BL12XU
NSRRC ID

1. Overview

The beamline BL12XU is one of the two contact beamlines between the National Synchrotron Radiation Research Center (NSRRC, Taiwan) and Japan Synchrotron Radiation Research Institute (JASRI). BL12XU has an undulator source and two branches of the mainline and a sideline (see Fig.1). The mainline has been fully operational since 2001 and used by many domestic / foreigner scientists from Japan, Taiwan, Germany, USA and so on. Inelastic x-ray scattering (IXS) experiments were mainly performed in BL12XU and several other experiments such as high-resolution diffraction or coherent diffractive imaging were also carried out. In the side line, the careful performance test was made and a good performance was shown. Several experiments of hard x-ray photoemission spectroscopy (HAXPES) experiments were successfully conducted and the commissioning is now at the final stage.

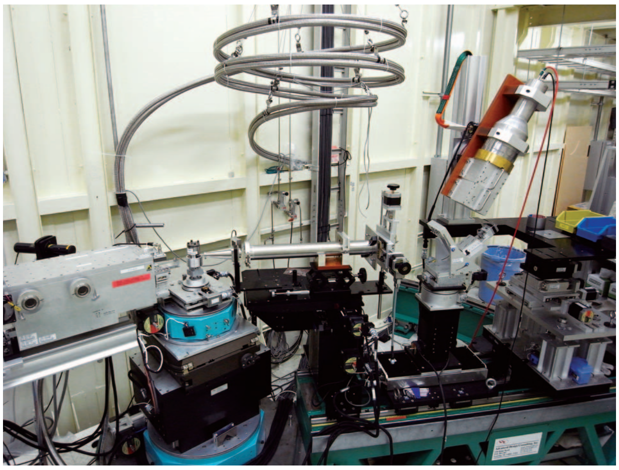

Fig. 2 FeS sample in diamond anvil cell, being measured by 20 keV spectrometer.

2. Mainline

2-1 Instrumentation

The resonant and nonresonant IXS spectrometers in the mainline are stably used. Electronic excitations are studied on various kinds of samples. In 2011, several improvements of the instrumentation and a performance test were made.

- **Strip detector:** A new strip detector having 32 strips of 125 μm width was tested, aiming to enhance the energy resolution of the resonant x-ray inelastic spectrometer. This detector was a simpler version of the one having 15 elements that was tested in 2010. The resolution was successfully improved with a high count-rate. The *dd* excitations in CoO were measured with this detector.
- **20 keV IXS spectrometer:** Satisfactory performance was proved during a series of tests. The spectrometer was applied to real experiments, such as EXAFS-type studies on magnesium silicate glass and XANES-type studies on iron sulfide (Fig.2). A discernible change of a local atomic structure was observed in the former while the spin transition in the latter.

2-2 Experiments

In 2011, we had 9 experiments of non-resonant IXS, 3 of resonant IXS, 2 of non-resonant x-ray emission spectroscopy, 11 of resonant x-ray emission spectroscopy, 4 of coherent diffractive imaging, 3 of high-resolution diffraction, and 2 of the optics development. An interesting example is introduced below.

- **Strong coupling between 4*f* valence instability and 3*d* ferromagnetism in $Yb_xFe_4Sb_{12}$:** The relationship between Fe 3*d* ferromagnetism and Yb 4*f* valency in $Yb_xFe_4Sb_{12}$ was studied. The x=0.88 sample shows a ferromagnetic order below 20 K while the x=1.0 sample stays paramagnetic down to 2 K. Yamaoka *et al*. [Phys. Rev. Lett. **107**, (2011) 177203.] found small increase

