

琉球大学学術リポジトリ

ユウロピウム化合物の純良単結晶育成と特異な電子状態

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博士論文の要約

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We succeeded in growing high-quality single crystals of Eu compounds, and measured the electrical resistivity, magnetic susceptibility, high-field magnetization, specific heat, thermoelectric power, and de Haas-van Alphen (dHvA) effect, together with the electrical resistivity and thermoelectric power under pressures.

A simple canting magnetization was observed in Eu-divalent antiferromagnets of EuBi_3 , EuCd_{11} , and EuGa_4 , together with the previous result in EuPb_3 . We propose a relation between H_c and $T_N - \theta_p$, namely $H_c = (k_B/3\mu_B)(T_N - \theta_p)$, based on an antiferromagnetic two-sublattice model, where H_c is a critical field reaching $7\mu_B/\text{Eu}$, T_N is the Néel temperature, and θ_p is the paramagnetic Curie temperature. This is one of the characteristic features in the Eu-divalent electronic state.

We carried out the dHvA experiments for Eu-divalent compounds of EuBi_3 , EuSn_3 , EuPd_2 , EuCd_{11} , EuGa_4 , and EuRu_2P_2 . The angular dependences of the dHvA frequencies $F (=c\hbar S_F/2\pi e)$, where S_F is the maximum or minimum cross-sectional area of the Fermi surface, are well explained by the results of energy band calculations for the corresponding non-4*f* reference Sr compounds, for example SrBi_3 for EuBi_3 . We found a charge density wave (CDW) in EuGa_4 at pressures higher than about 1 GPa, for example $T_{\text{CDW}} = 160$ K at about 2 GPa. The similar CDW phenomenon was also observed at $T_{\text{CDW}} = 140$ K in EuAl_4 and $T_{\text{CDW}} = 243$ K in SrAl_4 at ambient pressure.

The Fermi surface properties of a typical Eu-trivalent compound EuPd_3 , which was obtained from the dHvA experiments, are well explained from the results of energy band calculations in the LDA+*Ud*-scheme. This means that the 4*f* orbitals are far separated from the Fermi level, and do not contribute to the conduction electrons.

We also clarified that the heavy fermion state in EuNi_2P_2 with an electronic specific heat coefficient $\gamma = 93$ mJ/(K²·mol) is based on the Kondo effect, revealing a characteristic shrinkage of the volume below about 100 K. The thermoelectric power also possesses a characteristic peak at 40 K. The Kondo temperature is thus determined as $T_K = 80$ K. Furthermore, we found the valence transition in EuGa_4 , EuNi_2Ge_2 , EuRu_2P_2 , and EuRhSi_3 at $P_c \approx 6, 2.3, 8,$ and 4 GPa, respectively, by measuring the electrical resistivity under pressure. After the valence transition, the electronic state of EuNi_2Ge_2 is almost the same as the typical trivalent electronic state of EuPd_3 , while the heavy fermion state is realized in EuGa_4 , EuRu_2P_2 , and EuRhSi_3 .

The divalent, trivalent, and heavy fermion states in Eu compounds are clarified in the present study.