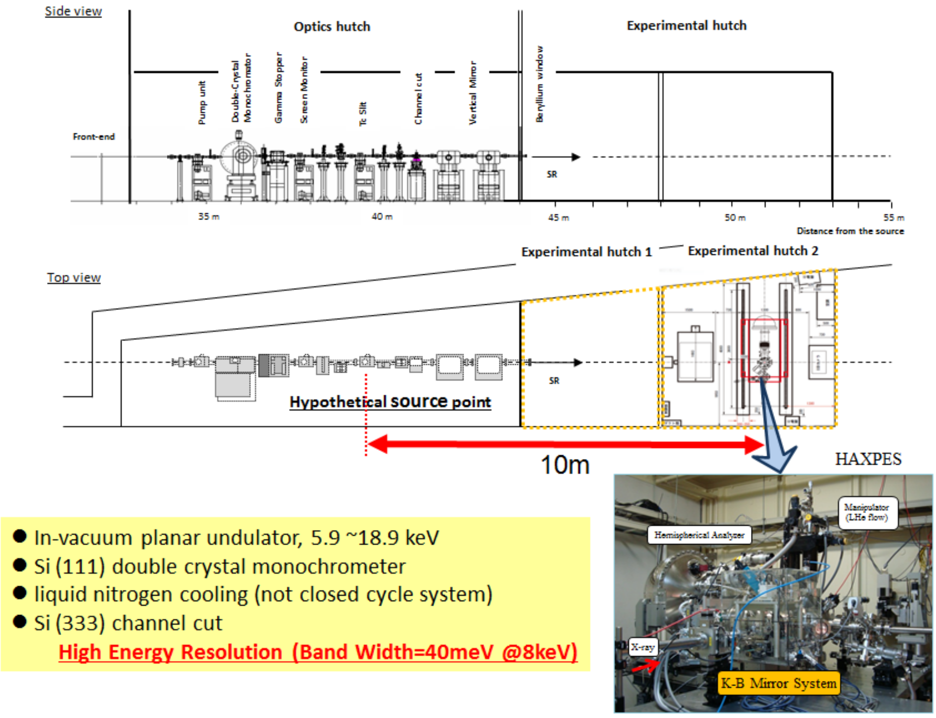
Wide angle-resolved Hard X-ray Photoemission Spectroscopy

BL47XU is an undulator beamline dedicated to promote the utilization of synchrotron radiation for industry. The light source of this beam line is a standard in-vacuum undulator in SPring-8 and the X-ray optics adopts a Si (111) direct LN_2 cooling double-crystal monochromator with tunable energy range of 6-35 keV. Two Rh-evaporated mirrors (70 cm length, reflection direction is horizontal) are placed in the most downstream part of the optics hutch to eliminate harmonics. The mirrors can be bent for horizontal beam focus. A Si (111) channel-cut monochromator is placed between the monochromator and the mirrors to get finer energy resolution of incident X-ray for hard X-ray photoemission spectroscopy (HAXPES). The HAXPES systems at this beam line are equipped with VG-SCIENTA hemispherical R-4000 photoelectron energy analyzers as shown in Fig. 1.

