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MAGNETISM AND HEAVY FERMION SUPERCONDUCTIVITY IN CERIUM COMPOUNDS

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Abstract

The f electrons of rare earth and actinide compounds are typical in exhibiting a variety of characteristic properties including spin and charge orderings, spin and valence fluctu-ations, heavy fermions, and unconventional superconductivity [1, 2]. These are mainly competitive phenomena between the RKKY interaction and Kondo effect. The RKKY interaction enhances the magnetic ordering at T_{mag}, where spins of localized 4f electrons at Ce atoms exchange magnetically with spins of conduction electrons. On the other hand, the magnetic moment of the 4f electrons are screened by the spins of conduction electrons and reduced to zero via the many-body Kondo effect, which brings about the heavy fermion state below the Kondo temperature T_K. The relation between T_{mag} and T_K was expressed by Doniac as a function of $|J_{cf}|D(\varepsilon_f)$. Here, J_{cf} is the magnetic exchange interaction between the f electrons and conduction electrons, and $D(\varepsilon_f)$ is the electronic density of states at the Fermi energy ε_f. The Doniac phase diagram is a good guiding principle to reach the quantum critical point, which is defined as $T_{mag} \rightarrow 0$. This is realized experimentally by applying external pressure P, namely $T_{mag} \rightarrow 0$ for $P \rightarrow P_c$. Here we present two experimental results of Ce-based antiferromagnets $CeRhIn_5$ and $CeIrSi_3$. With increasing pressure, antiferromagnets $CeRhIn_5$ and $CeIrSi_3$ with the tetragonal structure are changed into heavy fermion superconductors. We clarified that a change of the electronic state from 4f-localized to 4f-itinerant occurs at P_c^* = 2:4 GPa in $CeRhIn_5$, revealing the first order phase transition. The cyclotron mass of conduction electrons diverses at P_c^*, forming the heavy fermion state. In $CeIrSi_3$ with the noncen-trosymmetric tetragonal structure, a huge upper critical field is obtained at P_c^* = 2:6 GPa: $H_{c_2}(0) \approx$ 450 kOe for H//[001]. These works were carried out with Rikio Settai, Tetsuya Takeuchi, Fuminori Honda, Kiyohiro Sugiyama, Yoshinori Haga, Etsuji Yamamoto, Tatsuma D. Matsuda, Naoyuki Takeiwa, and Hisatomo Harima.

[1] Y. Onuki and R. Settai : Low Temp. Phys. 38 (2012) 89-153.

[2] Y. Onuki and R. Settai : Non-centrosymmetric Superconductors, E. Bauer and M. Sigrist (eds.), Lecture Notes in Physics 847 (Spring-Verlag Berlin Heidelberg 2012) Chap. 3, 81-126.