New Display-type analyzer

for 3D Fermi surface mapping and atomic orbital analysis

N. Takahashi[1], F. Matsui[1,2], H. Matsuda[1,2] S. Shigenai[1], Y. Hirama[1]
K. Nakanishi[3], Y. Hamada[4], H. Namba[3] and H. Daimon[1-3]

1. Introduction

Photoelectron spectroscopy is a direct method for studying electronic structure of solids. Apart from conventional analyzers, Display-type spherical mirror analyzer (DIANA) [1][2], enables measurement of photoelectron intensity angular distribution (PIAD) in wide solid angle at once, without sample or analyzer rotating. PIAD measured by DIANA is the iso-energy cross section of valence band dispersion at certain k_z. Therefore by combining with energy tunable synchrotron radiation (SR) as the excitation source, 3D Fermi surface, that is the most important information to understand properties of materials such as CDW superconductivity and electronic transport, can be obtained. Furthermore, configuration of atomic orbitals composing each band is deduced experimentally from PIADs excited by linearly polarized SR. Atomic orbital analysis is the essential key for the development of Orbitronics that is one of the latest frontiers of solid state physics as well as catalysis. In the case of investigation of surface electronic state, fast experiment is required, since some of surfaces are easily contaminated. DIANA can satisfy this demand, because typical acquisition time for taking one PIAD is less than 10 minutes. In other words, Fermi surface is measured for about 10 minutes by using DIANA.

Up to now, we have succeeded in 3D band mapping of graphite [3] and atomic orbital analysis of Cu [4]. However, it was hard to apply these methods to more complicated band dispersion due to the limited energy resolution of beam line and analyzer (⊿E/E = 1%). Hence, we are developing and installing New-DIANA with higher energy resolution at BL- 7.

---

[1]*Graduate School of Materials Science, Nara Institute of Science and Technology(NAIST) Ikoma, Nara*
[2]*CREST-JST*
[3]*Department of Physics, Faculty of Science and Engineering, Ritumeikan University, Kusatsu, Shiga*
[4]*SR Center Ritsumeikan University, Kusatsu, Shiga*

2. Improved points

Compared with old type of DIANA, New-DIANA has three improved points.

First, the design of obstacle rings, which is most important factor for energy resolution, was fully optimized. The number of obstacle ring electrodes to generate spherical electrical field, used as low-pass filter, was increased from 26 to 158. As a result, expected energy resolution (⊿E/E) of analyzer is 0.05%.

Second, size-variable aperture was newly developed for tuning angular resolution and transmission efficiency. Fig. 2 shows a size-variable aperture. The size is changed easily by a rotation driver.

Lastly an electronic gun equipped with DIANA for measurement of LEED was refined. By this new electronic gun, LEED, Auger electronic diffraction and scanning electron microscope (SEM) can be measured at microscopic region. Fig. 3 shows a photograph of New-DIANA.

3. Results and Discussion

At first, we measured angle-integrated energy distribution curve (EDC) of gold at room temperature (RT) as shown Fig. 4 and estimated the energy resolution of New-DIANA. The photon energy is 45 eV and slit size is 0.07 mm. Fermi edge appeared at the kinetic energy of 41.5 eV. After calculation of FWHM, We estimated that the total energy resolution is about 230 meV (⊿E/E=0.554 %).

Next, we measured PIAD of HOPG (Highly Orientated Pyloric Graphite), that is polycrystalline of graphite, to check the condition of the analyzer. Clean surface of HOPG was obtained easily by cleaving the surface and annealing.

Fig. 5 shows PIAD of valence band maximum state of HOPG. Fig 5 (a) is raw image and (b) is background removed image divided by different kinetic energy PIAD. Single crystal graphite has six-fold π-band around K point derived from p_z orbital. On the other hand, we obtained ring pattern. This is due to the summation of PIADs from different domains. Because of linearly polarized excitation, left and right parts of the ring appeared strongly. This data is consistent with theoretical simulation, indicating that the analyzer is property working. However, there exists an homogeneous background in raw data, which is to be removed through further fine tuning of the analyzer.

4. Conclusion

We developed and installed New-DIANA at BL-7. The design of obstacle ring was changed. A size variable aperture and new electronic gun for measurement of LEED, Auger electron diffraction and SEM were installed. PIAD of HOPG was measured and expected ring pattern was observed. But intensity of PIAD of HOPG was not flat, so we need to align the analyzer more. Energy resolution (⊿E/E) estimated by EDC of gold was greatly improved from 1 % to 0554 %.

5. Acknowledgement

We acknowledge Dr. Matsushita at Japan Synchrotron Radiation Research Institute (JASRI) for letting us use his software of the CCD camera and pass energy of analyzer controlling and data analysis.

