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

（様式第３号）

論　文　要　旨

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High-quality single crystal growth and unique electronic states in Eu-based intermetallic compounds
（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）

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 $7\mu_B$/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_{CDW} = 160 K at about 2 GPa. The similar CDW phenomenon was also observed at T_{CDW} = 140 K in $EuAl_4$ and T_{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 γ = 93 mJ/(K^2·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 $P_c \simeq$ 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.

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