Doctoral Thesis

Magnetic and Fermi Surface Properties in RCu_2Si_2 (R: Rare Earth), $Ce_2Pd_3Si_5$ and $Lu_2Rh_3Ga_9$

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Abstract

In the rare earth compounds, the Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction and the crystalline electrical field (CEF) effect play an important role in their electrical and magnetic properties. In some Ce- and Yb-based compounds, the hybridization between the localized $4f$-electrons and the conduction electrons leads to electronic instabilities associated with the Kondo effect, giving rise to a variety of characteristic features such as spin and valence fluctuations, heavy fermions and unconventional superconductivity. In the present thesis, we studied three kinds of compounds RCu_2Si_2 (R: rare earth), $Ce_2Pd_3Si_5$ and $Lu_2Rh_3Ga_9$, from a viewpoint of the crystal structure vs. the magnetic and Fermi surface properties.

RCu_2Si_2 compounds crystallize in the $ThCr_2Si_2$-type body-centered crystal structure. Among RCu_2Si_2, $CeCu_2Si_2$ is well known as a heavy fermion superconductor. We grew high-quality single crystals of RCu_2Si_2 by the Sn-flux method. The anisotropy in the magnetic susceptibility and magnetization was found to be relatively small. This is due to a small overall $4f$-level splitting energy of about 100 K, which was clarified from the CEF calculation based on the previous results of neutron scattering experiment. From the de Haas-van Alphen (dHvA) experiment and the energy band calculation, the Fermi surface in YCu_2Si_2, $LuCu_2Si_2$ and $YbCu_2Si_2$ was clarified to be three dimensional in topology. In $YbCu_2Si_2$, the $4f$-electrons were found to be itinerant and contribute to the volume of the Fermi surface, with large cyclotron effective masses of 5-40 m_0.

We observed the typical magnetization curve with a metamagnetic transition at H_c = 5.7 T and a saturation at H_s = 12.1 T in $Ce_2Pd_3Si_5$ of which the orthorhombic crystal structure is similar to the $ThCr_2Si_2$-type tetragonal one, but is highly distorted. The magnetization process was clarified as follows. The antiferromagnetic moments are canted at H_c, and a canted angle decreases as a function of magnetic field and becomes zero at H_s.

The orthorhombic structure of $Lu_2Rh_3Ga_9$ possesses a hexagonal-like network in the (001) plane and is stacked along the [001] direction. The electronic state of $Lu_2Rh_3Ga_9$ was found to be quasi-two dimensional, indicating nearly cylindrical Fermi surfaces along the [001] direction, which was clarified by the dHvA experiment and the energy band calculation.