DECOUPLING OF MAGNETIC GROUND STATE AND ELECTRONIC TRANSPORT PROPERTIES IN URh_2Ge_2*

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We present a study of the susceptibility and electronic transport properties of the alloying series $URh_2Ge_{2-x}Sn_x$, $x \leq 0.1$. The magnetic behavior varies as function of x from an antiferromagnetic to a spin glass ground state. In contrast, the electronic transport does not correspondingly reflect the modification of the magnetic ground state properties. Instead, we argue that it indicates diffusive transport for all samples, possibly related to disorder induced electronic localization.

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In recent years the effect of crystallographic disorder on the ground state properties of heavy fermion compounds has been studied intensively [1–5]. It has been found that moderate levels of disorder control the ground state properties of in particular uranium heavy fermion systems. It causes spin glass and disordered antiferromagnetic ground states in systems like U_2(Pd,Pt)Ga_3 [2], U_2(Pd,Pt,Au)Si_3 [3], URh_2Ge_2 [6] and affects the Non-Fermi-Liquid (NFL) properties of $UCu_{5-x}Pd_x$ [4,5].

For $UCu_{5-x}Pd_x$ the resistivity, which rises linearly upon approaching $T = 0$, has been interpreted in terms of NFL behavior: within the Kondo disorder model [7], the Griffiths-phase scenario [8] or on basis of conformal invariance scaling arguments [9]. For disordered antiferromagnetic systems the Kondo effect has been proposed to account for anomalous resistivity [2].

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Based on the similarity of the electronic conduction of materials with different magnetic ground states, an alternative view of the resistivity assumes that disorder induced electronic localization plays a role [1]. Here, we present further experiments on alloyed material URh_2Ge_2 in support of this argumentation. Our study demonstrates the decoupling between electrical conductivity and magnetic ground state properties, which for the alloying series $URh_2Ge_{2-x}Sn_x$ ranges from long-range magnetic order to a spin glass ground state.

Samples of nominal composition $URh_2Ge_{2-x}Sn_x$, $x = 0.02$, 0.04 and 0.1 have been produced by arc-melting the constituents in stoichiometric ratio under purified argon atmosphere on a water cooled copper crucible. No further heat treatment was applied to the samples. The polycrystalline buttons contain mm-sized preferentially oriented single crystalline grains.

Phase homogeneity was checked by means of Electron Micro Probe Analysis. It indicates that the samples consist of a majority phase plus a small volume fraction ($\sim 1\,\%$ volume amount) of μm-sized inclusions of a Sn rich secondary phase. For all samples U:Rh:Ge/Sn ratios of 1:2:2 are found within experimental resolution. However, the actual Sn content of the matrix is smaller than the nominal value x. For $x = 0.02$ a weak Sn signal too low for a quantitative evaluation ($< 0.5\,\%$) was detected in the matrix. For $x = 0.04$ and 0.1 Ge/Sn ratios of 1.99:0.01 and 1.93:0.07 are determined. Still, in the following we refer to the samples by their nominal composition.

Susceptibility experiments have been carried out using a Foner magnetometer between 5 and 300 K. Resistivity has been measured employing a standard four probe ac technique from 2 to 300 K.

In Figure 1 we plot the susceptibility of $URh_2Ge_{2-x}Sn_x$, $x = 0.02$, 0.04 and 0.1, measured in a field cooled (FC) and zero field cooled (ZFC) mode in $B = 0.05$ T. For comparison we include the result for single crystalline spin glass URh_2Ge_2, $B = 0.005\,\mathrm{T} \parallel a$ and c axes [6]. The absolute values χ for the polycrystalline samples vary by a factor 2, but within the limits of the single crystalline data. It reflects pronounced preferential orientation of the polycrystals.

As previously noted [1], for stoichiometric material URh_2Ge_2 the magnetic ground state (spin glass or antiferromagnet) very sensitively depends on the sample production procedure. Here, under present production conditions we obtain an antiferromagnetic sample for $x = 0.02$, as indicated by an antiferromagnetic anomaly at $T_N = 13.3$ K without irreversibility between FC and ZFC measurement [10].

