

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 $5f$ -electron systems are different from those for $4f$ -electrons. This is because electrons with different spin and orbital character can coexist in $5f$ actinide systems, in contrast to the case of $4f$ 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 $4f$ and $5f$ compounds, including transuranium.

In this mid-term project, we also try to reclaim new fields such as topological and spintronic aspects in these compounds.

Itinerancy of the $5f$ electrons in actinide ferromagnets revealed by spin fluctuation theory [2]

The nature of the $5f$ electrons in actinide compounds is one of important topics from views point of the localization (or itinerancy) of the electrons. We have carried out analyses of magnetic data in 68 uranium, 7 neptunium and 4 plutonium ferromagnets with spin fluctuation theory developed by Takahashi[1]. We have determined the basic and spin fluctuation parameters of the actinide ferromagnets using experimental data obtained in our experiment as well as those from literatures.

Itinerant ferromagnets of the $3d$ transition metals and their intermetallics follow generalized Rhodes-Wohlfarth relation between p_{eff}/p_s and T_C/T_0 viz., $p_{\text{eff}}/p_s \propto (T_C/T_0)^{-3/2}$. Here, p_s , p_{eff} , T_C and T_0 are the spontaneous and effective magnetic moments, the Curie temperature and the width of spin fluctuation spectrum in energy space, respectively. The same relation is satisfied for

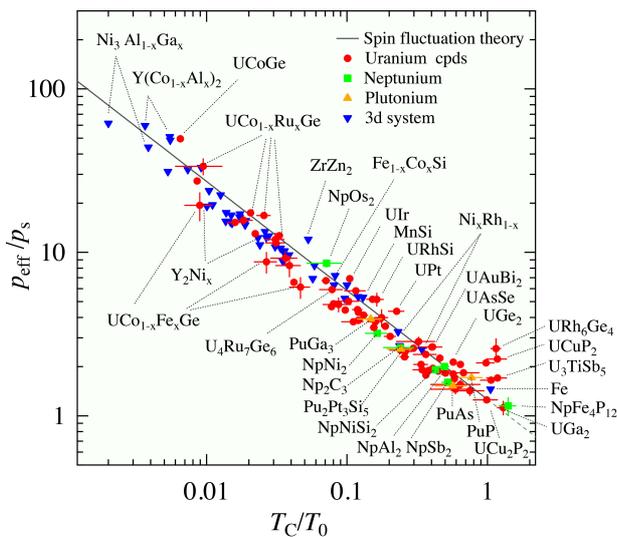


Fig. 1 Generalized Rhodes-Wohlfarth plot. Data points for uranium, neptunium, and plutonium compounds, and transition 3d metals are plotted as closed circles, squares, triangles and anti-triangles, respectively. Solid line is theoretical relation in the theory.

$T_C/T_0 < 1.0$ in the actinide ferromagnets as shown in Fig. 1. This suggests the itinerant nature of the $5f$ electrons in most of the actinide ferromagnets. Meanwhile, the relation is not satisfied in a few ferromagnets with $T_C/T_0 \sim 1.0$ that correspond to local moment system in the spin fluctuation theory. This deviation may be due to several other effects not included in the spin fluctuation theory such as crystalline electric field effect on the $5f$ electrons from surrounding ligand atoms.

Evolution of magnetism in $U(\text{Ir}_{1-x}\text{Rh}_x)\text{Ge}$ [3]

UIrGe , belonging to a big family of uranium compounds crystallizing in the orthorhombic TiNiSi -type structure, shows antiferromagnetic (AFM) order at low temperature. UIrGe is important in the context of magnetism and superconductivity in general. When Ir is substituted by isoelectronic Co or Rh, the magnetic ground state changes to ferromagnetic (FM), and superconductivity appears inside the FM state. It is widely believed that ferromagnetic fluctuation is the possible source of superconducting pairing interaction.

We studied evolution of magnetic ground state of UIrGe on substituting Ir by Rh. Figure 2 shows the magnetic phase diagram as a function of substitution in $U(\text{Ir}_{1-x}\text{Rh}_x)\text{Ge}$. For comparison, the result of $U(\text{Co}_{1-x}\text{Rh}_x)\text{Ge}$ is also shown [4]. It is remarkable to note that magnetic transition temperature changes drastically upon substitution in $U(\text{Ir}_{1-x}\text{Rh}_x)\text{Ge}$. We found that the AFM ground state switches to the FM state suddenly. Precise experiments near the critical concentration confirmed that AFM/FM transition is of first order. This demonstrates that FM and AFM are equally stable in this system and subtle crystallographic change alters the ground states. We also confirmed the absence of the superconductivity in AFM in UIrGe even using a cleanest single crystal sample [5]. The results strongly suggest the importance of ferromagnetic ground state for superconductivity in UCoGe and URhGe .

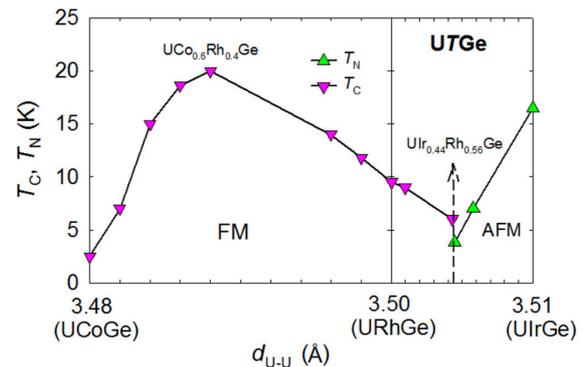


Fig. 2 Magnetic phase diagram of UIrGe and its alloys.

References

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