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TRANSPORT PROPERTIES OF THE $U_{1-x}Th_xPt$ SYSTEM

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We present the results of measurements of electrical resistivity ($\rho(T)$) and magnetoresistance ($\Delta\varrho/\varrho_0(T)$) on the solid solutions $U_{1-x}Th_xPt$ ($x = 0-0.8$). The Curie temperature ($T_C = 21$ K) found for the parent compound UPt, is steadily reduced upon the Th-substitution. The $\rho(T)$ and $\Delta\varrho/\varrho_0(T)$ functions provide evidence of electron scattering due to spin fluctuations. The most interesting feature of $\Delta\varrho/\varrho_0$ is its high value of about -22% found for UPt and $U_{0.9}Th_{0.1}Pt$ at their T_C and $B = 8$ T. For samples with $x \geq 0.2$, the value of $\Delta\varrho/\varrho_0$ at 4 K and 8 T increases with x and becomes positive for Th-composition $x \geq 0.6$.

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The uranium intermetallic compound UPt was reported to crystallise either in the orthorhombic CrB-type structure [1, 2] or in the monoclinic PdBi-type structure [3]. This material was studied thoroughly by means of magnetisation [4–7], electrical resistivity [6–10], specific heat [5–7, 11–13], and neutron diffraction measurements [2, 6, 12]. On this basis, two magnetic transitions into a ferromagnetic state at 27 K and 19 K have been inferred for this compound by some authors [4–13]. So far, no systematic investigations of the magnetic properties have been done in cases of the dilution of U by non-magnetic metal, as for instance Th. Therefore, we have studied such solid solutions $U_{1-x}Th_xPt$ for $0 \leq x \leq 1$. The detailed results of structural, magnetic, and thermal properties of this system will be published elsewhere [14]. In this work we have focused mainly on the electrical resistivity and magnetoresistance (MR) investigations.

The $U_{1-x}Th_xPt$ samples with $x = 0, 0.1, 0.2, 0.4, 0.6$, and 0.8 were prepared by arc melting the appropriate amounts of the high-purity metals under an argon atmosphere with further annealing for a week at 900°C. Weight losses were checked to be within 0.5% mass. The X-ray diffraction analysis of all these samples has proved them to be single phase. However, for UPt we could not decide which crystal structure type, i.e. the CrB or PdBi one is the proper one, while for the remaining solid solutions, the crystal structure is certainly of the orthorhombic CrB-type. The electrical resistivity $\varrho(T)$ was measured using a standard dc-four-probe method in the temperature range between 1.5–290 K. The magnetoresistance data, $\Delta\varrho/\varrho_0 = [\varrho(B,T) - \varrho(0,T)]/\varrho(0,T)$, were recorded in the temperature range 4.2–100 K and at a fixed magnetic field of 8 T.

Shown in Fig. 1a are the temperature dependencies of the normalised resistivity, $\varrho(T)/\varrho(290\ \mathrm{K})$, for several selected solid solutions $U_{1-x}Th_xPt$. We recall first some features observed previously in the resistivity of UPt. According to previous researches [6–10], the electrical resistivity of UPt exhibits two distinguishable temperature zones. In the paramagnetic zone (> 50 K), the resistivity is weakly temperature dependent, while in the magnetically ordered state zone (< 30 K) the resistivity drops dramatically and its low-temperature part is characterised by either a quadratic variation of $\rho_0 + AT^2$ [6, 9] or of more complex one $\rho_0 + BT^2 + c\Delta T(1+2T)\exp(-\Delta/T)$ [7] (A, B, and c are the constants of the electron–phonon and electron–magnon couplings, respectively, while Δ is a gap in the dispersion relation of magnons).

