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Physical properties of ternary cerium-based compounds CeRhX (X=Bi,Sb,As) and CePtX (X=Sb,As,P)

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Among rare-earth compounds, cerium-based systems have attracted much attention because of their variety of unusual physical properties, such as heavy-fermion behavior with an antiferromagnetic ground state, coexistence of heavy-fermion behavior and superconductivity, Kondo effect, valence-fluctuation, etc.

We have investigated the physical properties of ternary compounds CeRhX and CePtX systematically, where X is a pnictogen element. In CeRhX system, CeRhSb is Kondo insulator, a new type of Kodno lattice materials which have temperature dependent small energy gap. In CePtX system, CePtSb shows strong magnetic anisotropy. The purpose of this study is to elucidate experimentally the systematic change of the electronic state with variation of pnictogen.

◎ CeRhX-system (X=Bi, Sb, As)

We have synthesized CeRhBi and CeRhAs for the first time and found that they crystallize in the ε-TiNiSi type orthorhombic structure similar to CeRhSb.

The results of the measurements of the electrical resistivity, Hall constant, magnetic susceptibility and specific heat show that CeRhBi is a metallic dense Kondo compound with large electronic specific heat coefficient γ value of 620 mJ/K^{2}mol, whereas CeRhAs is a mixed-valent semiconductor with an energy gap Δ of 80 K, about 10 times larger than that of CeRhSb. In addition to this, all of the experimental results throughout the CeRhX series vary in the sequence CeRh (Bi-Sb-As). The shift of T_{max} , the temperature at which the resistivity show Kondo like peak, implies that the strength of the mixing between f-electrons and conduction electrons increases with variaton of pnictogen from Bi to As. Therefore, it is concluded that the mixing is the origin of the gap formation.

The pressure dependence of the resistance of CeRhAs show that the gap increases slightly below 1.5 GPa and Δ is estimated about 90 K at 1.5 GPa, which cause the same effect as substituting As for Sb, resulting in the volume contruction and increase of the energy gap. On the other hand, CeRhAs changes rapidly into dense Kondo like metal with increasing pressure above 1.5 GPa, which suggest that chemical and external pressure does not cause the same effect at high pressure.

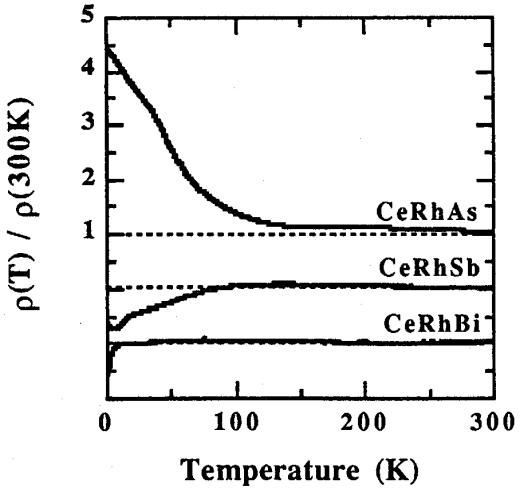

Fig.1 Electrical resistivity of CeRhX.

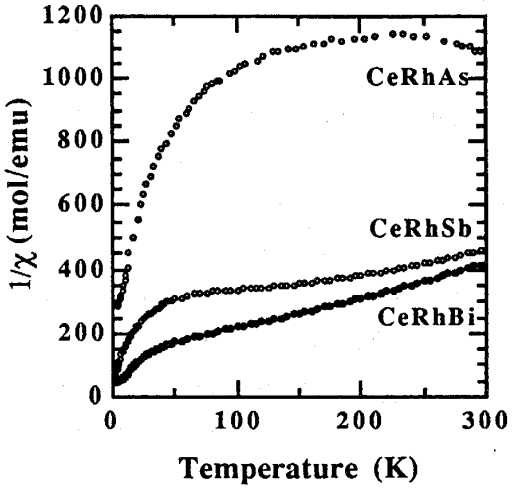

Fig.2 Reciprocal magnetic susceptibility of CeRhX.

◎ CePtX-system (X=Sb, As, P)

We have succeeded in the preparation of the single crystals of CePtSb, CePtAs and CePtP. The X-ray diffraction study shows that CePtAs and CePtP crystallize in the YPtAs type hexagonal structure and have two inequivalent Ce sites which are slightly different from that of CePtSb of hexagonal LiGaGe type.

