HiSOR, BL-1, BL-9A / SPring-8, BL-25SU

Fermi surface of chiral magnet $Yb(Ni_{1-x}Cu_x)_3Al_9$ observed by ARPES

Y. Tanimoto[a], M. Sugimoto[a], R. Kamimori[a], Y. Nakashima[b], H. Sato[c], K. Yamagami[d], M. Arita[c], S. Kumar[c], K. Shimada[c], S. Nakamura[e], S. Ohara[e]

[a]*Graduate School of Advanced Science and Engineering, Hiroshima University, Higashi-Hiroshima 739-8526, Japan*
[b]*Faculty of Science, Hiroshima University, Higashi-Hiroshima 739-8526, Japan*
[c]*Hiroshima Synchrotron Radiation Center, Hiroshima University, Higashi-Hiroshima 739-0046, Japan*
[d]*Japan Synchrotron Radiation Research Institute, Sayo 679-5148, Japan*
[e]*Graduate School of Engineering, Nagoya Institute of Technology, Nagoya 466-8555, Japan*

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Trigonal $YbNi_3Al_9$ has a chiral crystal structure belonging to space group of *R*32 (No. 155) and is of interest as the first chiral magnetic alloy discovered in 4*f* electron compounds [1]. The localized Yb 4*f* spins are magnetically ordered below T=3.4 K, ferromagnetic in the *c*-plane, and exhibit left-handed or right-handed helimagnetism with propagation vector $\boldsymbol{q}$=(0, 0, 0.8) [2]. Substitution of Ni with Cu significantly alters the magnetic interaction and shortens the helical propagation vector to $\boldsymbol{q}$=(0, 0, 0.4) for $Yb(Ni_{0.94}Cu_{0.06})_3Al_9$. Spin-polarized conduction electrons are thought to be responsible for this phenomenon. In this study, we have performed vacuum ultraviolet and soft x-ray angle-resolved photoemission spectroscopy (VUV-ARPES and SX-ARPES) on $YbNi_3Al_9$ and $Yb(Ni_{0.94}Cu_{0.06})_3Al_9$ to observe the Fermi surface. The experiments were carried out at BL-1 and BL-9A of Hiroshima Synchrotron Radiation Center (HSRC), Hiroshima University for VUV-ARPES and at BL-25SU of SPring-8 for SX-ARPES. Single crystals used for the SX-ARPES measurements were synthesized by the flux-method [3].

VUV-ARPES revealed five hole-like Fermi surfaces around the $\bar{\Gamma}$ points and an electronic Fermi surface around the $\bar{K}$ point for $YbNi_3Al_9$ and $Yb(Ni_{0.94}Cu_{0.06})_3Al_9$. The Fermi surface of $Yb(Ni_{0.94}Cu_{0.06})_3Al_9$ is shrink compared to that of $YbNi_3Al_9$, although the feature is almost unchanged with the Cu substitution.

Figure 1(a) shows the SX-ARPES intensity plots of $YbNi_3Al_9$ along the $\bar{\Gamma}$-$\bar{M}$ directions of the surface Brillouin zone measured at $h\nu$=548 eV with circular-polarized light. Figure 1(b) shows the angle integrated spectrum. Two flat bands derived from the localized Yb^{2+} $4f_{7/2}$ states below the Fermi level (E_F) and Yb^{2+} $4f_{5/2}$ states at E_B=1.4 eV are observed. Two hole-like bands around the $\bar{\Gamma}$ point cross E_F at k_x=0.31 and 0.45 $Å^{-1}$. These two hole-like bands are clearly observed in the VUV-ARPES spectra measured at $h\nu$=24 eV with *s*-polarized geometry.

Figure 2 represents the Fermi surface of $YbNi_3Al_9$ measured at $h\nu$=450~652 eV with circular- polarized geometries. The horizontal and vertical axes are the wavenumbers k_x along $\bar{\Gamma}$-$\bar{M}$ direction of the surface Brillouin zone and k_z along the Γ-*Z* direction of the bulk Brillouin zone, respectively. A barrel-shaped Fermi surface the with the minimum k_x at the Γ point and the maximum k_x at the *Z* point is observed, as indicated by a black line. Inside it, in addition, we find another barrel-shaped Fermi surface. On the other hand, the Fermi surface observed around k_x=0.15 $Å^{-1}$(white line) appears to be a drum-shaped Fermi surface with the minimum k_x at the *Z* point and is closed between the Γ and *Z* points as indicated by the arrows. These Fermi surfaces are quantitatively consistent with the Fermi surfaces inferred from de Haas-van Alphen effect [4].