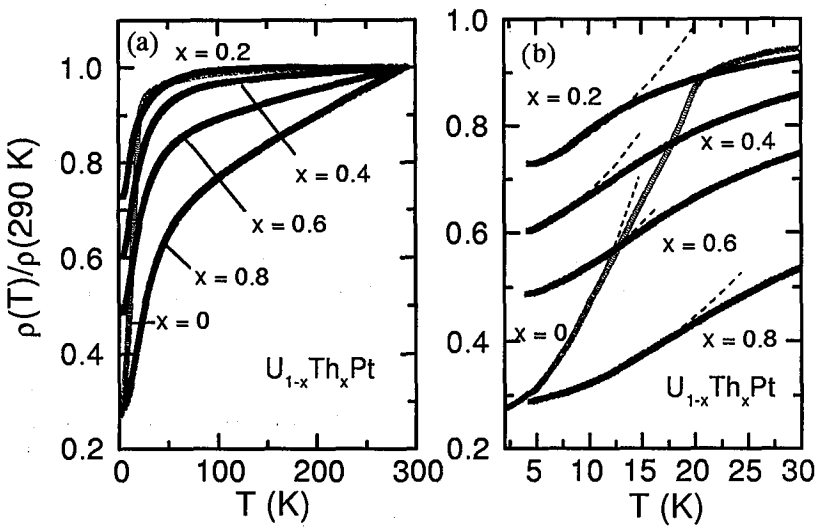

Fig. 1. (a) Temperature dependence of the normalised resistivity $\varrho(T)/\varrho(290\ \mathrm{K})$ for various samples of $U_{1-x}Th_xPt$. (b) The low-temperature part of $\varrho(T)/\varrho(290\ \mathrm{K})$ vs. T. The dashed lines are fits of experimental data to AT^2 law.

The resistivity behaviour of our UPt sample, in general, is similar to the data reported in Refs. [6] and [9]. There is almost saturation in $\varrho(T)$ at high temperatures and a distinct decrease in this function below the magnetic ordering temperature due to a steady loss of spin-disorder contribution in the total resistivity. Between 1.5–8 K, the resistivity data could be well fitted using the nongapped dispersion relation of the $\rho_0 + AT^2$ type (see Fig. 1b), with $\rho_0 = 40.3\ \mu\Omega$ cm and $A = 0.30\ \mu\Omega$ cm/K^2. The latter value is comparable with those reported in the literature, i.e. 0.19 $\mu\Omega$ cm/K^2 [6] and 0.45 $\mu\Omega$ cm/K^2 [9]. The Curie temperature of our UPt sample, defined as a maximum in the derivative $\mathrm{d}\varrho(T)/\mathrm{d}T$, is 19.5 K. In contrast, the authors of Ref. [7] reported such an anomaly near 27 K, indicating the magnetic transition temperature, being not observed in our case.

We found that the effect of Th-substitution on the electrical resistivity of $U_{1-x}Th_xPt$ is significant. Firstly, the room temperature value of the resistivity decreases from 151 $\mu\Omega$ cm for UPt to 86 $\mu\Omega$ cm for $U_{0.2}Th_{0.8}Pt$. Secondly, with

increasing x the resistivity at high temperatures is becoming more temperature dependent, and being reminiscent of spin-fluctuation systems. At low temperatures, the experimental resistivity data could be fitted with the $\rho_0 + AT^2$ law (see Fig. 1b), reflecting again spin-fluctuation phenomena in the studied system. Furthermore, by doping of more than 20% Th, the anomaly associated with the magnetic transition becomes less pronounced. Hence, we have not been able to determine the transition temperature for Th-rich alloys by means of the derivative $\mathrm{d}\varrho(T)/\mathrm{d}T$. Nevertheless, as one can infer from the magnetic susceptibility (χ) measurements [14], the minimum of derivatives $\mathrm{d}\chi/\mathrm{d}T$, corresponding to the magnetic ordering temperatures for Th-substituted samples are continuously lowered, and they amount to 16.0, 13.6, 8.6, 6.0, and 4.5 K for $x = 0.1$, 0.2, 0.4, 0.6, and 0.8, respectively.

