MAGNETIC PROPERTIES OF $Ce(Rh_{1-x}Ru_x)_2Si_2$ SINGLE CRYSTALS FOR x UP TO 0.5*

P. Haen, F. Lapierre, P. Lejay,

CRTBT, CNRS, BP 166, Laboratoire associé à l'Université Joseph Fourier
38042 Grenoble cedex 9, France

T. Jaworska-Golab

M. Smoluchowski Institute of Physics, Jagellonian University
Reymonta 4, Kraków 30-059, Poland

C. Sekine

Department of Electrical and Electronic Engineering
Muroran Institute of Technology
27-1 Mizumoto-cho, Muroran 050-8585, Japan

and S. De Brion

LCMI, CNRS, BP 166
38042 Grenoble cedex 9, France

(Received July 10, 2002)

Magnetoresistance measurements performed at 4.2 K up to $B = 22$ T applied along the tetragonal c-axis on antiferromagnetic single crystalline $Ce(Rh_{1-x}Ru_x)_2Si_2$ solid solutions ($x = 0.05$, 0.1 and 0.2) are reported. The 4.2 K resistivity, *i.e.* the residual resistivity, ρ_0, is strongly reduced in 22 T, showing that the large increase of ρ_0 with x can not be attributed to disorder alone. The results evidence two transitions at fields B_{c_1} and B_{c_2} which correspond to metamagnetic transitions, similar to the two step transition occuring in $CeRh_2Si_2$ at 25.8 and 26.3 T, respectively. B_{c_1} and B_{c_2} decrease rapidly with increasing x, and their splitting increases (showing some analogy with measurements reported for Ge doped $CeRh_2Si_2$). These variations and the rapid decrease of T_{N_1} (which has vanished for $x = 0.35$), are discussed.

PACS numbers: 71.27.+a, 74.25.Fy, 74.25.Ha, 75.30.Kz

* Presented at the International Conference on Strongly Correlated Electron Systems, (SCES 02), Cracow, Poland, July 10–13, 2002.

1. Introduction

The properties of tetragonal compound $CeRh_2Si_2$ have attracted much attention: It shows antiferromagnetic (AF) order at $T_{N_1} = 36$ K [1, 2], whereas the occurence of additional magnetic lines below $T_{N_2} = 26$ K [2] is still a matter of discussion [3, 4]. It also exhibits a metamagnetic transition, occuring in two steps below T_{N_2}, at B_{c_1} and $B_{c_2} = 25.9$ and 26.3 T, respectively for the field B applied along the c-axis [5]. Several studies of $Ce(Rh_{1-x}Ru_x)_2Si_2$ solid solutions have been reported, either on polycrystals, for $x \geq 0.05$ [6], or on single crystals ($x = 0.2$ [7], $0.3 \leq x \leq 0.6$ [8–10]). No transition at T_{N_2} was detected and no high field measurements were performed in these studies. Thus, we have started new studies on $Ce(Rh_{1-x}Ru_x)_2Si_2$ single crystals. Here we report high field ($B \leq 22$ T) magnetoresistance (MR) results.

2. Experiments and results

$Ce(Rh_{1-x}Ru_x)_2Si_2$ single crystals ($x = 0$, 0.01, 0.05, 0.1, 0.2, 0.35, 0.42 0.48 and 0.5) were grown by the Czochralski method in a tri-arc furnace under purified argon atmosphere, starting from high purity elements. Measurements were performed on annealed pieces cut from these crystals. Our magnetic susceptibility data do not reveal any indication of the occurence of T_{N_2}, even for $x = 0.01$. For $x \leq 0.1$, we observe an almost exponential decrease of T_{N_1} on increasing x, in rough agreement with that reported for polycrystals [6]. For $x \geq 0.2$, our values differ from the former: We do not observe AF order for $x = 0.35$ down to 1.2 K, in agreement with the absence of AF order down to 0.04 K reported [10] for a $x = 0.4$ single crystal.

