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MAGNETIC SUSCEPTIBILITY AND SPECIFIC HEAT STUDY ON THE
NONMAGNETIC TO MAGNETIC TRANSITION IN URh3Bx (0 ≤ x ≤ 1) SYSTEM

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Abstract. - Lattice parameter, susceptibility, specific heat and resistivity measurements are presented on URh3Bx (0 ≤ x ≤ 1). This alloy series exhibits a transition from an almost temperature independent paramagnet to a magnetic system. Results are interpreted in terms of U-5f Rh-4d dehybridization induced by boron addition.

One of the basic parameters dictating the properties of f-electron systems is the degree of hybridization of the f-electrons with the conduction band electrons [1]. The alloy system URh3Bx with 0 ≤ x ≤ 1 exhibits a transition from an itinerant paramagnet (x = 0) to an antiferromagnet (x = 1) in which the 5f hybridization effects can be studied in a continuous way as a function of x. URh3 is a temperature independent paramagnet [2] where the 5f electrons are itinerant, while URh3B exhibits a Curie-Weiss susceptibility and orders antiferromagnetically at 9.8 K [3] suggesting a more local nature of the 5f electrons.

URh3 and URh3B parents were prepared by arc melting in an argon atmosphere stoichiometric amounts of appropriate elements of higher than 99.9 % purity. X-ray patterns of both compounds showed single phase AuCu3 structure with lattice parameters of 3.98 Å and 4.14 Å respectively in agreement with previous studies [2, 3]. Parents were then cut into few pieces, mixed in the appropriate ratios and remelted to form the final URh3Bx alloys with 0 ≤ x ≤ 1. No second phases were detected by X-ray diffraction.

Lattice parameter measurements are shown in figure 1a. The lattice parameter increases almost linearly up to x ~ 0.8 after which the lattice parameter stabilizes. As stated above, careful X-ray studies for x > 0.8 indicate that these samples are single phase. Thus, the nonlinearity of the x-dependence of the lattice constant reflects that boron addition not only expands the lattice but also changes the electronic structure of the matrix presumably by bonding with the Rh atoms [4] and by adding electrons to the conduction band. Similar behavior was found in all the LRh3Bx where L = rare earth element [5].

Susceptibility measurements were done using a dc SQUID magnetometer in an external field of 10 kOe. The data (Fig. 2) was fitted to a Curie-Weiss susceptibility plus a constant, \( \chi = \chi_0 + C / (T - \theta) \). In figure 1b we show the fitted values for the high temperature paramagnetic moment and the Curie-Weiss temperature \( \theta \). The susceptibility data shows a cusp (Fig. 2) for x = 1.0 and x = 0.9 at \( T_N = 9.8 \) K and 6.8 K respectively. This magnetic anomaly is believed to be due to antiferromagnetic or spin glass-like ordering of the U ions. This speculation is supported by the fact that the high temperature paramagnetic moment, \( \mu_p = 3.2 \mu_B \), is close to that of the free uranium \( U^{3+,3+} \) ion (\( \mu_p = 3.6 \mu_B \)) and \( T_N \) decreases with field as expected for an antiferromagnet. The large negative values of \( \theta \) point to strong hybridization of the f-electrons, which decreases with increasing x.

From figure 1 we may divide the alloy series into three different regions; x ≤ 0.5, 0.5 < x < 0.8 and 0.8 ≤ x. In the first region, x ≤ 0.5, boron addition...
expands the lattice but the 5f electrons remain essentially itinerant. In the second region, 0.5 < x < 0.8, boron addition expands the lattice even further but the 5f electrons start to dehybridize as indicated by the increase of $\mu_p$ and $\theta$. At $x = 0.8$, $\mu_p = 3.2 \mu_B$ is almost that of the free uranium atom $U^{2+},^{3+}$. In the third region these quantities stabilize and clear evidence for a magnetic transition is seen in $\chi(T)$.

A change in slope in the resistivity is seen at temperatures close to $T_N$, as defined by the cusp in $\chi(T)$. This allows for an independent estimate of the magnetic ordering temperature shown in figure 1a. From there we see an increase in the transition temperature as a function of boron content with further stabilization at around $x = 0.8$. These results track the susceptibility ones and are further evidence of the dehybridization.

Finally, in figure 3 the specific heat $C_p$ is plotted as $C_p/T$ versus $T^2$ for URh$_3$B. The electronic contribution to $C_p$, i.e. $\gamma$, is enhanced by about one order of magnitude from 14 mJ/mole-K$^2$ to 114 mJ/mole-K$^2$. This increase in $\gamma$ also points towards a dehybridization of the 5f electrons induced by boron addition. Surprisingly, there is no anomaly in the specific heat of URh$_3$B as would be expected for an antiferromagnetic system. This result shadows the interpretation of the magnetic anomaly as originated from an antiferromagnetic ordering. Currently these studies are extended to include ac susceptibility, time-dependent magnetization and m"{o}ssbauer measurements to check for spin glass-like behavior.

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