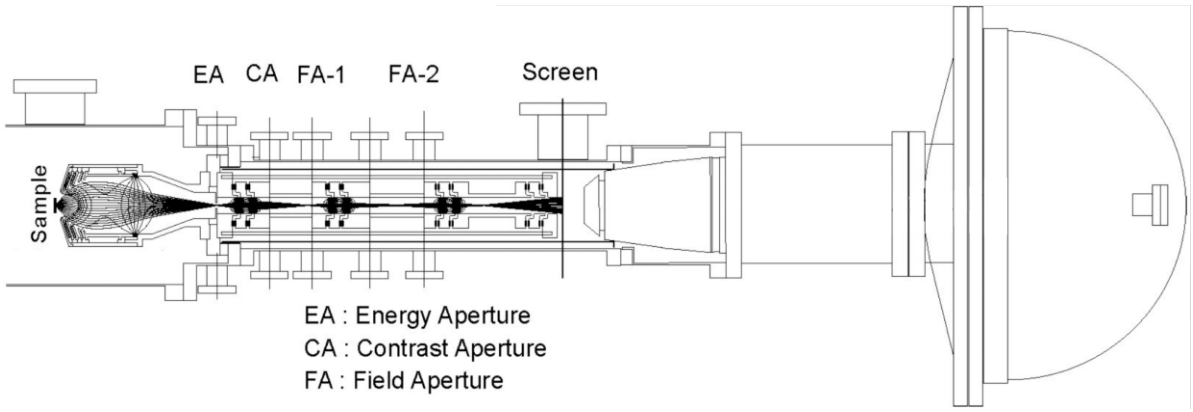

Fig. 1 WAAEL and lens system to realize PEEM with wide acceptance angle at high kinetic energies.

On the other hand photoelectron emission microscope (PEEM) is remarkably developed recently, which offers much information of small area of surface. Usual PEEM cannot measure 2D-PIAD at several hundred eV because the acceptance angular cone becomes about ±15° at several hundred eV. Then, if an electron spectrometer having both functions of photoelectron microscope and two-dimensional spherical mirror analyzer, 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 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.

In this experimental period this new spectrometer was tested at the free port of BL07LSU in SPring-8, and some basic performance was confirmed.

Energy resolution was tested by measuring the XPS from Ta 4*f* core level. The spin-orbit split of Ta $4f_{5/2}$ and Ta $4f_{7/2}$ was observed. The total energy resolution was estimated to be about 0.2% of the pass energy. This energy resolution is better than that of DIANA. We succeeded in improving the energy resolution of the analyzer for measuring the 2D-PIAD.

Angular distribution was tested by using a special tool which has many holes by 10° step. Figure 2 shows a kinetic energy dependence of one-dimensional photoelectron intensity mapping from Ta plate measured by CHA analyzer (Gammadata Scienta R4000). In this experiment, we kept the voltages of WAAEL and lens system constant. The mode of VG Scienta R4000 was transmission mode. In Fig. 2, we can see spike-shaped image, which is formed by the photoelectrons through the holes. We can see seven lines as are shown by red dotted lines, which correspond to ±30°. The Ta 4*f* peak at kinetic energy 680 eV has intensity much longer than ±30° up to around ±45°, which is the designed value. In this way we succeeded in confirming the function of angular distribution measurement up to ±45°.

The imaging function was tested by taking magnified image of mesh sample. SUS316 #100 was clearly magnified. We succeeded in confirming the function of magnifying image.

In this way we succeeded in confirming basic functions of new high-energy-resolution two-dimensional display-type photoelectron spectrometer for microanalysis [6].

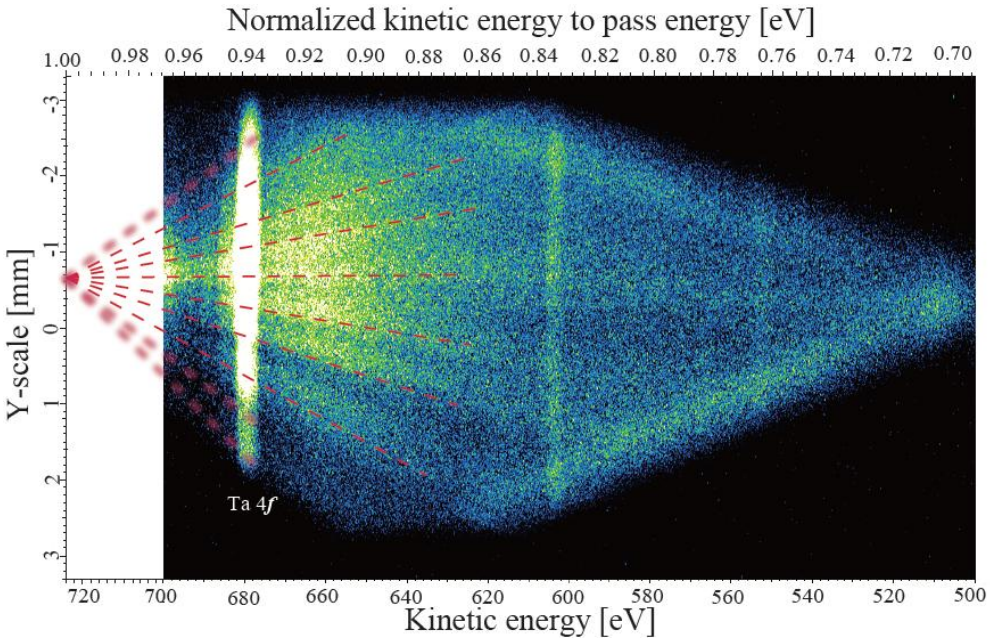

Fig. 2 Kinetic energy dependence of one-dimensional photoelectron intensity mapping measured by CHA analyzer.

References

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