QUASI-2D FERMI SURFACES OF THE MAGNETIC COMPOUND $CeAgSb_2$*

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We have succeeded in growing high-quality single crystals of $CeAgSb_2$, and carried out the de Haas-van Alphen (dHvA) experiment. Cylindrical Fermi surfaces were observed, together with closed Fermi suraces. The effective cyclotron mass is in the range from 0.9 to 32 m_0. Large cylindrical Fermi surfaces occupying half of the Brillouin zone were detected, which are highly different from small Fermi surfaces in the reference compounds $LaAgSb_2$ and $YAgSb_2$ with a semimetalic character. $CeAgSb_2$ is the first example in which the $4f$ electron becomes itinerant and possesses the magnetic moment.

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1. Introduction

RTX_2(R:rare earth, T:transition metal) crystallizes in the tetragonal $ZrCuSi_2$ type structure (space group P4/nmm) [1, 2]. The crystal structure of $CeAgSb_2$ can be understood from the stacking arrangement of Sb-CeSb-Ag-CeSb layers [1]. It shows the magnetic ordering below 9.7 K. The magnetic structure is reported to be ferromagnetic with a small ordered morment of 0.33 μ_B [3], although the magnetization curve is highly anisotropic and cannot be understood from the simple ferromagnetic structure [2].

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The dHvA and Shubnikov–de Haas (SdH) experiments on $CeAgSb_2$ as well as on reference compounds $YAgSb_2$ and $LaAgSb_2$ were reported by Meyers *et al.* [4]. A small Fermi surface was observed for $CeAgSb_2$. On the other hand, the Fermi surface in $YAgSb_2$ and $LaAgSb_2$ was found to consist of a cylindrical Fermi surface and a few kinds of closed (ellipsoidal) ones. The reason why larger Fermi surfaces were not observed in $CeAgSb_2$ was mainly due to the fact that the measurement was carried out at a high temperature of 2.1 K and the specific heat coefficient γ is reported to be $75\,\mathrm{mJ/K^2{\cdot}mol}$ for the polycrystalline sample of $CeAgSb_2$ [5], which is larger than that of $LaAgSb_2$ ($\gamma = 2.62\,\mathrm{mJ/K^2{\cdot}mol}$) [6].

We have thus done the dHvA experiment by standard field-modulation method at low temperatures down to 30 mK and in high magnetic fields up to 170 kOe to clarify the electronic state.

2. Experimental and discussion

Single crystals were grown by the self-flux method, as described in ref [2]. The starting materials were 3N(99.9% pure)-Ce, 5N-Ag and 5N-Sb. The typical size was $8{\times}5{\times}3\,\mathrm{mm^3}$, being flat in the (001) plane.

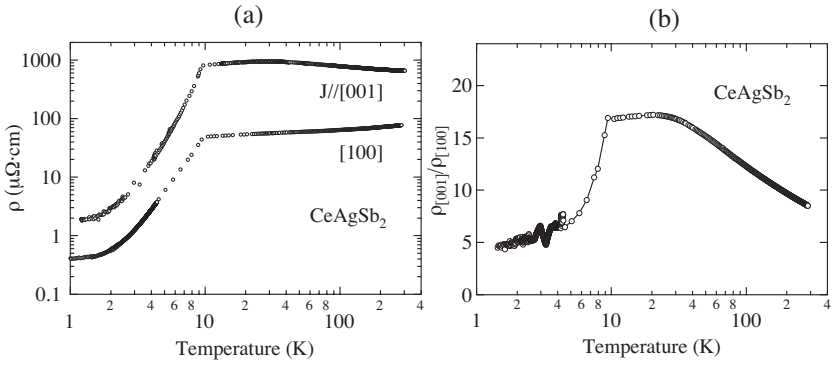

Fig. 1. Temperature dependence of (a) electrical resistivities and (b) anisotropic ratio, ρ_{001}/ρ_{100}, in $CeAgSb_2$