Increasing the Sn content increases the disorder level and stabilizes the spin glass ground state. Thus, for $x = 0.04$ we find coexistence of antiferromagnetic and spin glass phases, as corroborated by the antiferromagnetic anomaly at T_N and the onset of magnetic irreversibility below the freezing

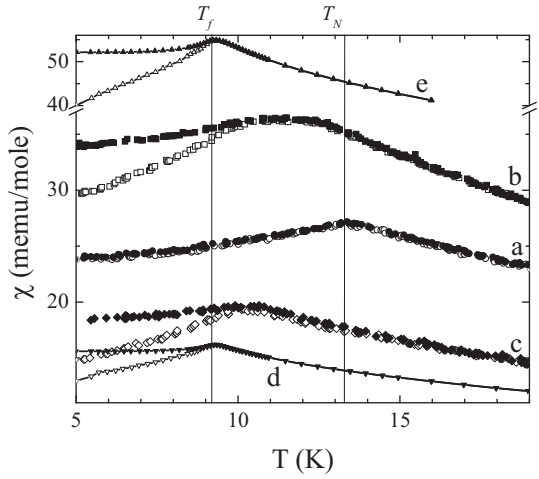

Fig. 1. Susceptibility of $URh_2Ge_{2-x}Sn_x$, $x = 0.02$ (a), 0.04 (b), 0.1 (c), and of single crystalline URh_2Ge_2, $B \parallel a$ (d) and c (e) axes, measured in field cooled (open symbols) and zero field cooled (filled symbols) mode.

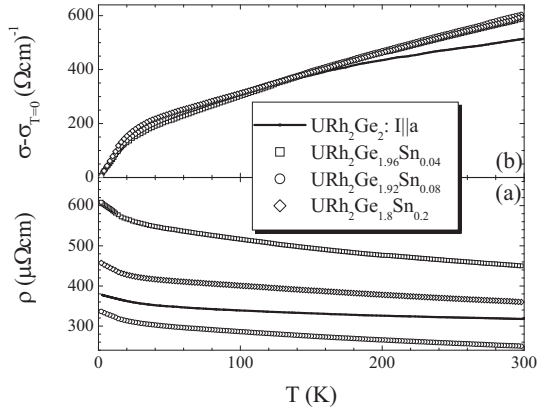

Fig. 2. The resistivity ρ (a) and reduced conductivity σ–$\sigma(T = 0)$ (b) of $URh_2Ge_{2-x}Sn_x$, $x = 0.02$, 0.04, 0.1 and single crystalline URh_2Ge_2 along the a axis.

temperature $T_f \sim 10$ K between FC and ZFC experiment. Finally, for $x = 0.1$ the susceptibility indicates pure spin glass behavior below T_f.

The tuning of the magnetic ground state properties is not reflected in the electronic transport properties. In figure 2(a) we plot the resistivity ρ of $URh_2Ge_{2-x}Sn_x$, $x = 0.02$, 0.04, 0.1, as function of temperature. For none of the samples we observe resistive anomalies at the antiferromagnetic and/or freezing transitions.

In the plot we include the a axis resistivity of a single crystalline specimen [10]. The comparison between poly- and single crystalline samples indicates that for the polycrystals ρ reflects preferential orientation, with the resistivity probing the easy resistance path along a.

The variation of the absolute resistivity values for $URh_2Ge_{2-x}Sn_x$ cannot be accounted for by Matthiesen's rule. Instead, as previously proposed [1], by plotting the reduced conductivity σ–$\sigma(T = 0)$, the data can be scaled onto a single curve (Fig. 2(b)). As well, with this procedure scaling with the a axis resistivity of the single crystal is achieved up to 200 K.

Our findings support the notion, that in these moderately disordered intermetallic uranium compounds the resistivity does not probe the magnetic ground state properties. The electronic transport processes are diffusive rather than ballistic, reflecting the failure of Matthiesen's rule. In consequence, the reduced conductivity σ–$\sigma(T = 0)$ represents the relevant quantity for the temperature dependence of the electronic transport mechanisms.

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