Electron Transport Properties of Non-Fermi-Liquid Alloys $U_{1-x}Y_xAl_2$

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Previous measurements of the solid solutions $U_{1-x}Y_xAl_2$ have revealed interesting magnetic and thermodynamic properties [1]. This system shows spin fluctuation behaviour for $x \leq 0.2$, spin-glass freezing for $0.2 < x < 0.9$ and non-fermi-liquid (nFL) behaviour around $x = 0.85$–0.95. The fact that the nFL property appears nearby spin-glass phase suggests a close relationship between nFL and magnetic instability. However, similar nFL behaviour without spin-glass freezing was observed in $U_{1-x}Sc_xAl_2$ [1], thus origin of the nFL state in $U_{1-x}Y_xAl_2$ remains an open question. There exist three competing models [2], which are able to interpret behaviour of such class of materials; The quantum phase transition mentioned above, the two-channel Kondo effect and distribution of Kondo temperatures.

Very recently, one of us (V.H.T.) has measured electrical resistivity and thermoelectric power of $U_{0.05}Y_{0.95}Al_2$ [3]. The obtained experimental data for $U_{0.05}Y_{0.95}Al_2$ appear to be consistent with the two-channel Kondo (TCK) scenario [4]. The description of physical properties in terms of TCK effect requires the presence of single-ion Kondo behaviour in preceding or following alloys within series, before the overcompensation of the impurity moments by the two channels of the conduction electrons sets in. To clarify the mechanism providing nFL in $U_{0.05}Y_{0.95}Al_2$ we investigate electrical resistivity and thermoelectric power for several selected alloys $U_{1-x}Y_xAl_2$.

Polycrystalline samples of $U_{1-x}Y_xAl_2$ with $x = 0.1$, 0.3, 0.5, 0.7, 0.9 and 0.95 were prepared using arc-melting method. The obtained samples were annealed in sealed quartz glass tubes at 800°C for one week. Quality of the samples was checked by X-ray diffraction and microprobe EDX. The electrical resistivity $\rho(T)$ was measured by the standard four-probe ac-technique. Thermoelectric power *TEP* was measured using the differential method.

Fig. 1 shows temperature dependence of the normalized resistivity $\rho(T)/\rho(300K)$ for the studied alloys. The resistivity for $x = 0.1$ exhibits normal metallic behaviour. Comparison of the behaviour with that of UAl_2 [5] indicates that the spin-fluctuation scattering is weakened by the Y-substitution.

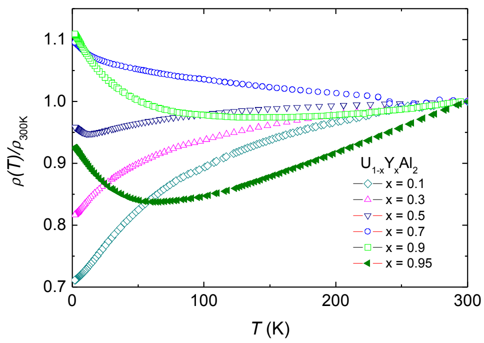

Fig. 1 Temperature dependence of the resistivity of $U_{1-x}Y_xAl_2$.

As the Y concentration x is increased up to 0.7, the ratio $\rho(2K)/\rho(300K)$ gradually increases. At the first glance one attributes this to an atomic disorder effect. However, inspection of the derivative $d\rho(T)/dT$ reveals a dramatic change. With increasing x, $d\rho(T)/dT$ decreases and even changes its sign to the negative value at $x = 0.5$, thus signalling the development of the Kondo effect. This effect distinctly occurs for $x = 0.9$ and 0.95.