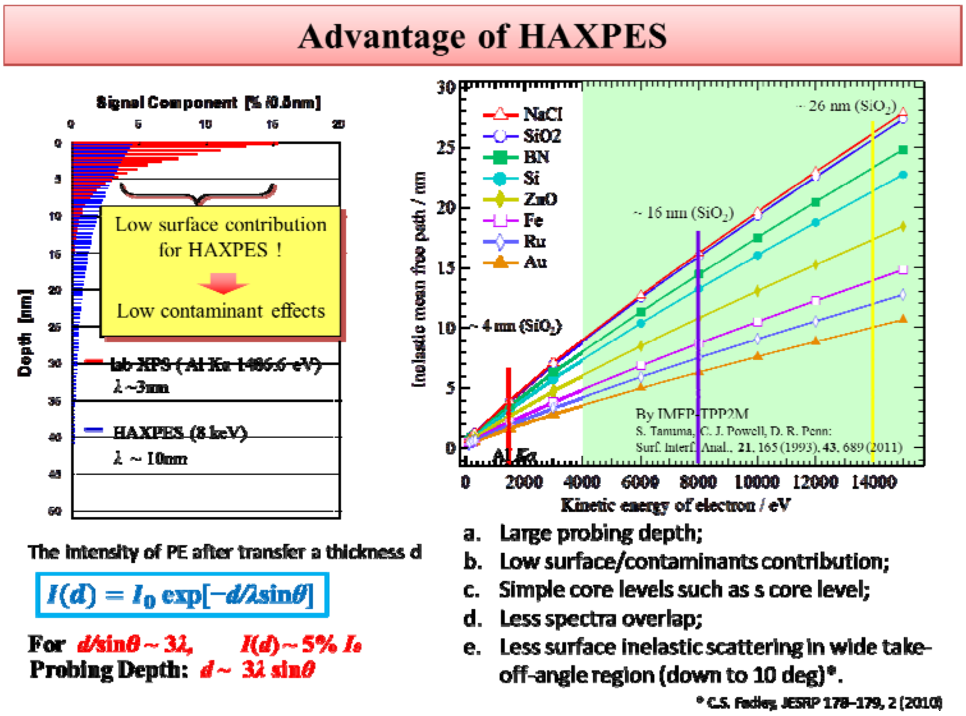


- In-vacuum planar undulator, 5.9 ~18.9 keV
- Si (111) double crystal monochrometer
- liquid nitrogen cooling (not closed cycle system)
- Si (333) channel cut

High Energy Resolution (Band Width=40meV @8keV)

Fig.1 The beam line of BL47U

One of the advantages of HAXPES compared to conventional photoemission spectroscopy is its potential for bulk sensitive measurements in a non-destructive manner. As we know that the probing depths of PES are determined by the inelastic mean free paths (IMFP) of photoelectrons within the solid. The conventional PESs (ultraviolet photoemission spectroscopy and X-ray photoemission) usually utilize radiation from He discharge tube, synchrotron radiation as well as Al or Mg-anode X-ray tube with energy range of several-ten to several-hundred eV. Their obtained data are strongly dependent on the surface condition of the sample because detection depth is shallow due to a short IMFP of photoelectrons inside the solid material. Therefore, it has been difficult to observe bulk electronic states that contribute to the solid-state properties (as shown in Fig. 2). One of the solutions for this is so-called depth-profiling with sputtering. However there is a concern about property changes during the sputtering process. The 3rd generation synchrotron radiation of SPring-8 with undulator light source enable us to use high brilliant (photon flux ~10^{11} photons/sec) hard X-ray (6-8 keV) for high excitation energy photoemission spectroscopy. The large detection depth of several tens of nanometers (typically, as around 20 nm for 8 keV) is sufficient for the observation of bulk electronic states. Besides standard bulk-sensitive measurements, one can also get deeper core levels as well as a surface-to-bulk profile of electronic states in angle-dependent photoemission spectroscopy experiments where probing depth can be controlled by changing the detection angle of photoelectrons to the sample surface.



Advantage of HAXPES

Low surface contribution for HAXPES !

Low contaminant effects

The intensity of PE after transfer a thickness d

$$I(d) = I_0 \exp[-d/\lambda \sin\theta]$$

For $d/\sin\theta \sim 3\lambda$, $I(d) \sim 5\%\ I_0$

Probing Depth: $d \sim 3\lambda \sin\theta$

a. Large probing depth;
b. Low surface/contaminants contribution;
c. Simple core levels such as s core level;
d. Less spectra overlap;
e. Less surface inelastic scattering in wide take-off-angle region (down to 10 deg)*.

* C.S. Fadley, JESRP 178–179, 2 (2010)

Fig. 2 Advantages of HAXPES

The variable depth analysis of electronic properties provided by HAXPES has realized various applications both in basic and applied research fields. Recently, a wide angle-resolved hard X-ray photoemission spectroscopy using an objective lens has realized at BL47XU in SPring-8. The objective lens system originally developed to investigate the variable the depth profile at once without rotating the sample angle along the incidence X-ray. The aim of this course is to learn the principle of HAXPES and gain experience of measuring the core level photoemission spectra using the objective lens system with angular resolving capability. Participants will learn how we can realize wide angle-resolved HAXPES to study the depth analysis of electronic structures in buried interface layers.

On the practices at the BL47XU, we are planning to conduct the followings.

1. Explanation of the beamline optics of BL47XU.
2. Explanation of HAXPES measurement including of the objective lens system.
3. Sample preparation of typical buried layers.
4. Measurement.
5. Data analysis.