All the compounds show the strongly anisotropic behaviors in transport and magnetic properties.

Magnetic phase transitions are observed at low temperature and the magnetic states vary strongly with variation of pnictogen. Especially an easy axis of magnetization is drastically changed from c-plane in CePtSb to c-axis in CePtP.

	Transition temperatur	Easy direction
CePtSb	$T_C = 4.5$ K	c-plane
CePtAs	$T_N = 1$ K	?
CePtP	$T_C = 3.1$ K $T_N = 1$ K	c-axis

Table 1 Magnetic properties of CePtX.

The magnetization curve of CePtSb below T_C shows that it is an usual ferromagnet. On the other hand, CePtAs and CePtP show more complicated behaviors. In both compounds, metamagnetic transition are observed in the magnetization curve below T_N. Moreorver, in CePtP below T_N, magnetization along the c-axis shows successive anomalies and is saturated to 2.14 μ_B above 3T.

The specific heat and the entropy of CePtAs and CePtP indicate that short range magnetic interacton persists at high temperature and the both may be suitably described as quasi-two-dimensional system.

From the calculation of a crystalline field of CePtX, using a point charge model with an ionic configuration of $Ce^{3+}Pt^{0}X^{3-}$, it is suggested that the variation of the magnetic anisotropy in these system arises mainly from the stabilization of J_Z=5/2 state due to contraction of c-axis with X from Sb to P.

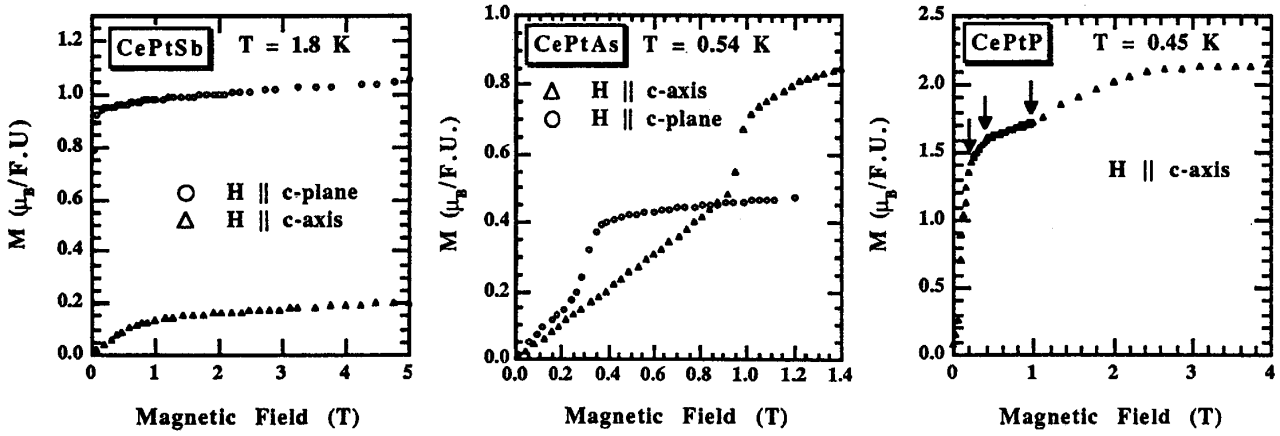

Fig.3 Magnetization curves of CePtX.

From the measurements of the electrical resistivity and the transverse magnetoresistance of non-f LaPtAs, it becomes clear that the strong anisotropy of ρ in CePtX system is not directly correlated with their magnetic properties and can be considered to have originated essentially from the shape of Fermi surface, which contains the open orbit along the c-axis. This is consistent with the result of the calculation of the band structure for LaPtAs by Harima.

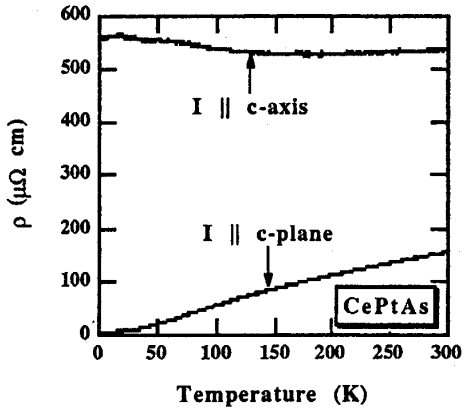

Fig.4 Electrical resistivity of CePtAs.