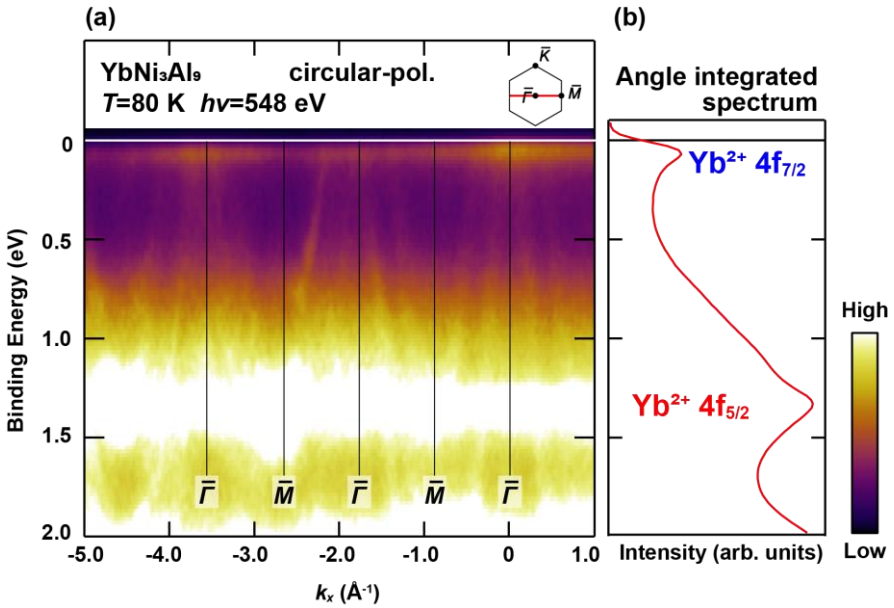

Fig. 1 (a) SX-ARPES intensity plots of $YbNi_3Al_9$ measured along the $\bar{\Gamma}$-$\bar{M}$ direction measured at $h\nu$=548 eV with circular-polarized light. (b) Angle integrated spectrum of (a).

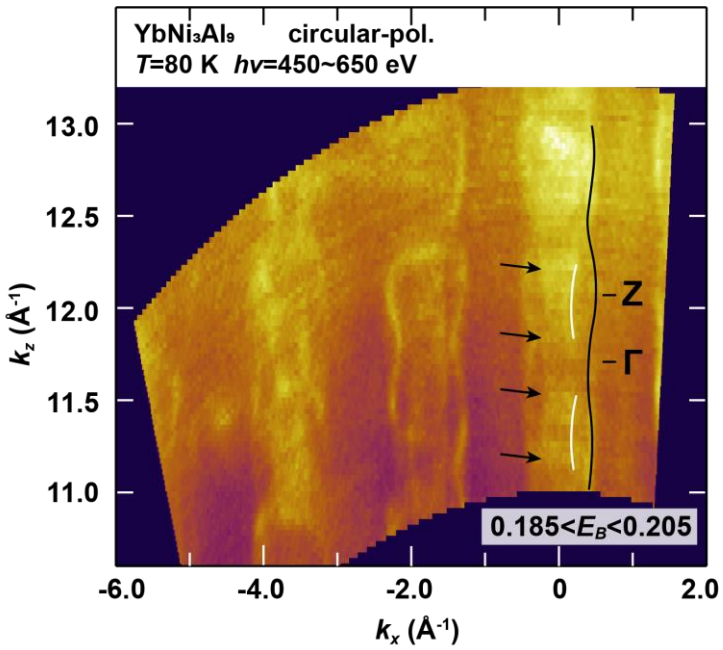

Fig. 2 Fermi surfaces of $YbNi_3Al_9$ obtained from SX-ARPES spectra measured at $h\nu$=450~652 eV with circular-polarized light.

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