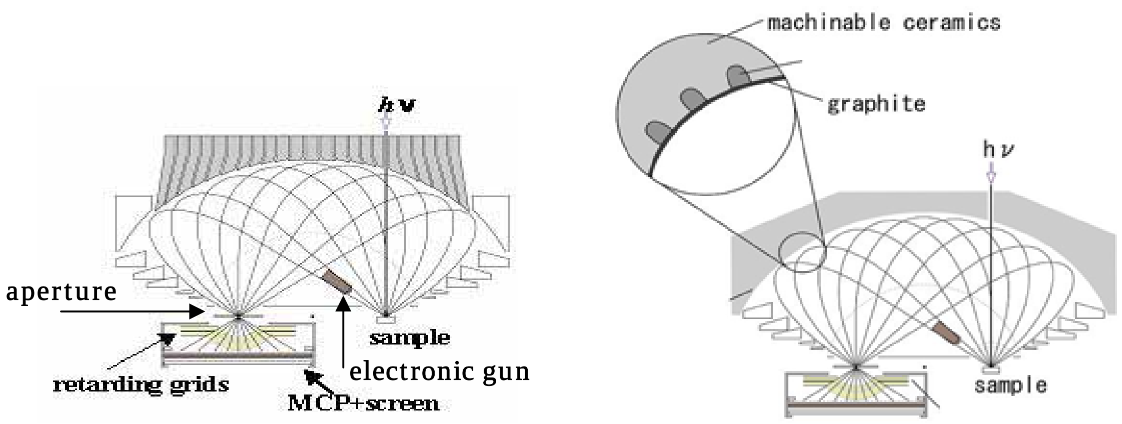
6. Reference

[1] H. Daimon, Rev. Sci. Instrum. **59**, 545 (1988)

[2] T. Nohno, H. Daimon et. at. Jpn. J. Appl. Phys. Vol. **42** (2003) 4752-4755

[3] F. Matsui et al., Appl. Phys. Lett., **81**, 2556 (2002)

[4] F. Matsui et al., Phys. Rev. B **72**, 195417 (2005)



(a) old type (b) new type

Fig. 1. Schematic diagram of old (a) and new DIANA (b).

Fig. 2. A size-variable aperture.

Fig. 3. A photograph of New- DIANA.

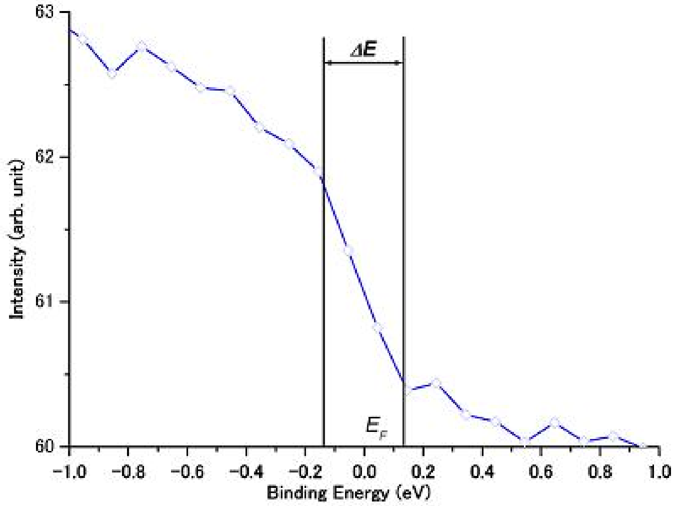


Fig. 4. Angle integrated energy distribution curve of gold at RT. Photon energy (hν) is 45 (eV) and retarding grid voltage is 200 mV. The energy resolution estimated from Fermi edge width is about 230 meV.

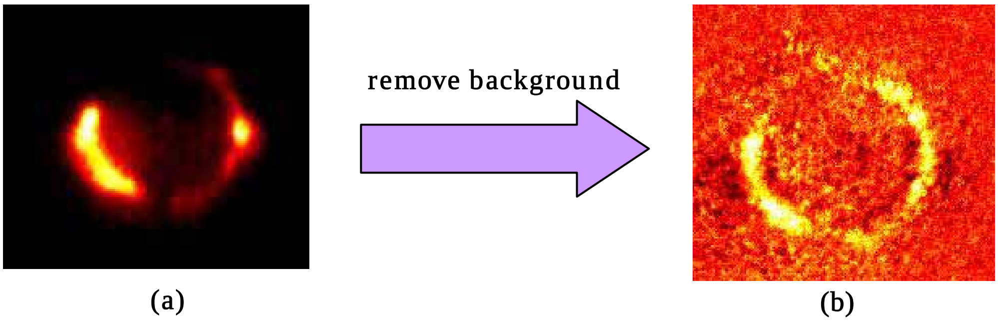


Fig. 5. PIAD of valence band maximum state of HOPG measured by New-DIANA. (a) shows a raw image and (b) shows a background removed image