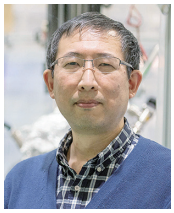
Photoemission Imaging in *k* and *r* Spaces

UVSOR Synchrotron Facility
Division of Beam Physics and Diagnostics Research



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Complete measurements of photoelectron, including three- dimensional spin degrees of freedom are challenging techniques for pioneering electron spin physics and spintronics. We are developing a new system that combines a photoelectron momentum microscope (PMM), two-dimensional spin filter, and a synchrotron light source. Our goal is to achieve reliable electronic structure analysis by complete photoelectron measurement of band dispersion and core levels, and link it to developments and applications of materials and devices.

1. Photoelectron Momentum Microscope

We have built a new PMM station for 3D momentum-resolved photoelectron spectroscopy with a microscopic field of view at the soft X-ray beamline BL6U of UVSOR. The details of the specification evaluation result are described elsewhere.[1] In brief, the energy, spatial, and momentum resolutions of the analyzer were estimated to be 20 meV, 50 nm, and 0.012 Å^{-1}, respectively. Samples can be cooled down to 8 K and heated up to 400 K.

A gold checkerboard pattern on a Si wafer imaged by a microscopy mode is shown in Figure 1. Elemental specific information is obtained by spectro-microscopy as shown in Figure 1(b) and (c). Figure 2 shows an example of 3D valence band dispersion imaging by a momentum mode.

With a photon energy range up to 800 eV covered by the BL6U, core-level excitation of a variety of important elements including C, N, O and transition metals is possible. Specific atomic sites and electronic states can be selectively characterized by the resonant Auger process. Resonant momentum-resolved photoelectron spectroscopy is a method unique to this station that opens the door to elemental- and orbital-selective valence band dispersion analysis.

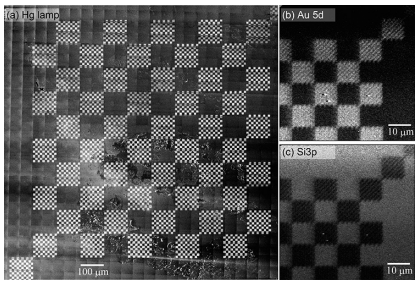

Figure 1. Real-space valence photoelectron images of a gold checkerboard pattern observed using (a) Hg lamp and (b)–(c) synchrotron radiation ($h\nu$ = 60 eV) as excitation.[2]

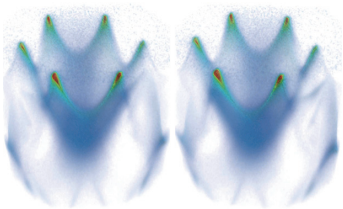

Figure 2. (a) Stereograph of valence band dispersion of graphite crystal surface. A parabolic π band with six Dirac points is imaged.

2. Original Analyzers towards Spin Imaging

Furthermore, we are aiming at highly efficient and comprehensive measurement of spin distribution as the final goal. *Omnidirectional photoelectron acceptance lens* (OPAL)[3] together with *Projection-type electron spectroscopy collimator analyzer* (PESCATORA)[4] enables photoelectron holography measurement of the full hemisphere. Moreover, we invented *Right angle deflection imaging analyzer* (RADIAN)[5] for spin vector analysis with ***k***/***r***-space resolution. We are expanding the MM system based on our original inventions.

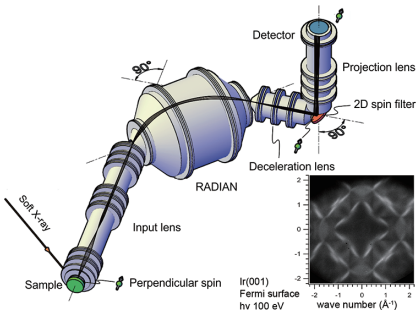

Figure 3. Schematic diagram of 3D-spin distribution projection analysis system.[5] Inset is the Fermi surface of the Ir(001) thin film for a 2D spin filter target measured by UVSOR-PMM.

References

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2) S. Makita, F. Matsui, *et al.*, *e-J. Surf. Sci. Nanotechnol.* **19**, 42 (2021).
3) H. Matsuda and F. Matsui, *Jpn. J. Appl. Phys.* **59**, 046503 (2020).
4) F. Matsui and H. Matsuda, *Rev. Sci. Inst.* **92**, 073301 (2021).
5) H. Matsuda and F. Matsui, *J. Electron Spectrosc. Relat. Phenom.* **245**, 147001 (2020).

Award

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