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ELECTRICAL RESISTIVITY OF $U_xTh_{1-x}Sb$ (x=0, 0.05, 030, 0.34, 0.97, 1) FROM 2 TO 1000 K

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Abstract: We report new electrical resistivity measurements from 2 to 1000 K on various pseudo–binary $U_xTh_{1-x}Sb$ single crystals, showing evidence for Kondo scattering in the paramagnetic phase of most concentrations.

1. Introduction

Antiferromagnetic USb and weakly paramagnetic ThSb form solid solutions showing a large variety of magnetic structures [1]. Thus, for uranium concentrations x above about 0.3 ferromagnetic order sets in. For x exceeding 0.8 antiferromagnetism is found. In the past, electrical resistivity measurements have been performed for x = 0, 0.14, 0.67, 0.9 and 1 in the temperature range 2 to 300 K [2]. These measurements indicated Kondo behavior for x = 0.14, a typical ferromagnetic electron–magnon resistivity for x = 0.67 and Brillouin zone folding in the antiferromagnets with x = 0.90 and 1. To study the competition between intraatomic Kondo interaction and interatomic exchange leading to magnetic ordering we have performed new electrical resistivity measurements extending up to 1000 K. The chosen uranium concentrations include a very diluted compound with x = 0.05, two compounds at the border line to ferromagnetic order (x = 0.30 and 0.34), a strongly antiferromagnetic compound (x = 0.97) and the two pure compounds ThSb and USb.

2. Results and Discussion

Pure ThSb shows for T > 20 K a linear dependence of the electrical resistivity on temperature. A substitution of 5% thorium by uranium leads to a negative $d\rho/dT$ for T < 80 K and an asymptotic approach of $\rho(T)$ to the x = 0 curve for the highest temperatures. For this compound, as well as for the pseudo–binary compounds with higher uranium concentration in the paramagnetic temperature range, we have made fits with the expression:

$$\rho(T) = \rho_o + c_{ph}T + c_K \ln T \qquad (1)$$

where ρ_o is a constant term including besides the residual resistivity a term which is proportional to the spin disorder–resistivity, c_{ph} is the electron–phonon coefficient and $c_K \ln T$ is the Kondo term. For $x = 0.05$ we find some deviations from eq. (1) which might be signs of clustering of Kondo centers. For $x = 0.30$ and $x = 0.34$ we observe very similar $\rho(T)$ curves for $T > 300$ K and good fits with eq. (1) using the same parameters c_{ph} and c_K are possible. However, for $x = 0.30$ $\rho(T)$ continues to increase with decreasing temperature also for $T < 300$, while for $x = 0.34$ $d\rho/dT$ is reversed for $T < 140$ K, indicating the onset of ferromagnetic order at still lower temperature. For the sample with $x = 0.97$ we find a large peak in $\rho(T)$ at 180 K and a negative temperature derivative up to 1000 K. Besides the strong deviations of $\rho(T)$ from eq. (1) in the neighborhood of and below T_N, we note further deviations in the 500–600 K temperature range.

The resistivity measurements up to 1000 K evidence Kondo behavior in the paramagnetic phases of those compounds which stay paramagnetic to the lowest temperatures and of those which order ferromagnetically. These are also those compounds having large free carrier concentrations, because every thorium atom contributes roughly one conduction electron. Both facts together indicate that in this concentration range the roughly linear decrease of the ordered magnetic moment with increasing thorium concentration is due to a partial compensation of the bare 5f moment by a cloud of conduction electrons and the formation of f–d hybridized, (medium heavy?) quasiparticles. It is therefore to be expected that the electronic part of the specific heat exceeds for the pseudo–binaries the values of the pure compounds. For x near 1 the free carrier concentration is rather low and mixing of the $5f^3$ state with p–valence electrons will dominate. The weak bump in $\rho(T)$ around 500 – 600 K may be an effect of crystal field splitting.

3. References

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