Displayed in Fig. 2 are plots of $(\rho(T) - \rho_0)$ as a function of temperature between 2–20 K, where ρ_0 is the residual resistivity. The ln–ln plot of the data clearly expresses a power law $|\rho(T)-\rho_0| \sim T^n$ behaviour of the resistivity at low temperatures. The exponent n varies with x, taking values of 2, 1.5, 1.5, 1.3, 1.0, and 1.1 at $x = 0.1$, 0.3, 0.5, 0.7, 0.9 and 0.95, respectively. The observed change of n with x may confirm the previously reported [1] evolution of the

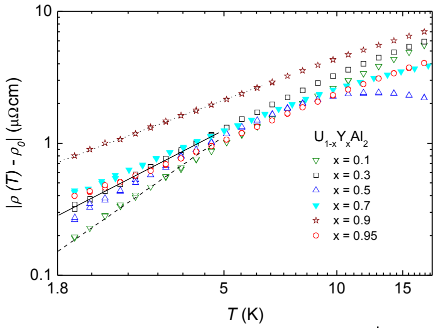

Fig.2 The ln-ln plot of the resistivity $|\rho(T)-\rho_0|$ vs T for $U_{1-x}Y_xAl_2$.

ground state, from the spin-fluctuation ($x = 0.1$) through the spin-glasses ($x = 0.3$–0.7) to non-Fermi-liquid state ($x = 0.9$ and 0.95). However, the explanation for nFL due to a magnetic instability is not consistent with the magnetoresistance data. For instance,

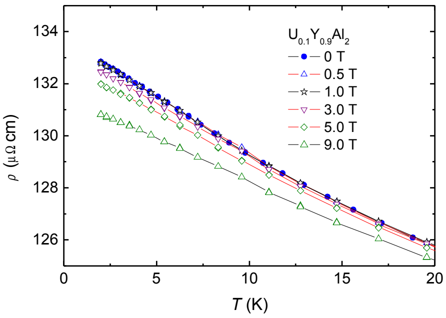

Fig. 3 The electrical resistivity of $U_{0.1}Y_{0.9}Al_2$ in various magnetic fields.

the resistivity for $x = 0.9$ (Fig. 3), seems to be weakly sensitive to magnetic fields. Thus, it is in contrast to the behaviour of $CeCu_{5.9}Au_{0.1}$ [6] being the nFL system associated with magnetic instability. For the latter compound, the resistivity and specific heat are extremely sensitive to applied magnetic fields.

The thermoelectric power S of the studied samples of $U_{1-x}Y_xAl_2$ is shown in Fig. 4. Observed enhancement in *TEP* for $x \le 0.3$ is due to the contribution of spin-fluctuation scattering. On the opposite side, the $S(T)$ dependence of $x = 0.9$ and 0.95 can be ascribed to a Kondo system. The most important finding of our study is, however, the observation of the transition from the Fermi-liquid behaviour with the $S \sim AT$ relation to nFL behaviour with the $S \sim AT^{1/2}$ dependence (see bottom panel of Fig. 4).

It is worthwhile to mention that the $T^{1/2}$ law was predicted by Cox [7] for the two-channel Kondo effect.

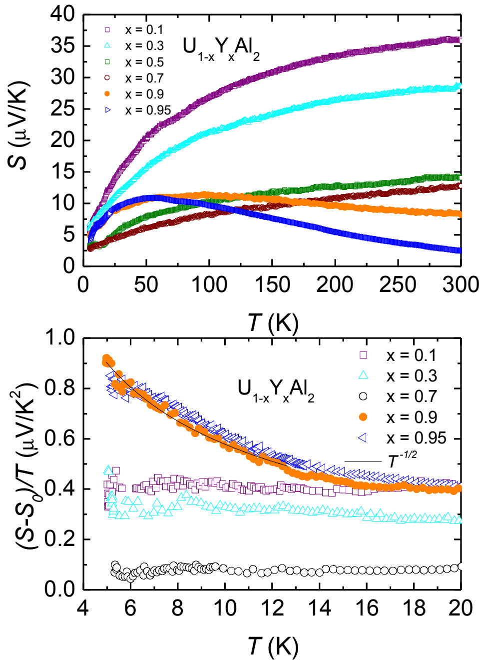

Fig. 4 Thermoelectric power (upper panel) and the ratio $(S(T)\text{-}S_0)/T$ (bottom panel) of $U_{1-x}Y_xAl_2$ as a function of temperature. S_0 is the residual *TEP*.

In conclusion, the Kondo-effect in $\rho(T)$ and in $S(T)$ together with weakly field dependence of $\rho(T)$ suggest that the nFL state for $x = 0.9$ and 0.95 may not be interpreted with a magnetic instability.

We propose two-channel Kondo effect as possible origin for the nFL behaviour.

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References

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