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High-Resolution Photoemission Study on Electronic Structure of Ce-compounds

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Using the high-energy-resolution photoemission spectroscopy, we studied the detailed electronic structure near the Fermi level (E_F) of Ce-based materials. The observed spectra near E_F exhibit the characteristic feature which governs the anomalous physical properties of the materials. We discuss the nature of 4*f* electrons in these compounds and possible models describing the anomalous physical properties based on the character of 4*f* electron.

High-resolution angle-resolved photoemission study on Ce-monopnictides

High-resolution angle-resolved photoemission has been performed on isostructural R-monopnictides (R = La, Ce, and U) to study the band structure near E_F, in particular the Fermi surface topology. For La and Ce-monopnictides, we clearly observed hole and electron pockets at the Brillouin-zone (BZ) center and boundary, respectively, in consistent with a semimetallic nature of these compounds. For CeSb, we found that the volume of both hole and electron pockets increases simultaneously when the temperature is lowered across the magnetic phase transition (T_N = 16 K) [**Fig. 1**]. The observed change of Fermi surface topology is in qualitative good agreement with the prediction of the *p-f* mixing model. These results indicate that the anisotropic temperature-dependent *p-f* mixing and the semimetallic band-structure plays an essential role in the complex magnetic phase transition of the Ce-monopnictides. For USb, on the other hand, we found that USb has a metallic band structure with the fully occupied Sb 5*p* bands in contrast to semimetallic CeSb which has the partially filled Sb 5*p* bands. This suggests that the magnetic phase transition of USb is not understood within the framework of the *p-f* mixing model.

High-resolution photoemission study on Kondo Insulator CeRhSb and CeRhAs

High-resolution photoemission spectroscopy has been performed on CeRhAs and CeRhSb to study the temperature-induced evolution of the "Kondo-insulator" gap. We have observed that a pseudogap opens at E_F in the electronic structure formed by conduction electrons at low temperatures while it is gradually filled with increasing temperature [**Fig. 2**]. The size of pseudogap is well scaled with the characteristic temperature (T_{max}) at which the magnetic susceptibility of each compound has a broad maximum and the temperature evolution is also dominated by T_{max}, indicating that the magnetic interaction plays an essential role in the pseudogap formation for both compounds. I also observed another pseudogap in 4*f*-derived density of states which is simultaneously formed through the hybridization between the 4*f* and conduction electrons near E_F. These results indicate that the hybridized nature of the electronic states at E_F is responsible for the energy-gap formation in Kondo insulators.

Resonant angle-resolved photoemission sturdy on heavy fermion $CeRu_2Si_2$

Resonant angle-resolved photoemission spectroscopy has been performed on a typical heavy fermion material $CeRu_2Si_2$ at the 4*d*-4*f* core thresholds to study the heavy 4*f*-band formation in the vicinity of the Fermi level. We clearly observed that the 4*f*-derived sharp peak at E_F shows strong amplitude variation with analyzer angle and rapid decrease in its intensity with increasing temperature. The momentum and temperature dependence indicates the narrow 4*f*-band formation at low temperature as predicted from the Kondo lattice model. However, the amplitude variation persists at least up to the high temperatures which are much higher than the Kondo temperature (T_K), while 4*f*-lattice derived bands are expected to exist only at T << T_K. The results suggest that the Kondo lattice effect is protracted well above the Kondo temperature.

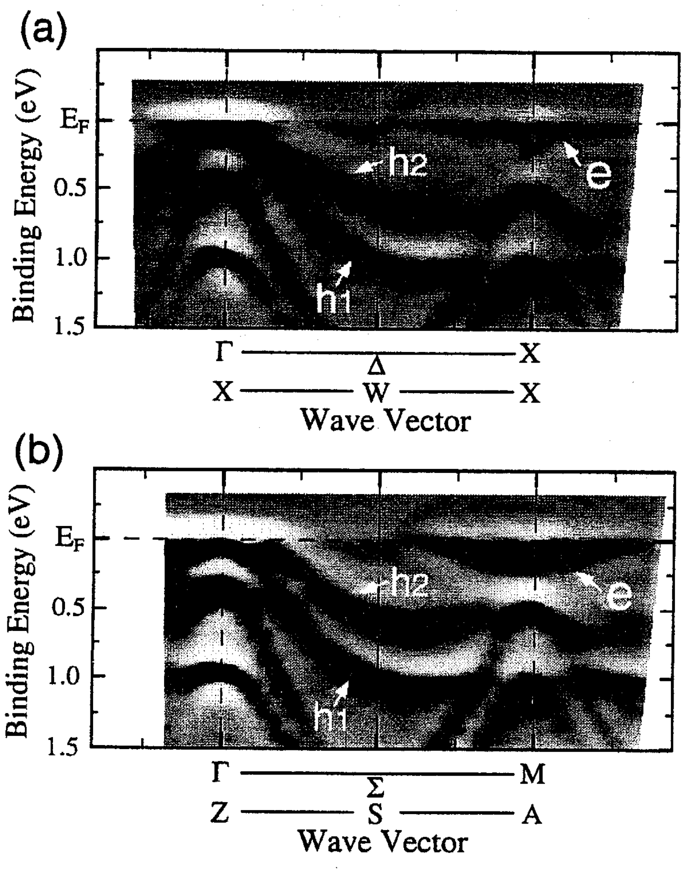

Fig. 1. Experimental band structure of paramagnetic (upper panel, T = 30 K) and antiferroparamagnetic (lower panel, T = 10 K) CeSb determined by the present high-resolution angle-resolved photoemission measurements. Dark parts correspond to the energy bands.

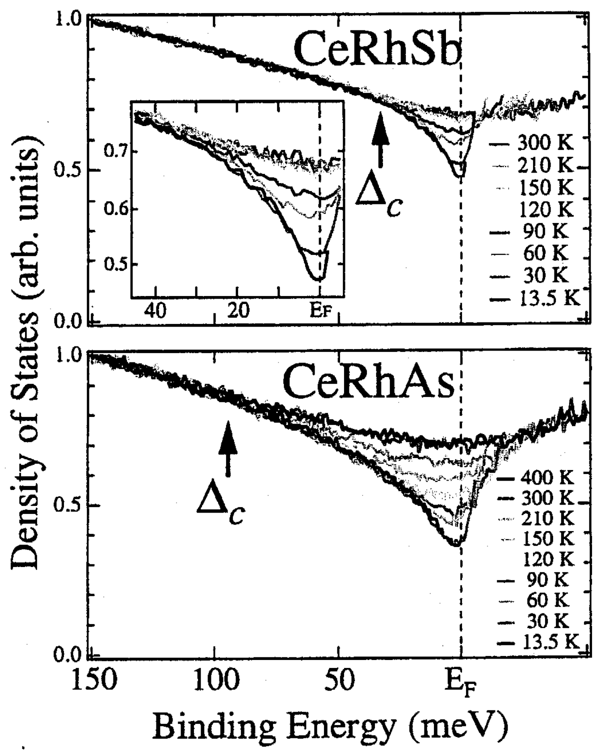

Fig. 2. Temperature dependence of spectral density of states near E_F of CeRhSb and CeRhAs. Insets show the expansion near E_F.