Non-Fermi-Liquid Behavior in Amorphous UPd_2Al_3

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Abstract

To investigate the relation between the non-Fermi liquid state and the disordered state, a crystallographycally disordered amorphous UPd_2Al_3 has been prepared. At low temperatures, the measured electronic specific heat coefficient γ has a typical temperature dependence of non-Fermi-liquid state, $\gamma \propto -\log T$.

Key words: amorphous, UPd_2Al_3, non-Fermi-liquid, resistivity, specific heat, magnetic susceptibility

These ten years, unusual behaviors in physical quantities different from Fermi liquid state have been reported in many heavy Fermion materials [1]. Some experimental results of non-Fermi-liquid behavior have been explained from the disorder-induced non-Fermi-liquid theories [2]. To investigate the relation between the non-Fermi liquid state and the disordered state further, a crystallographycally disordered amorphous UPd_2Al_3 (a-UPd_2Al_3) has been prepared. Electrical resistivity, specific heat and magnetic susceptibility have been measured in a-UPd_2Al_3. They show anomalous behaviors at low temperatures, which are discussed by connecting with non-Fermi-liquid state and comparing with those observed in a crystalline UPd_2Al_3 (c-UPd_2Al_3). An a-UPd_2Al_3 was prepared by sputtering method from pure elements U, Pd and Al. The magnetization was measured by a conventional V. S. M. The electrical resistivity was measured by a standard DC and AC 4-probe method. The specific heat was measured by a conventional adiabatic heat-pulse method.

The temperature dependence of the electrical resistivity ρ measured down to 0.5 K is shown in Fig. 1. ρ does not show any anomaly at 14 K at which c-UPd_2Al_3 reveals the antiferromagnetic transition nor at 2 K at which c-UPd_2Al_3 becomes superconducting. The a-UPd_2Al_3 is proved not to reveal antiferromagnetism nor superconductivity down to 0.5 K. We can fit the obtained data to a logarithmic function of temperature T between 2.4 K and 30 K, $\rho(\mu\Omega\mathrm{cm}) = 276 - 1.2\log T$, which is shown by the solid curve. This logarithmic behavior is considered to originate from Kondo effect because the effective mass is still heavy in a-UPd_2Al_3 as discussed in the previous papers [3].

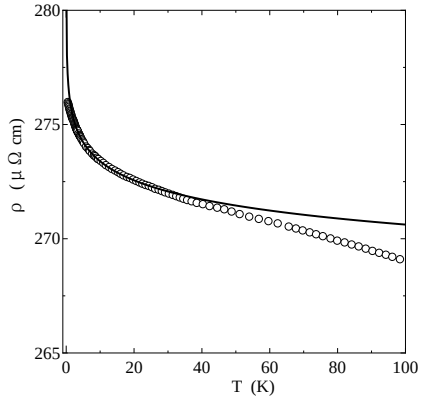

Fig. 1. Temperature dependence of the electrical resistivity of a-UPd_2Al_3.

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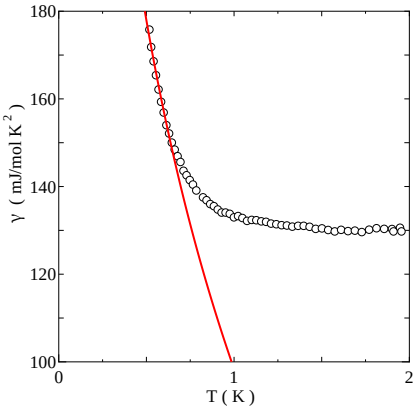

Fig. 2. Temperature dependence of the electronic specific heat coefficient γ of a-UPd_2Al_3 measured at an external field 7.65 T.

However, the effect on the electrical resistivity caused by the amorphous structure is not yet understood well.

Fig. 2 shows the temperature dependence of the electronic specific heat coefficient γ which was derived by subtracting the part of specific heat due to lattice vibrations from the raw data. It is ascertained that the nuclear specific heat is negligibly small in UPd_2Al_3 [4]. The amorphous structure adds a constant term to γ , which is independent of temperature [5]. With decreasing temperature γ increases, and the data points are fitted to $\gamma(\mathrm{mJ/molK^2}) = 98.4 - 115 \log T$ below 0.65 K as shown by the solid curve, which is the typical behavior of non-Fermi-liquid state [1].

The DC magnetic susceptibility χ measured at an external field of 1 kOe under the zero-field cooling condition is shown in Fig. 3. χ has a clear cusp at about 3.4 K, which indicates that a-UPd_2Al_3 reveals a spin-glass phase transition as discussed in the previous papers [3]. It is known that the antiferromagnetism is suppressed in the amorphous disordering. Spin-glass phase is considered to appear instead of antiferromagnetism. The temperature dependence of χ above 4 K can be represented as $\chi(\mathrm{emu/mol-U}) = 0.124 \times T^{-0.684}$ as shown by the solid curve. χ measured at an external field of 1 T under the zero-field cooling condition is shown in Fig. 4. The cusp at the spin-glass phase transition temperature becomes smaller with increasing the external field as well known as a characteristic behavior in spin-glass materials [6]. The temperature dependence of χ above 5 K can be also represented as $\chi(\mathrm{emu/mol-U}) = 0.10 \times T^{-0.604}$, which is shown by the solid curve. The same temperature dependence has been reported in $Th_{1-x}U_xCu_2Si_2$, in which γ shows the typical temperature dependence of non-Fermi-liquid, $\gamma \propto -\log T$ [7]. $Th_{1-x}U_xCu_2Si_2$ is known as a system which displays a non-Fermi-liquid behavior near to ferromagnetism. Our results seem to give evidence for the idea that a disordered state induces a non-Fermi-liquid state.

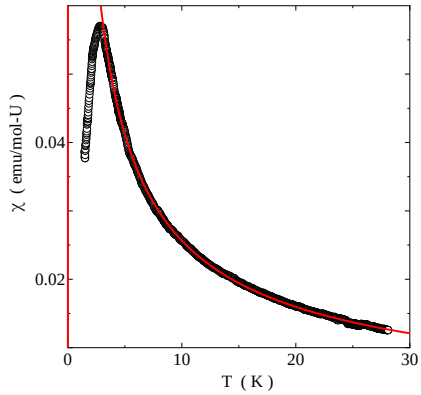

Fig. 3. DC magnetic susceptibility χ of a-UPd_2Al_3 measured at an external field of 1 kOe under the zero-field cooling condition.

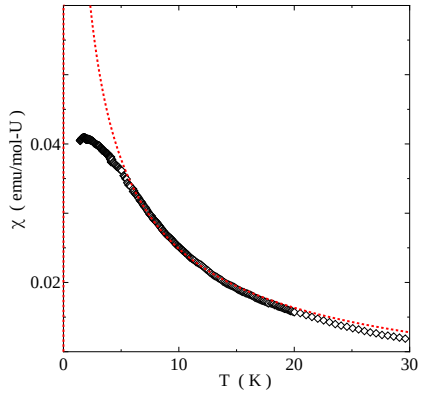

Fig. 4. DC magnetic susceptibility χ of a-UPd_2Al_3 measured at an external field of 1 T under the zero-field cooling condition.

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