Figure 1(a) shows the temperature dependence of the electrical resistivity in the current J along [100] and [001]. The residual resistivity ρ_0 and residual resistivity ratio $\rho_{\mathrm{RT}}/\rho_0$ were $1.25\,\mu\Omega{\cdot}\mathrm{cm}$ and 522 for the current $J \parallel [001]$ and $0.37\,\mu\Omega{\cdot}\mathrm{cm}$ and 210 for the current $J \parallel [100]$, respectively, indicating a high-quality sample. The temperature dependence of the resisitivity ratio between $J \parallel\parallel [001]$ and [100] is shown in Fig. 1(b). Anisotropy of the resistivity is large: the ratio is 8.3 at room temperature and 17 around 10 K, reflecting the quasi-two dimensional electronic state. The electrical resistivity in both

directions decreases steeply below $T_{\rm ord}$ =9.7 K. The temperature dependence of the electrical resistivity below 3 K follows:

$$\rho = \rho_0 + AT^2 + BT(1 + 2T/\Delta)\exp(-\Delta/T)\,. \tag{1}$$

The third term in Eq. (1) is applicable to the magnetic compound with a spin gap of Δ. The value of Δ are 7.6 K for $J \parallel [001]$ and 9.7 K for $J \parallel [100]$, respectively.

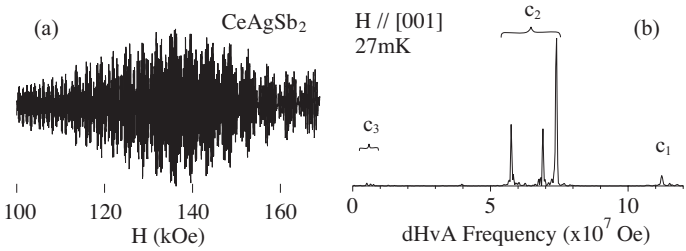

Fig. 2. (a) Typical dHvA oscillation and (b) the corresponding FFT spectrum in $CeAgSb_2$

Figure 2 shows a typical dHvA oscillation and its fast Fourie transform (FFT) spectrum for $H \parallel [001]$. Here, the dHvA frequency $F(= \hbar c S_{\rm F}/2\pi e)$ is proportional to the extremal (maximum or minimum) cross-sectional area $S_{\rm F}$ of the Fermi surface. Three groups of branches, $c_{1,2,3}$, were observed at high magnetic fields ranging 100 to 169 kOe. The frequencies of these branches increase approximately as a function of $1/\cos\theta$, where θ is a tilted field angle from [001] to [100]. These branches correspond to cylindrical Fermi surfaces. The presence of these branches indicates the quasi-two dimensional electronic state as expected from the anisotropy of the electrical resisitivities shown in Fig. 1.

These branches possess rather heavy cyclotron masses, $32\,m_0$ for branch c_1, $20\,m_0$ for branch c_2 and $10\,m_0$ for branch c_3. The cross-section of branch c_1 in $CeAgSb_2$ ($F = 1.12 \times 10^8$ Oe) occupies approximately half of the Brillouin zone because the cross-sectional area of the Brillouin zone corresponds to $2.2{\times}10^8$ Oe in the (001) plane.

In the localized f-electron systems, the Fermi surfaces of a cerium compounds is similar to those of corresponding reference La or Y compounds. The main dHvA frequencies in $CeAgSb_2$ are, however, an order of magnitude larger than those in $LaAgSb_2$ or $YAgSb_2$. Namely, the largest cylindrical Fermi surface in $LaAgSb_2$ or $YAgSb_2$ corresponds to $1.7{\times}10^7$ Oe, which means a small Fermisurface. $LaAgSb_2$ or $YAgSb_2$ are a semimetalic with a small electronic specific heat coefficient $\gamma \simeq 1\,{\rm mJ/K^2{\cdot}mol}$.

It is concluded that one $4f$-electron per cerium in $CeAgSb_2$ contributes the volume of the Fermi surface, indicating a band electron in $CeAgSb_2$. $CeAgSb_2$ is the first example in which the $4f$ electron becomes itinerant and possesses the magnetic ordered moment.

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