The Fermi Surface in the Heavy Fermion Systems(Abstracts of Doctral Dissertations)

The Fermi Surface in the Heavy Fermion Systems

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Abstract

Chap.I.Introduction

The study on the cyclotron mass on the Fermi surface by means of the de Haas-van Alphen(dHvA)effect reveals a hybridization between the conduction electrons and f-electron on each Fermi surface. The dHvA effect in heavy fermion systems is observed only at very low temperatures, generated by a ^{3}He-cryostat or a dilution refrigerator. However, the measuring technique at very low temperatures has not been established yet. We present a development of the measuring technique at very low temperatures and the fermiolozy on semimetallic compounds YbAs, CeAs and U_3P_4.

Chap.II. Samples and the experimental apparatus

Single crystals used in the present studies were given by Professor Suzuki.

The dHvA effect was measured in a ^{3}He-cryostat or a dilution refrigerator. To determine the shape of the Fermi surface, it is necessary to measure the dHvA frequency by rotating a sample. It is easy to rotate a sample in a ^{3}He-cryostat or a top-loading dilution refrigerator, because a part of a sample rotating system can be extended to out of a cryostat. However, it is impossible in a non-top-loading dilution refrigerator. We have constructed a new type of sample rotating system with a stepping motor and a spiral gear at very low temperatures, and developed a new type of pick up coil without a bobbin to increase a filling factor.

Chap.III.The experimental results

We found in YbAs the Fermi surfaces of three ellipsoidal electron surfaces centered at X points and one spherical hole surface centered at a Γ point. Two principal radii of the ellipsoid, $k_{//}$ and $k_{\perp}$, which are parallel and perpendicular to the Γ-X direction, are 0.32Å^{-1} and 0.096Å^{-1}, respectively. The radii of a spherical hole surface(k) is 0.12Å^{-1}. The dHvA effect was observed above and below T_N. The Fermi surfaces were the same shape above and below T_N. The cyclotron mass of the electron surface above T_N was estimated to be $0.18m_0$ in the <100> direction and $0.19m_0$ in the <110> direction. Since the temperature dependence of dHvA amplitude is small below T_N, the cyclotron mass can not be determined by a conventional method. We have proposed a new method to

estimate the cyclotron mass and found not to change so much. However, we have found an anomaly of the dHvA amplitude at T_N and clarified the change of the cyclotron mass and the Dingle temperature.

The Fermi surfaces of CeAs are three ellipsoidal electron surface($k_{//}$=0.20 $Å^{-1}$, $k_{\perp}$=0.045$Å^{-1}$) and one hole surface(k=0.068$Å^{-1}$). The cyclotron mass in the <100> direction at 5.6T is 0.35m_0(electron) and 0.47m_0(hole). The cyclotron mass of hole surface decreases with increasing magnetic field, i.e. from 0.55m_0 at 4.5T to 0.4m_0 at 7T.

We have observed four branches in U_3P_4. Two of them are spherical. The cyclotron mass of three branches of them is estimated to be 7.4m_0, 6.6m_0 and 12.5m_0.

Chap.IV.Discussion

The cyclotron mass of a electron surface in YbAs is almost the same as that of LaSb. This means that a hybridization effect between conduction electrons and f-electron is small. In CeAs, however, a hybridization effect increases and the cyclotron mass of the electron surface is two times larger than that of LaSb. The volume of the Fermi surface of YbAs and CeAs has 0.014 electrons/formula unit(f.u.) and 0.0027 holes/f.u. for YbAs, 0.0024 electrons/f.u. and 0.00058 holes/f.u. for CeAs. Since YbAs and CeAs are semimetallic compounds, there should be a equal number of electrons and holes. Therefore unobserved other hole surfaces should exist. The cyclotron mass of such hole surfaces is estimated from an electronic specific heat coefficient to be one order of 10^3m_0 at 0T for YbAs, and 60m_0 at 5T for CeAs. These hole surfaces are in the most heavy fermion states.

The dHvA effect for U_3P_4 was observed at first by Henkie et.al.. They found two branches, and proposed a model with one spherical electron surface and eight spherical hole surfaces. However, present result is not explained by Henkie's model. It is considered that two spherical Fermi surfaces are electron surface and the others hole surfaces with open orbits predicted by a study of magnetoresistivity. A hybridization effect in U_3P_4 increases the cyclotron mass on all of the Fermi surfaces.

Chap.V.Conclusion

We have constracted a new type of sample rotating system and a sensitive pick up coil, and made it possible to study the Fermi surface at very low temperatures down to 40mK. We have studied a hybridization of semimetallic compounds YbAs, CeAs and U_3P_4. In YbAs and CeAs, there should exist other hole surfaces which are not observed and in the most heavy fermion state. In contrast to YbAs and CeAs, all of the Fermi surfaces of U_3P_4 are in the heavy fermion state.