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Journal of Magnetism and Magnetic Materials 226–230 (2001) 208–210

Journal of magnetism and magnetic materials

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Fermi surface of CeTe

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Abstract

CeTe is a typical Kondo lattice compound with antiferromagnetic ordering at 2 K. We have succeeded in observing the de Haas–van Alphen (dHvA) effect of CeTe. The dHvA frequencies denoted by α can be explained by the three equivalent ellipsoidal Fermi surfaces at the X points of the Brilluoin zone. We have discovered the splitting of the α branch into the α_1 and α_2 branches in most of the field directions, which is attributed to splitting of the up and down Fermi surfaces. The relatively large difference between the effective masses of α_1 is α_2 is observed for the field along the [1 1 1] direction.

Keywords: Rare earth monochalcogenide; Fermi surface

Rare earth monochalcogenides have been the subject of a number of studies for its simple NaCl-type cubic structure and its attractive magnetic and transport properties. For example, SmS shows metal–insulator (M–I) transition under a pressure of 6 kbar [1]. Tm monochalcogenides show continuous valence change under pressure [2]. CeTe is a typical Kondo lattice compound and shows attractive magnetic properties. The temperature dependence of the electrical resistivity has the ln T range which is the characteristic behavior of Kondo lattice compounds [3]. The neutron diffraction and magnetic susceptibility measurements show that type-II antiferromagnetic ordering occurs at 2 K with highly reduced magnetic moment 0.3 μ_B/Ce [4]. These attractive magnetic properties of the rare earth monochalcogenides have the origin in its electronic structure, especially the interaction between the 4f electrons and conduction d-band [5–7]. However, the electronic structures of the rare earth monochalcogenide have not been clarified yet. The de Haas–van Alphen (dHvA) effect measurement is the most effective experimental method to investigate the electronic structure of metals. To observe the dHvA effect, the sample must be of high quality. However, the sample qualities of CeTe single crystals which were grown in the past are not good enough to observe the dHvA oscillations. In this paper, we present the first observation of the dHvA effect among the rare earth monochalcogenides.

The single crystal of CeTe was grown by the Bridgeman method using a tungsten heater furnace. The starting materials were the mixture of Ce (4N) and Te (6N) and were sealed in an evacuated tungsten crucible. The crucible was heated up to 2000°C and grown at 2 mm/h. The residual resistivity ratio is 18. This value shows that the quality of the present single crystal is highest among the crystals so far grown. The dHvA effect and AC susceptibility were measured by the conventional field modulation technique. A dilution refrigerator with a 20 T superconducting magnet was used for the measurements.

Fig. 1 shows the magnetic field dependence of the AC-susceptibility for the field along the [0 0 1] direction. We have observed at least two anomalies at $H_{c1} = 7.7$ T and $H_{c2} = 15.7$ T but the origin of these anomalies is not clarified yet. The oscillations below 2 T may be attributed to the flux jump of the superconducting magnet. The dHvA effect measurements were performed above H_{c2}.

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0304-8853/01/$ - see front matter
PII: S0304-8853(00)01132-X

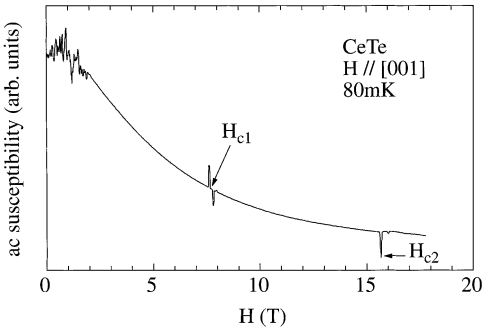

Fig. 1. Magnetic field dependence of the AC susceptibility for the field along the [0 0 1] direction.

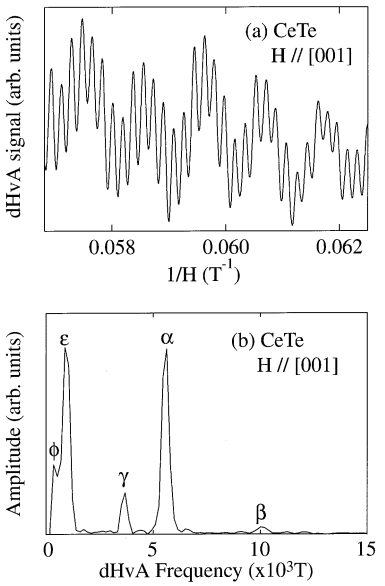

Fig. 2. (a) dHvA oscillation and (b)its fast fourier transform (FFT) spectrum of CeTe for the field along the [0 0 1] direction.

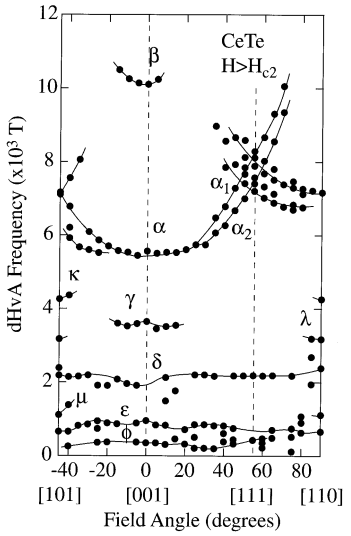

Fig. 3. Angular dependence of the dHvA frequencies of CeTe. The open circles are the measured results and the solid lines are guides to the eye.

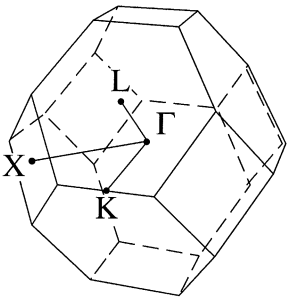

Fig. 4. First Brillouin zone of CeTe.

Fig. 2 (a) and (b) shows the dHvA oscillations and its fast fourier transform (FFT) spectrum for the field along the [0 0 1] direction. Five dHvA frequencies have been observed for this direction and they are denoted by α, β, γ, ε and ϕ. Fig. 3 shows the angular dependence of the dHvA frequencies of CeTe. Nine dHvA branches have been observed and they are denoted by α, β, γ, ε, ϕ, κ, λ and μ. The δ, ε and ϕ branches have approximately flat angular dependences which indicate that these frequencies arise from spherical Fermi surfaces. The β and γ branches are observed around the [0 0 1] direction and the κ, λ and μ branches are observed around the [1 1 0] direction. The α branch is observed for almost all the field directions and has the characteristic angular dependence. Fig. 4 shows the first Brillouin zone of CeTe. The characteristic angular dependence of the α branch can be mostly explained by three equivalent ellipsoidal Fermi surfaces at the X point in the Brillouin zone. However, from this simple model the dHvA frequency branches above 9000 and 10 000 T are expected to be around the [0 0 1] and [1 1 0] directions, respectively. The disappearance of these branches indicates that three ellipsoidal Fermi surfaces are possibly connected to each other at the Γ point. It is noted that the α branch splits into the α_1 and α_2 branches in most of the field directions. The measured effective masses of α_1 and α_2 branches for the field along the [1 1 1] direction are $5.6m_0$ and $12m_0$, respectively. We think that the splitting may be attributed to the splitting of the up and down Fermi surfaces due to the exchange interaction with the localized f electrons. The large difference of the effective masses indicates that the interaction between the f and conduction electrons is more significant for the one of the up and down Fermi surface. It is not clear that which branch arises from the up or down Fermi surface in this experiment.

The band structure calculation is helpful to gain a better understanding of the electronic structure of CeTe.

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