Transport properties of the dense Kondo system $Ce_{0.5}La_{0.5}B_6$

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Abstract

We have measured the electrical resistivity of the dense Kondo system $Ce_{0.5}La_{0.5}B_6$ at very low temperatures. A large term which is in proportion to temperature squared is found in the resistivity of $Ce_{0.5}La_{0.5}B_6$ below ∼0.3 K. The proportion coefficient of this term of $Ce_{0.5}La_{0.5}B_6$ is 37 times larger than that of CeB_6.

Key words: dense Kondo effect; $Ce_{0.5}La_{0.5}B_6$; electrical resistivity ;magnetoresisitivity

The magnetic phases of $Ce_xLa_{1-x}B_6$ have attracted much attention because of their unusual profiles originating from the dense Kondo effect and intersite multipole interactions. Phase I is a paramagnetic phase, phase II an antiferro quadrupole (AFQ) and phase III an antiferromagnetic with AFQ ordering. Recently, additional phase IV was found in the substitutional alloys $Ce_xLa_{1-x}B_6 (x = 0.75, 0.70, 0.65)$. No Bragg peak is found in phase IV in the neutron diffraction measurements [1] , while the clear λ-shaped peak is found in specific heat at the phase I-phase IV transition temperature T_c∼1 K [2]. In the case of $Ce_{0.5}La_{0.5}B_6$, only a broad maximum around 1K is shown in the specific heat in zero field, and the specific heat of this system is in proportion to $T^{1.5}$ at lower temperatures. The order parameter of phase IV and the ground state of $Ce_{0.5}La_{0.5}B_6$ are both current controversy [3]. Some previous studies have been made on the resisitivity of $Ce_{0.5}La_{0.5}B_6$ [4,5]. In the present study, we have measured the resistivity of this system extending the temperature range down to ∼50 mK.

The sample was grown by the floating zone method and cut to a rectangular shape $0.3 \times 0.7 \times 8$ mm^3. We measured the electrical resistivity by the four-terminal DC method using a top loading type dilution refrigerator. The current was 0.15 ∼ 0.6 mA. For a good thermal contact to ^{3}He-^{4}He mixture, we glued the sample onto a copper plate $10 \times 15 \times 1$ mm^3 using GE7031 grease and immersed them into the mixture directly.

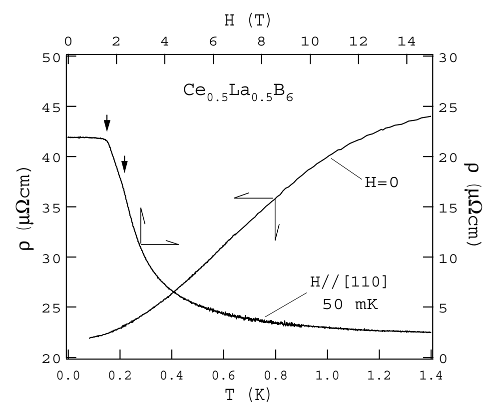

Fig. 1. Temperature dependence of the resisitivity of $Ce_{0.5}La_{0.5}B_6$ for H=0 and magnetoresistivity for T=50 mK. Fields and the current are directed along the [110] and [1$\bar{1}$0] axes, respectively.

The electrical resisitivity at 0 T and the magnetoresistivity at 50 mK are shown in Fig. 1. Magnetic fields and the current are directed along the [110] and [1$\bar{1}$0] axes, respectively. In the case of $Ce_{0.75}La_{0.25}B_6$, rapid

