Fermi Surfaces Detected by de Haas-van Alphen Experiments in U_2RhIn_8

We succeeded in growing high quality single crystals of the heavy fermion antiferromagnet U_2RhIn_8 and performed the de Haas-van Alphen (dHvA) experiments. The angular dependence of dHvA frequencies reveals quasi-two dimensional Fermi surfaces as well as small Fermi surfaces. The effective masses are in the range from 2 to $14m_0$ for the field along c-axis. The experimental results are compared with the LDA band structure calculations associated with both paramagnetic and antiferromagnetic Brillouin zone.

Uranium based heavy fermion compounds exhibit a variety of ground states including the coexistence of ferromagnetism and superconductivity (URhGe, UCoGe, UGe_2), hidden order (URu_2Si_2) and more recently a new spin-triplet superconductor UTe_2. The electronic structures, in particular Fermi surface dimensionality, is a key ingredient to understand such unusual physical properties[1].

In Ce-based heavy fermion superconductors, a prototype is so-called Ce115 and Ce218 systems, which form $CeTIn_5$ (T: transition metal) and Ce_2TIn_8, respectively. The structure of $CeTIn_5$ consists of $CeIn_3$ and TIn_2 layers, and thus the quasi-two dimensional Fermi surfaces are expected. Indeed, the dHvA experiments revealed the quasi-two-dimensional Fermi surfaces with heavy effective masses in $CeCoIn_5$ and $CeIrIn_5$, which agree well with the results band structure calculations based on the 4f-itinerant model. In the antiferromagnet $CeRhIn_5$, the Fermi surfaces consist of the quasi-two dimensional Fermi surfaces as well, which are explained by the band calculations based on the 4f-localized model. The 4f-itinerant and -localized Fermi surfaces are an important issue from the theoretical point of view related to the “large” and “small” Fermi surfaces.

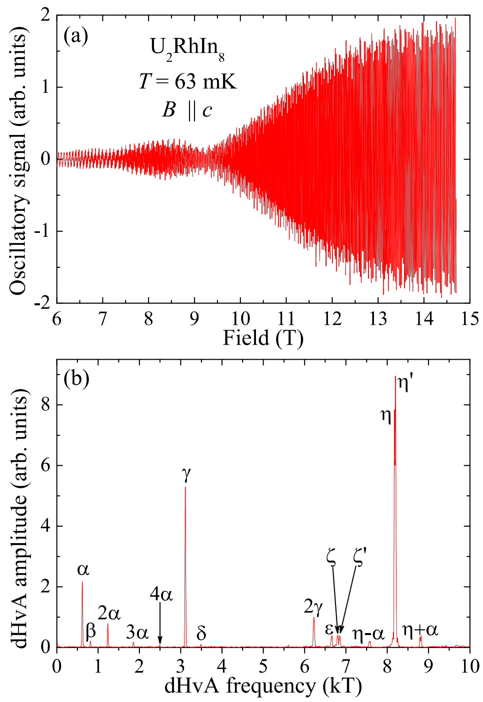

Fig. 1 (a) dHvA oscillations for the field along c-axis in U_2RhIn_8 and (b) the corresponding FFT spectrum

In Ce_2TIn_8, the crystal structure can be considered as the stacking of two layers of $CeIn_3$ and TIn_2. The degrees of two dimensionality is less than that in $CeTIn_5$, as it is confirmed by the dHvA experiments[2,3,4].

U_2RhIn_8 crystalizes into a tetragonal crystal structure with space group *P4/mmm* (#123). It undergoes an antiferromagnetic transition at a Neel temperature T_N = 117 K. The Sommerfeld coefficient γ = 47 mJ K^{-2} mol^{-1} is rather large given the high Neel temperature. The magnetic structure determined by single-crystal neutron diffraction is commensurate with propagation vector Q = (1/2, 1/2, 0) and magnetic moments aligned along the c axis.

In order to clarify the electronic structure of U_2RhIn_8 through the dHvA experiments, first we grew high quality single crystals using the In self-flux method. The resistivity and specific heat measurements clearly show the antiferromagnetic transition at T_N=117K without contaminations of UIn_3 and $URhIn_5$ as impurty phases. The high quality was demonstrated by the large residual resistivity ratio (RRR=700).

A plate-shaped single crystal was placed in a pickup coil to perform the dHvA experiments with the field-modulation technique. The dHvA experiments were done using a top-loading dilution fridge at low temperature down to 60mK and at high fields up to 15T.

Figure 1(a) shows the typical dHvA oscillations for the field along c-axis. The oscillations are already visible at low field, 6T, indicating the high quality of our sample. The corresponding FFT spectrum is shown in Fig.1(b). One can see fundamental dHvA branches named η, ε, ζ, δ, γ, β, α as well as the harmonics and sum/subtraction of fundamental branches. The large Fermi surfaces, η, ε, ζ, δ, γ, correspond to the main Fermi surfaces.

Figure 2 shows the angular dependence of the

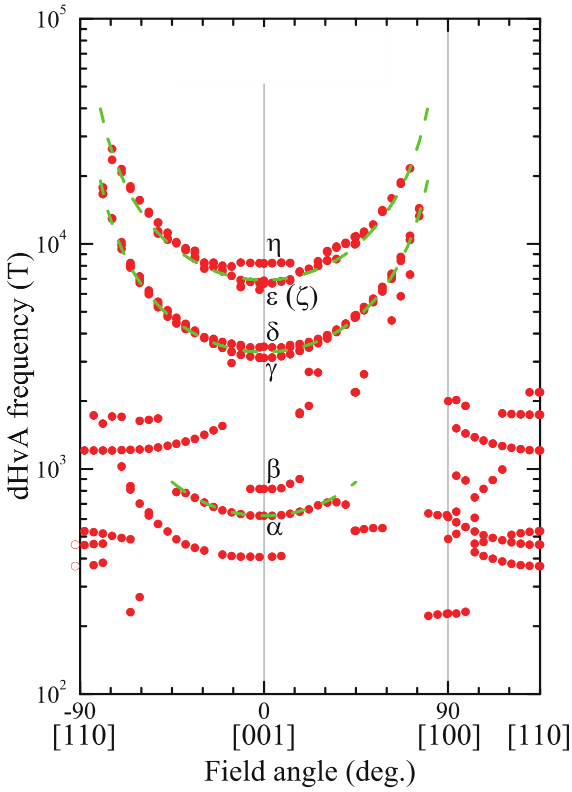

Fig. 2 Angular dependence of the dHvA frequencies in U_2RhIn_8.

dHvA frequencies. It should be noted that the experiments were done in the antiferromagnetic state, which changes the paramagnetic Brillouin zone into the antiferromagnetic Brillouin zone.

The main dHvA branches, η, ε, ζ, δ, γ, correspond to two kinds of quasi-two-dimensional Fermi surfaces, in which the frequencies approximately follow 1/cosθ dependence. The angular dependence of these frequencies is much larger than those expected in the antiferromagnetic Brillouin zone. Therefore the magnetic breakdown must occur at high fields.

Indeed, according to the band structure calculations, the magnetic breakdown is expected in the Brillouin zone boundaries.

From the temperature dependence of the dHvA amplitude, the cyclotron effective masses are determined for the field along c-axis. The masses are 4.3, 6.8, 6.7, 3.5 and 3.1m_0 for branches η, ε, ζ, δ, and γ, respectively. These values are consistent with the Sommerfeld coefficient, 47 mJ K^{-2} mol^{-1}, indicating that main Fermi surfaces are detected in this experiment.

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