Research Group for Materials Physics for Heavy Element systems

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In heavy element systems, valence fluctuations, the Kondo effect, and the RKKY interaction compete with one another. Because of this, exotic behaviors such as quantum critical points, heavy fermions, non-Fermi liquids, anisotropic superconductivity and multipolar ordering appear when such competition is strong. Recently, it has become clear that these exotic behaviors for 5*f*-electron systems are different from those for 4*f*-electrons. This is because electrons with different spin and orbital character can coexist in 5*f* actinide systems, in contrast to the case of 4*f* electrons. By means of advanced experimental and theoretical approaches, our research group tries to clarify these exotic behaviors due to the “many-fold” character of both 4 *f* and 5*f* compounds, including transuranium.
In this mid-term project, we also try to reclaim new fields such as topological and spintronic aspects in these compounds.

Gradual localization of 5f states in orthorhombic UTGe ferromagnets [1]

Unusual domes of stable ferromagnetism (FM) appear in the magnetic phase diagrams of substituted orthorhombic UTGe compounds. Within this scope we have investigated FM dome in FM SC UCoGe substituted by Ru by XMCD and polarized neutron diffraction (PND). UCoGe is unique material where very unusual compensation of the antiparallel U and large Co moments was proposed by PND [2]. Our PND results carried

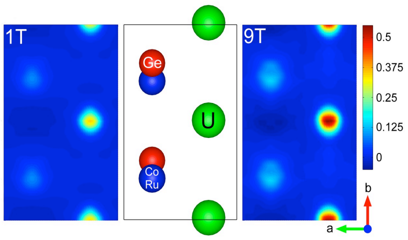

Fig.1 Magnetization density maps for $UCo_{0.88}Ru_{0.12}Ge$; projection onto the *a*-*b* plane in applied magnetic field 1 T and 9 T in $\mu_B/Å^2$ unit.

out on $UCo_{0.97}Ru_{0.03}Ge$ and $UCo_{0.88}Ru_{0.12}Ge$ single crystals showed parallel arrangement of both U and Co magnetic moment (Fig. 1). In addition, extrapolation of our results to the limit of pure UCoGe predicted identical arrangement. To confirm our controversial result, we have performed XMCD experiment at the JAEA beamline in SPring-8. The XMCD spectrum of $UCo_{0.88}Ru_{0.12}Ge$ indicates that the direction of the magnetic moment at U site is parallel to that at the Co site consistently with the PND experiments. We have also investigated the U magnetic moment components μ_L/μ_S ratio carrying indirect information about hybridization strength in the system. 1.9 and 2.3 values were found for $UCo_{0.97}Ru_{0.03}Ge$ and $UCo_{0.88}Ru_{0.12}Ge$, respectively. As these are smaller than 3.2 of the localized case, a strong hybridization is indicated here. We have recognized that FM dome is connected with weak localization of the U 5f states which strong itinerant character remains however still conserve. We found general rule for U 5f states character for all ferromagnetic UTGe compounds based on our results together with scaling of heat capacity data jumps at T_C. We also extrapolated value of μ_L/μ_S = 1.5 for UCoGe signalizing strong itinerant character of 5f states in this compound. Our results point to necessity of another deep research of FM state in UTGe compounds to understand unconventional SC in FM SC UCoGe and URhGe [1].

Itinerant-localized transitions in magnetic phases of the periodic Anderson model [3]

In heavy element systems, since the characteristic energy scale can be reduced by the strong electron correlations, external perturbations such as pressure and a magnetic field are able to change the Fermi-surface structure, which is an important ingredient to characterize a metal. In particular, such Fermi-surface reconstructions, called Lifshitz transitions [4], are observed in magnetically ordered states, such as in UGe_2.

To clarify the characteristics of the Lifshitz transitions theoretically, we have investigated magnetically ordered states of the periodic Anderson model, which is a typical model to describe the heavy element systems. Around half-filling, i.e., the electron number per site n is nearly two, we find an antiferromagnetic (AF) phase, and far away from half-filling, we find a ferromagnetic phase. For example, we show the AF moment m_{AF} as a function of the energy level of the f electrons ε_f at n=1.917 in Fig. 2. Inside the AF phase, a Lifshitz transition takes place, and the size of the AF moment changes there. In order to understand this transition further, we have also analysed the f-electron contribution to the Fermi surface by evaluating the momentum distribution function at the Fermi momentum. Then, we find that, in the large ordered-moment state (AF2), the f-electron contribution to the Fermi surface becomes small. This observation clearly shows that this Lifshitz transition is an itinerant-localized transition of the f electrons. For the ferromagnetically ordered case, we have reached a similar conclusion.

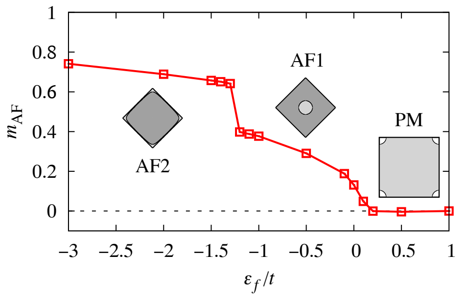

Fig. 2 AF moment m_{AF} as a function of ε_f. Fermi-surface structures in each state are also shown. There are two AF states, AF1 and AF2, and the transition between them is a Lifshitz transition.

References

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