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decrease in the resistivity was reported in association with the transition from phase I into phase IV [5]. However, we found no indication of the phase I-phase IV transition in the resistivity for $H = 0$ in $Ce_{0.5}La_{0.5}B_6$. Probably, $Ce_{0.5}La_{0.5}B_6$ is in phase I in the low T, low H region. Two anomalies indicated by bold arrows are shown in the magnetoresisitivity of $Ce_{0.5}La_{0.5}B_6$. One is the bending point at 1.6 T and the other is a weak bending point at around 2.3 T. Under the magnetic fields $H//[110]$, $Ce_{0.5}La_{0.5}B_6$ may be in phase III in the range 1.6 T$< H <$ 2.3 T. The anomalies at 1.6 T and at 2.3 T may correspond to the phase I-phase III transition and the phase III-phase II transition, respectively. We illustrate the magnetic phase diagrams of $Ce_{0.5}La_{0.5}B_6$ in Fig. 2. As shown in Fig. 1, magnetoresistivity at 15 T is only 11% of that at 0 T. This implies that the large residual resistivity of $Ce_{0.5}La_{0.5}B_6$ under low fields is originated from the dense Kondo effect, *i. e.*, from the large cross section of randomly distributed Ce ions.

The temperature dependence of the resistivity at very low temperatures is shown in Fig. 3. The resistivity follows the formula $\rho(T) = \rho_0 + AT^2$ below ∼0.3 K. Here, ρ_0 is the residual resisitivity and A is the proportional coefficient. The magnitude of A of $Ce_{0.5}La_{0.5}B_6$ for $H = 0$ is 30.5 $\mu\Omega\mathrm{cmK}^{-2}$ which is 37 times larger than that of CeB_6 (0.832 $\mu\Omega\mathrm{cmK}^{-2}$) [6]. Although Ce ions are distributed randomly in $Ce_{0.5}La_{0.5}B_6$, a strongly correlated Fermi liquid state is likely realized in this system. When the long range ordering is induced by the applied field, A becomes small. The magnitude of A at 3 T is 53 % of that at 0 T. The large A under lower fields may be attributed to the non-ordered ground state of $Ce_{0.5}La_{0.5}B_6$.

In conclusion, the large term which is in proportion to temperature squared is found in the resistivity of $Ce_{0.5}La_{0.5}B_6$ in the temperature range $0.1 \lesssim$ T $\lesssim 0.3$ K. This strongly suggests the formation of strongly correlated Fermi liquid state in this system.

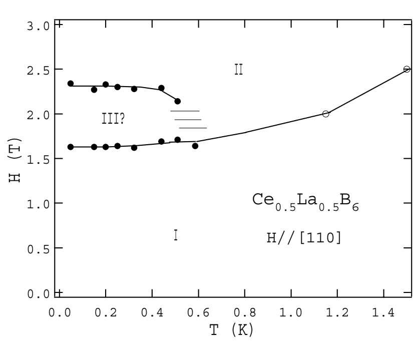

Fig. 2. Magnetic phase diagrams of $Ce_{0.5}La_{0.5}B_6$ for $H//[110]$. Closed circles are present results and open circles are taken from Ref. [7].

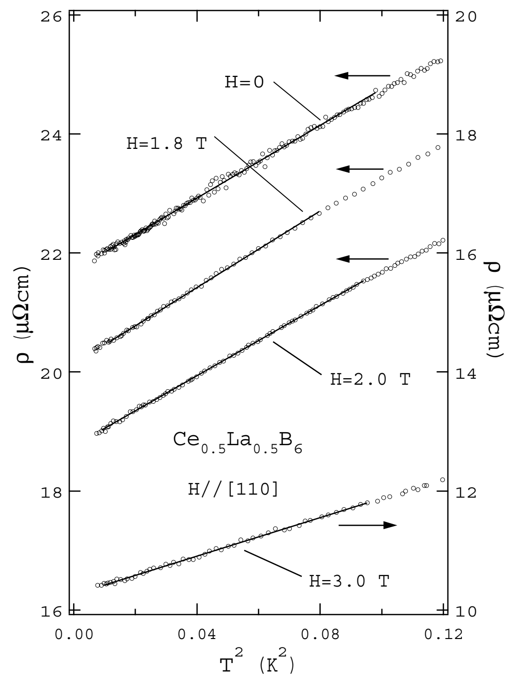

Fig. 3. Resistivity of $Ce_{0.5}La_{0.5}B_6$ at very low temperature. Fields and the current are directed along the [110] and [1$\bar{1}$0] axes, respectively. Solid lines are fits according to the formula $\rho(T) = \rho_0 + AT^2$.

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