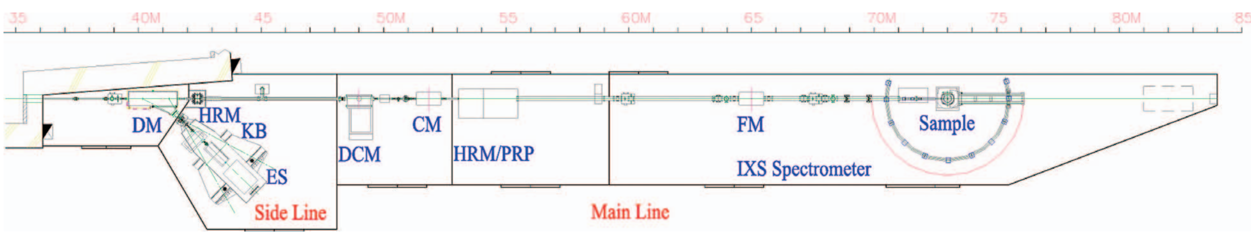

Fig. 1 Schematic diagram (top view) of the BL12XU: DM is a diamond monochromator for the sideline, DCM a double crystal monochromator for the mainline, CM a collimating mirror, HRM a high resolution (channel cut) monochromator, PRP a phase retarding plate, FM a focusing mirror, and IXS an inelastic x-ray scattering spectrometer.

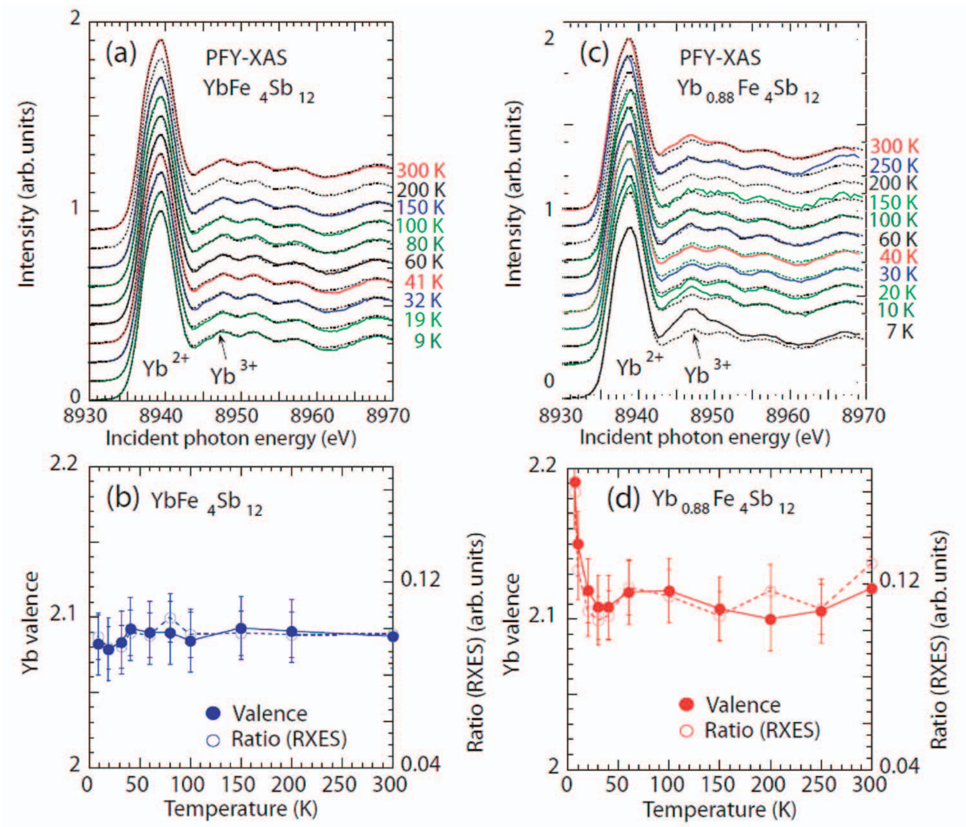

Fig. 3　PFY-XAS spectra (a) and derived valence number (b) of $YbFe_4Sb_{12}$ while PFY-XAS spectra (c) and derived valence number (d) of $Yb_{0.88}Fe_4Sb_{12}$ [Phys. Rev. Lett. **107**, (2011) 177203.].

of the valence number in the ferromagnetic sample while no such anomaly in the paramagnetic sample (see Fig.3). The strong coupling between the Yb 4*f* valence instability and the Fe 3*d* ferromagnetism was discussed as the possible origin.

