Direct observation of Kondo resonance in a localized f-electron system

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A resonant angle-resolved photoemission spectroscopy (ARPES) in $CeNiGe_2$ were carried out to clarify the Kondo behavior in a local f-electron system such as Ce-based compounds showing magnetic ordering and geometrically frustrated triangle lattice, $Pr_5Ni_2Si_3$. The data reveal that a localized f-electron forms the large coherent peak near the Fermi level (E_F), the so-called Kondo resonance peak, which persists up to the high temperature of over 100 K. This indicates that a localized f-electron, which derives magnetic ordering or frustration, influences on physical properties through the competition between the localization by itself and the hybridization with conduction electrons

Keywords : Heavy-fermion system, Kondo resonance peak, ARPES

1. Purpose

Kondo effect is a crucial phenomenon to understand the strongly correlated electrons systems (SCESs), since it is commonly observed in several kinds of SCESs such as rare-earth heavy-fermion systems (Ce-, U-, and Yb-based compounds) and Mott-Hubbard systems (V_2O_3). However, the microscopic mechanism is poorly understood and remains as a puzzle until now. Especially, the Kondo effect in a very localized f-electron system has been debated because of the observation of the periodicity of f-electrons in Ce-based compounds showing magnetic ordering and Kondo-like behaviors in some Pr-based compounds ($PrFe_4P_{12}$, $Pr_2Ir_2O_7$, etc.) where Pr 4f electrons are considered to be too localized to form the Kondo-singlet with conduction electron through hybridization. Here, we clarify the Kondo effect in a localized f-electron system by directly observing a large coherent peak near E_F in photoemission measurements in $CeNiGe_2$, which has the low Kondo temperature (about 4 K) and shows the magnetic ordering in the ground state (T_N ~ 4 K).

2. Method

Ce 3d-4f resonant ARPES measurements have been performed at BL23SU using the continuous photon energy from 870 to 890 eV which corresponds to Ce 3d-4f threshold. Photon energies of on- and off-resonance were estimated to 886 and 879 eV, respectively, by X-ray absorption spectroscopy (XAS) measurements. Total energy resolution was about 120 meV at on-resonance photon energy. Measurement temperatures were 20, 60, and 120 K. Sample surfaces were prepared by *in situ* cleaving at 120 K under 2 X 10^{-8} Pa.

3. Result and Conclusion

The ARPES data show that a localized f-electron forms the large coherent peak near EF, the so-called Kondo resonance peak. They have momentum-dependence and persist up to the high temperature of over 100 K. This indicates that a localized f-electron, which derives magnetic ordering or frustration, influences on physical properties through the hybridization with conduction electrons from the low- to high-temperature. In addition, it is expected that our results play an important role to understand the fundamental physics of SCESs.