コバルト化合物の相関電子状態

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博士論文の要約

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論　文　題　目

「Correlated electronic states in Co-based intermetallic compounds (コバルト化合物の相関電子状態)」

In the present study, we mainly grew high-quality single crystals of Co-based transition metal compounds and clarified the Fermi surface and magnetic properties by measuring the electrical resistivity, specific heat, magnetic susceptibility, magnetization, and de Haas-van Alphen (dHvA) effect, together with the help of energy band calculations done by Prof. Hisatomo Harima, Kobe University. Co-3d electrons are studied from a viewpoint of correlations, which induce magnetic moments and itinerant conduction electrons with the relatively large masses.

First, we studied Fermi surface properties based on the dimensionality of electronic states for single crystals of V_2Ga_5, $CoGa_3$, $TiGa_3$, and $ZrGa_3$ ($ZrAl_3$) with different tetragonal structures. For example, a nearly one-dimensional plate-like Fermi surface is obtained in the band calculations for V_2Ga_5 with a flat tetragonal structure. The corresponding single crystal is of needle shape along the tetragonal [001] direction. Among these compounds mentioned above, the electronic specific heat coefficient γ in V_2Ga_5 is determined as γ = 16.7 mJ/(K^2·mol), which is compared with the theoretical one γ_b = 10.41 mJ/(K^2·mol). On the other hand, those of the other compounds are γ/γ_b = 1.01–1.08. The present relatively large ratio γ/γ_b = 1.60 in V_2Ga_5 is due to correlations of V-3d conduction electrons. Next, we studied a superconductor Zr_2Co with a slightly larger effect of correlations, namely γ/γ_b = 1.90 (γ = 22.5 mJ/(K^2·mol)). γ in the superconducting state is found to increase not linearly but as a function of $H^{1/2}$ up to magnetic fields close to the upper critical field H_{c2}, suggesting that Zr_2Co is the BCS superconductor with an anisotropic gap, for example. We grew high-quality single crystals of $SrCo_2P_2$ which is known to be a nearly ferromagnetic compound, very close to a well-known compound YCo_2. Thus, γ and the cyclotron effective masses m_c^* are large: γ = 40 mJ/(K^2·mol), $0.87 \leqq m_c^* \leqq 7.2 m_0$ (m_0: rest mass of an electron). The dHvA experiments are well explained by the results of the energy band calculations. We also grew single crystals of a ferromagnet $LaCo_2P_2$ and an antiferromagnet $CaCo_2P_2$ with an ordered moment of 0.4 and 0.3 μ_B/Co, respectively. For $LaCo_2P_2$, we also carried out the dHvA experiments. m_c^* of main dHvA branches are $(2–3)m_0$ which are compared with much larger cyclotron masses of $(3–7)m_0$ in a nearly ferromagnet $SrCo_2P_2$. Note γ = 19 mJ/(K^2·mol) in $LaCo_2P_2$, which is half of that in $SrCo_2P_2$.

From these experimental and theoretical results, Co-3d electrons in these compounds are itinerant and become main conduction electrons. Namely, the Fermi surfaces are mainly composed from Co-3d electrons. Correlations between these conduction electrons are reflected in the electronic specific heat, or the cyclotron mass. The effect of correlations is largest in the nearly ferromagnet $SrCo_2P_2$ and becomes weak when the electronic states deviate from this ferromagnetic instability, revealing a Pauli paramagnetic state in $CoGa_3$ and the ferromagnetically ordered state in $LaCo_2P_2$