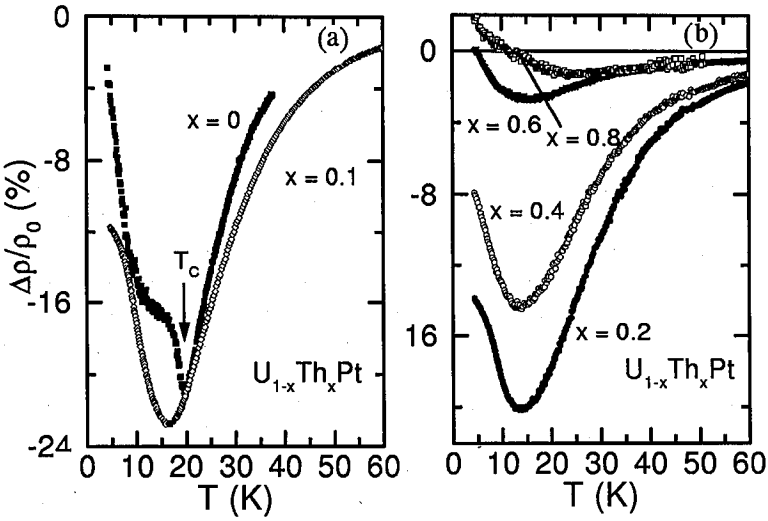

Fig. 2. Magnetoresistance, $\Delta\varrho/\varrho_0$, as a function of temperature for the solid solutions $U_{1-x}Th_xPt$ with the following concentrations: (a) $x = 0$, 0.1 and (b) $x = 0.2$, 0.4, 0.6, and 0.8.

Figure 2 shows the temperature dependencies of the magnetoresistance for the above compositions. As seen from this figure, MR for UPt and $U_{0.9}Th_{0.1}Pt$ (Fig. 2a) is as large as -22% at their T_C in applied magnetic field $B = 8$ T. We note that magnetoresistance at this temperature does not reach saturation in the maximum fields applied here. It appears also that the magnitude of MR is still large even in the paramagnetic state ($\Delta\varrho/\varrho_0 \approx -10\%$ at $2T_C$), implying an important effect of short-range correlations between the uranium atoms. An application of a magnetic field alters the correlation length and simultaneously enhances the mobility of charge carriers, which are associated with the so-called magnetic polarons. Such a concept has previously been proposed for interpreting the large negative magnetoresistance observed in metallic alloys GdNi [15] or in URhSi and URhGe [16] at T_C and very slow decay of MR in the paramagnetic state.

For more Th-doped samples, the response of the resistivity to the application of B is considerably weaker (Fig. 2b). $\Delta\varrho/\varrho_0$ of the $x = 0.2$, 0.4, and 0.6 samples attains in each case a minimum at about $T = 14$ K with the magnitudes of −20, −14 and −3%, respectively. We should also note that MR for $x \geq 0.2$ at 4 K and $B = 8$ T increases with increasing x and becomes positive for $x = 0.8$. This reveals the existence of at least two competing contributions to $\Delta\varrho/\varrho_0$: a positive contribution arising from the normal MR and a negative contribution resulting from the scattering of charge carriers by spin fluctuations and/or magnetic polarons in the presence of a magnetic field. The latter effects are strongly temperature dependent, giving rise to a large and negative contribution into $\Delta\varrho/\varrho_0$ at high temperatures, but almost negligible contribution at low temperatures. Because of a dominant contribution of the normal MR at low temperatures, the observed minimum in $\Delta\varrho/\varrho_0(T)$ is shifted to higher temperatures in respect of T_C.

In conclusion, we measured the temperature dependence of the electrical resistivity and the magnetoresistance for the solid solutions $U_{1-x}Th_xPt$ with $x = 0$, 0.1, 0.2, 0.4, 0.6, and 0.8. We conclude that the transport properties of these solid solutions are strongly affected by spin fluctuations and probably by magnetic polarons.

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