3. Sideline

The major advantage of HAXPES is its large probing depth enabling measurement of electronic structure of the deep bulk and buried interface. These are not possible using conventional VUV and soft x-rays owing to small probing depth. We examined an interface case of a polar slab $LaAlO_3$ (LAO) on another non-polar slab $SrTiO_3$ (STO). It is found recently that the interface between these two non-magnetic wide band gap insulators becomes conductive, magnetic, and even superconducting. These peculiar observations have stimulated great interest on investigating the underlying physical reasons. Various models are proposed including electronic reconstruction and oxygen defect models. In order to avoid polar catastrophe in LAO the electronic reconstruction model assumes half amount of electrons transfer from the LAO-vacuum interface to the LAO-STO interface. This electron transfer converts half of the original Ti^{4+} to Ti^{3+} at the top layer of STO, and these transferred 2D electron gas (2DEG) are responsible for conduction. A previous HAXPES investigation found indeed evidence of Ti^{3+} in 2*p* core level photoemission in support of the electronic reconstruction model and the amount and distribution can be determined by changing the photoelectron emission angles. The signals are rather week especially at large off-normal emission geometries. We adopted a different approach by using grazing incidence x-rays near total external reflection with normal emission geometry as illustrated schematically in Fig.4. The x-ray field is confined primarily in the surface region incorporating the LAO slab and the top layers of STO. The confined field greatly enhances the Ti 2*p* photoelectron intensity from the interface. Fig.5(a) shows the measured Ti^{4+} $2p_{1/2}$ and $2p_{3/2}$ spectra at

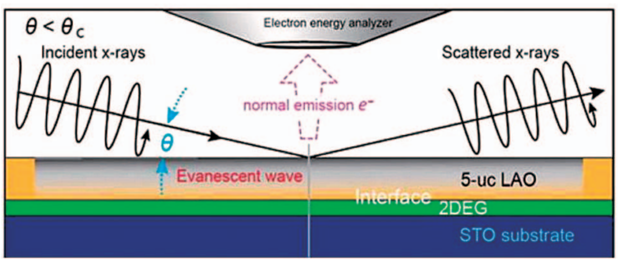

Fig. 4　Schematic geometry of photoelectron detection near normal emission with grazing incident x-rays near total external reflection.

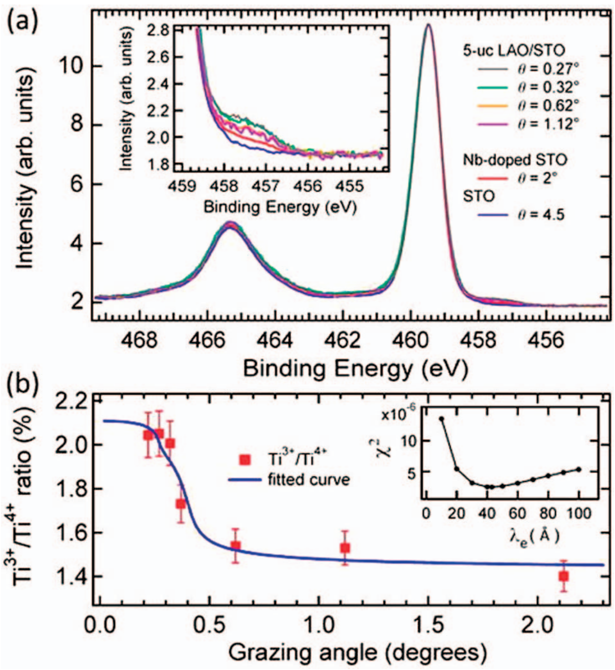

Fig. 5 (a) HAXPES spectra of Ti 2*p* with various grazing incident angles and samples. The inset shows enlarged region of Ti^{4+}. (b) Measured ratios of Ti^{3+}/Ti^{4+} compared to a model fit.

around 465.4 eV and 459.5 eV binding energies, respectively, of various incident angles and samples. The Ti^{3+} signal appears at about 2.1 eV smaller binding energy, or around 457.4 eV for $2p_{3/2}$. The inset shows an enlarged range. The ratio of Ti^{3+}/Ti^{4+} can be fit with a model as presented in Fig.5(b). Our results are in fair agreement with the electronic reconstruction model. The results are published in App. Phys. Lett. **99**, (2011) 262101 by Chu *et al*.

N. Hiraoka, H. Ishii, Y. F. Liao and K.-D. Tsuei
NSRRC, Taiwan