Abstract

The electrical and magnetic properties of the non-centrosymmetric rare earth compounds of RTX_3(R: rare earth, T: transition metal and X: Si and Ge) and Ce_2TGe_6 were studied by measuring the electrical resistivity, specific heat, magnetic susceptibility, magnetization and de Haas-van Alphen effect, together with the resistivity measurement under pressure. Two significant experimental results are obtained in RTX_3: the antisymmetric spin-orbit interaction and the unique superconducting property, which are based on the non-uniform lattice potential along the non-centrosymmetric tetragonal [001] direction.

As for RTX_3, we succeeded in growing single crystals of $LaTGe_3$(T: Fe, Co, Rh, Ir) and $PrCoGe_3$, and studied the split Fermi surface properties and the magnitude of the antisymmetric spin-orbit interaction $2|\alpha p_\perp|$. The $2|\alpha p_\perp|$ value is found to be changed when $LaTGe_3$ is changed from T = Co, Rh to Ir, but unchanged in $LaIrX_3$ from X = Si to Ge. It is noticed that this $2|\alpha p_\perp|$ value is large in $LaIrSi_3$ and $LaIrGe_3$: $2|\alpha p_\perp|$ = 460 K in $LaCoGe_3$, 510 K in $LaRhGe_3$, 1090 K in $LaIrGe_3$ and 1100 K in $LaIrSi_3$ for the main outer orbits named α of bands 69 and 70 electron Fermi surfaces, for example. This is mainly due to the large effective atomic number of Ir and a large distribution of the radial wave function of Ir-5*d* electrons close to the nuclear center, compared to those of Co and Rh. In the case of a paramagnet $PrCoGe_3$ and $LaFeGe_3$ with the relatively large cyclotron effective mass, the corresponding $2|\alpha p_\perp|$ value is found to become small: $2|\alpha p_\perp|$ = 280 K in $PrCoGe_3$ and 460 K in $LaCoGe_3$ for main orbits α, and 130 K for main orbits in $LaFeGe_3$. It is experimentally confirmed that the antisymmetric spin-orbit interaction becomes small in magnitude with increasing the cyclotron mass, being inversely proportional to the cyclotron mass.

We investigated the magnetic susceptibility for $CeTSi_3$ and $CeTGe_3$ single crystals. The susceptibility for H // [100], χ_a, is found to be larger than that for H // [001], χ_c, except for $CeCoGe_3$. This characteristic feature was clarified from the analyses of the crystalline electric field. The Néel temperature and the electronic specific heat coefficient were plotted as a function of volume in the crystal structure for $CeTSi_3$ and $CeTGe_3$. This relation roughly corresponds to the Doniach phase diagram indicating the competition between the RKKY interaction and the Kondo effect. We thus studied the effect of pressure on the electronic states in antiferromagnets $CeTGe_3$(T: Co, Rh, Ir). We confirmed superconductivity in the pressure region from 5.4 GPa to about 7.5 GPa in $CeCoGe_3$. It is characteristic that the slope of upper critical field H_{c2} at 6.5 GPa for H // [001] is extremely large: $-dH_{c2}/dT$ = 200 kOe/K at the superconducting transition temperature T_{sc} = 0.69 K, and the upper critical field indicates an upturn feature with decreasing temperature. $H_{c2}(0)$ is roughly estimated to be about 200 kOe. This might be an experimental evidence of the spin-triplet superconductivity in the non-centrosymmetric crystal structure.