De Haas - van Alphen effect under pressure in URu_2Si_2

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Abstract

We carried out the de Haas-van Alphen experiment under pressure for a heavy fermion antiferromagnet URu_2Si_2. The detected cyclotron mass for a nearly spherical Fermi surface under pressure changes considerably, reflecting a change of the magnetic moment. The present result is, however, inconsistent with the recent phase separated proposal.

Key words: URu_2Si_2; dHvA effect; pressure

The heavy-fermion compound URu_2Si_2 exhibits two successive transitions at $T_c = 1.4$ and $T_o = 17.5$ K. The former is the superconductivity transition temperature. On the other hand, the latter has still remained unidentified, although several characteristic features are associated with this phase transition. The energy gap was found to open over part of the Fermi surface, which is reflected by a term of $\exp(-\Delta/k_B T)$ for the specific heat, electrical resistively and nuclear spin-lattice relaxation rate below T_o. The neutron diffraction study also indicated the development of a simple type-I antiferromagnetic order with a tiny $5f$-magnetic moment of 0.03 μ_B along the tetragonal [001] direction below T_o [1].

Recent neutron scattering and NMR experiments under pressure shed a new insight to this phase transition. It was clarified from the neutron scattering experiment that the magnetic moment increases linearly as a function of pressure, saturates in the pressure region from 1.0 to 1.5 GPa, with a moment of $0.25\mu_B$, and jumps to $0.4\mu_B$, indicating a sharp phase transition at $P_c = 1.5$ GPa [2]. Furthermore, the result of NMR experiment indicated that there exist distinct antiferromagnetic and paramagnetic regions, and with increas-

ing pressure the antiferromagnetic region increases in space, reaching 100% of the antiferromagnetic volume fraction at 1.0 GPa [3].

The de Haas-van Alphen (dHvA) effect is the most powerful method to determine the topology of the Fermi surface, cyclotron effective mass and the Dingle temperature. Previously we studied the dHvA effect of URu_2Si_2 [4]. If the recent NMR experiment is right, the detected dHvA branch is mainly due to the paramagnetic region because the volume fractions of the paramagnetic and antiferromagnetic regions are about 99 and 1%, respectively, from the tiny moment of $0.03\mu_B$. The topology of the Fermi surface is generally influenced by the antiferromagnetic ordering. At 0.5 GPa we expect two kinds of dHvA branches based on the paramagnetic and antiferromagnetic regions. To clarify it we carried out dHvA experiment under pressure.

Figure 1 show the dHvA oscillation under 0.5 GPa in the field along [100] and its fast Fourier transform (FFT) spectra at 0.5, 0 and 1.8 GPa in URu_2Si_2. A detected branch is named α, which is observed at ambient pressure and is known to be nearly spherical in shape. There is no beat pattern in the dHvA oscillation, meaning that there are no two kinds of branches. A change of the dHvA frequency is small, as shown in

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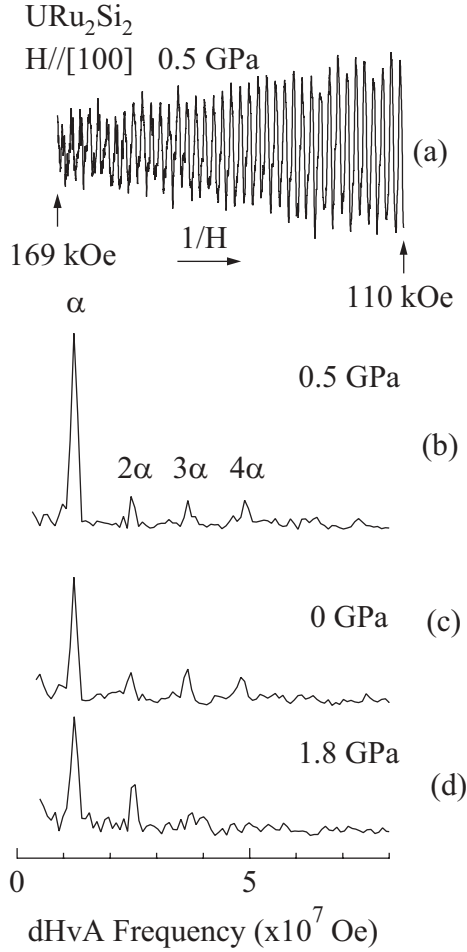[1] Corresponding author. E-mail:mnaka@crystal.phys.sci.osaka-u.ac.jp

Fig. 1. dHvA oscillation under 0.5 GPa in the field along [100] and its FFT spectra at 0.5, 0 and 1.8 GPa in URu_2Si_2.

Fig. 2. Pressure dependence of the dHvA frequency for branch α in URu_2Si_2.
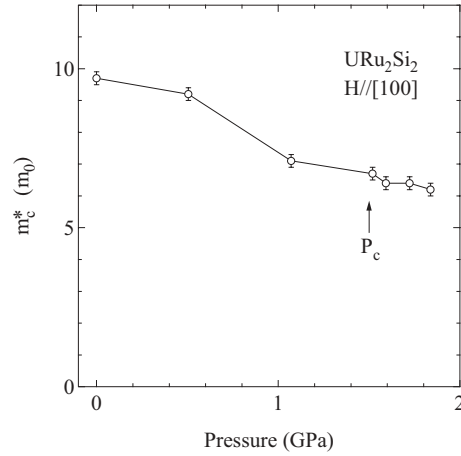
Fig. 3. Pressure dependence of the cyclotron mass for branch α in URu_2Si_2.

Fig. 2.

Figure 3 shows the pressure dependence of the cyclotron mass m_c^*. The cyclotron mass decreases considerably with increasing pressure. In the heavy fermion system, the magnetic specific heat of $5f$ electrons is partially changed into an electronic specific heat. The present result is consistent with the pressure dependence of the magnetic moment. The larger the magnetic moment is, the smaller the electronic specific heat coefficient or the cyclotron mass is. It is, however, noted that a change of the cyclotron mass at P_c is not observed.

We also determined the Dingle temperature and estimated the mean free path for branch α. The mean free path is 1100 Å ($\pm$ 50 Å), approximately independent on the pressure.

It is thus concluded that the present dHvA experiment under pressure is inconsistent with the phase-separated proposal based on the NMR experiment. The cyclotron mass under pressure changes considerably, reflecting a change of the magnetic moment.
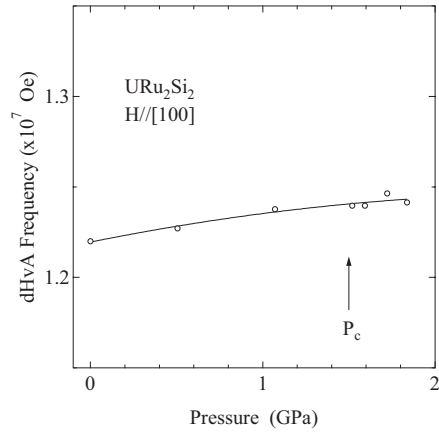
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