BL07LSU
The University-of-Tokyo Outstation Beamline for Materials Science

The soft X-ray undulator beamline, BL07LSU, was constructed by Synchrotron Radiation Research Organization [1], the University of Tokyo, at the long-straight section of SPring-8 and devoted to joint-researches with domestic and international researchers since 2009B. In this article, we report status of the beamline and introduce selected achievements at the experimental stations.

1. Undulator beamline

The high-brilliant soft X-ray undulator beamline, SPring-8 BL07LSU, generates the synchrotron radiation beam of (1) hv: 250-2000eV, (2) E/ΔE: > 10,000, (3) spot-size: < 10μm（zone-plate: 70nm）, (4) flux: 10^{12}photons/s, and (5) variable light polarization. Since 2012B, the beamline offers continuous polarization switching at a frequency of 13 Hz for user experiments at the end-stations.

2. Experimental stations

There are currently four different end-stations at the beamline: 1) time-resolved soft X-ray (TR-SX) spectroscopy, 2）3D nano-ESCA, 3） Ultrahigh resolution soft X-ray emission spectroscopy (HORNET), and 4) free-port. All the stations are opened for users. Here, two achievements are introduced [2,3].

2-1 Free-port station: Ambient-pressure X-ray photoelectron spectroscopy (AP-XPS)

Hydrogenation of CO_2 on zinc-deposited Cu(997) surface was investigated by ambient-pressure X-ray photoelectron spectroscopy (AP-XPS) as a model system of methanol synthesis on Cu-ZnO catalysts [1]. In the presence of 0.8 mbar CO_2 and 0.4 mbar H_2 gases, hydrogenation products are not observed; only carbonate is formed on Zn-Cu(997) surface (Fig. 1(a)). On the other hand, addition of water in the feed gas leads to hydrogenation of CO_2 to formate at sample temperatures around 400 K, and the produced formate is observed at 473 K (Fig. 1(b)). This indicates that hydroxyl produced from dissociative adsorption of water is a source for the CO_2 hydrogenation, and the reaction intermediates formed from CO_2 was stabilized in the presence of the surface Zn atoms on the Cu substrate.

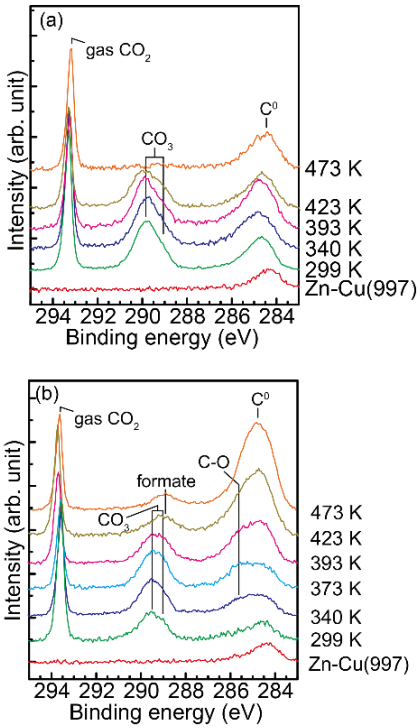

Fig. 1. C 1s AP-XPS spectra of the Zn(0.3 ML)-Cu(997) surface as a function of sample temperature in the presence of (a) 0.8 mbar CO_2, 0.4 mbar H_2, and (b) 0.8 mbar CO_2, 0.4 mbar H_2, and 0.05 mbar water.

2-2 HORNET station: resonant soft X-ray emission spectroscopy with MCD (RIXS-MCD)

RIXS and its MCD measurements (RIXS-MCD) in magnetic field were performed on a single-crystal half-metallic Heusler alloy, Mn_2VAl, in order to obtain the electronic-structure based evidence of its half metallicity by monitoring both V and Mn 3d states [3]. The delayed branching off in the V 3d-2p fluorescence peak from the elastic peak (Fig. 2(a, b)) demonstrated the nearly negligible V 3d partial density of states (PDOS) around the Fermi energy. The clear appearance of the t_{2g}-e_g RIXS of V reflects the rather localized character of the V 3d states. Under the Mn *L*-edge excitation, on the other hand, the RIXS-MCD spectra were dominated by the fluorescence peaks showing a clear magnetic circular dichroism with noticeable excitation photon energy dependence (Fig. 2(c, d, f)).

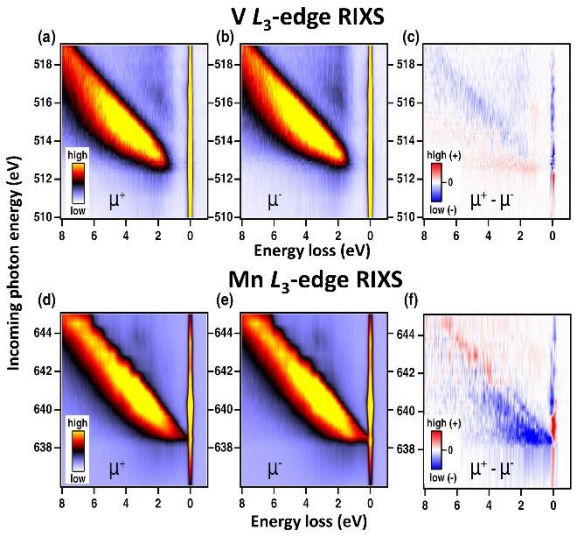

Fig. 2. (a-c) V L_3-edge and (d-f) Mn L_3-edge $h\nu_{in}$-dependent RIXS-MCD intensity maps of Mn_2VAl in a magnetic field of 0.25 T.

Compared with the theoretical prediction of the RIXS spectra based on the density-functional-theory band structure calculation, an itinerant, spin-dependent character of the Mn 3d states and decays of the Mn 2p core states are confirmed in consistence with the half-metallicity of the Mn 3d states.

The sign and the shape of the RIXS-MCD are qualitatively reproduced in consistence with the DFT calculations and confirmed the absence of the up-spin Mn 3d PDOS at the Fermi level, demonstrating the half-metallicity of the Mn_2VAl Heusler alloy. Thus, the bulk sensitive RIXS studies under external magnetic field are revealed to be essential to examine the detailed electronic structures of various Heusler alloys and family materials.

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References:

[1] http://srro.u-tokyo.ac.jp/

[2] T. Koitaya, S. Yamamoto, Y. Shiozawa, Y. Yoshikura, M. Hasegawa, J. Tang, K. Takeuchi, K. Mukai, S. Yoshimoto, I. Matsuda, and J. Yoshinobu, CO_2 Activation and Reaction on Zn-Deposited Cu Surfaces Studied by Ambient-Pressure X-ray Photoelectron Spectroscopy, ACS catalysis **9**, 4539 (2019).

[3] R. Y. Umetsu, H. Fujiwara, K. Nagai, Y. Nakatani, M. Kawada, A. Sekiyama, F. Kuroda, H. Fujii, T. Oguchi, Y. Harada, J. Miyawaki, and S. Suga, Half-metallicity of the ferrimagnet Mn_2VAl revealed by resonant inelastic soft x-ray scattering in a magnetic field, Phys. Rev. B **99**, 134414 (2019)