We performed resistivity, ρ(T), measurements down to 1.2 K. For single crystalline slices with the current i flowing along the a-axis (or simply inside the basal plane), ρ(1.2 K) increases from $\approx 2\ \mu\Omega$cm for $x = 0$, to 40 $\mu\Omega$cm for $x = 0.2$ (see [7]). For these ordered cases, ρ(1.2 K) represents almost the residual value, ρ_0. We measured the MR of these samples at 4.2 K in a 23 T Bitter coil for B parallel to the c-axis ($B \parallel c$). For $x = 0.05$, 0.1 and 0.2, the results are plotted in Fig. 1 under the form $\mathrm{d}\rho/\rho = (\rho(B)\text{-}\rho(B = 0))/\rho(B = 0)$. In all cases, $\mathrm{d}\rho/\rho$ shows first an increase (even a peak for $x = 0.2$), then a slow decrease, followed by a much more rapid drop. Thus, two transition fields can be determined, marked by arrows in Fig. 1, which we believe correspond to metamagnetic transitions similar to those occuring in $CeRh_2Si_2$. This justifies that we label them B_{c_1} and B_{c_2}. (For $x = 0$ and 0.01, we see huge initial increases of the MR, but we could not reach any transition field up to 23 T).

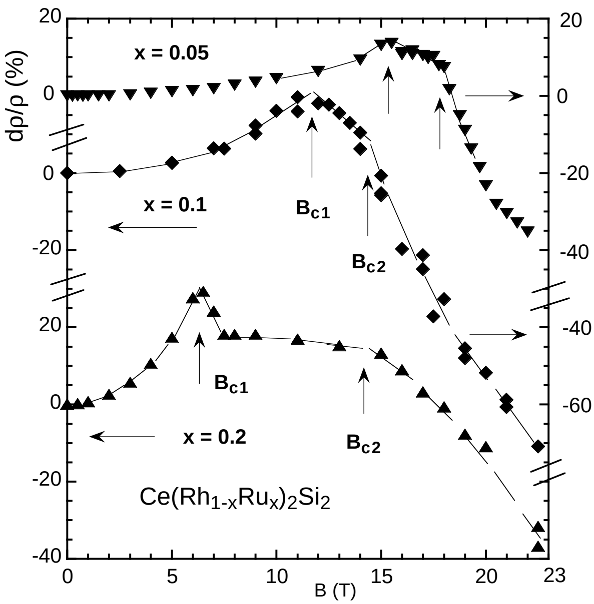

Fig. 1. Variations of dρ/ρ in Ce(Rh$_{1-x}$Ru$_x$)$_2$Si$_2$ single crystals (x = 0.05, 0.1 and 0.2) for $i \parallel a$ *vs.* $B \parallel c$. (Note the changes of scale.) Transition fields B_{c_1} and B_{c_2}2 are marked by arrows.

3. Discussion and conclusion

Fig. 1 first shows that ρ(4.2 K), which is also not far from ρ_0, is much smaller (more than 60 percent for $x = 0.1$) in 22 T than at $B = 0$. This means that the huge increase of ρ_0 with x does not arise exclusively from disorder and at least half of it is magnetic in origin. Thus, a more reasonable disorder contribution to ρ_0 of ≈ 1 $\mu\Omega$cm/%Ru can be estimated. The latter value is consistent with the ρ(1.2 K) values of 40-50 $\mu\Omega$cm, we obtain for our non-ordered samples ($0.35 \leq x \leq 0.5$). In these cases, ρ(T) is still largely decreasing at 1.2 K and ρ_0 is expected to be close to 35 $\mu\Omega$cm. The much larger value, $\rho_0 \approx 65$ $\mu\Omega$cm, reported [9] for $x = 0.5$ for the same current direction is surprising, considering that ρ_0 of only 17 $\mu\Omega$cm is reported for $i \parallel c$. Non-Fermi liquid properties were observed for $0.4 \leq x \leq 0.6$ [8–10].

Like T_{N_1}, B_{c_1} and B_{c_2} decrease rapidly with increasing x, especially for $x \leq 0.1$, and their splitting increases. Similar variations of B_{c_1} and B_{c_2} were observed in CeRh$_2$(Si$_{1-x}$Ge$_x$)$_2$ single crystals ($x \leq 0.5$) by magnetization measurements [11]. Unfortunately, to our knowledge, the variations of T_{N_1} were not reported for this system. These results, added to the rapid decreases of T_{N_1} (and T_{N_2}) under pressure [3, 12, 13] and the occurence of superconductivity when T_{N_1} vanishes [12,14], show the richness of the properties of $CeRh_2Si_2$. However, it seems difficult to get a consistent explanation of these variations by considering simply competition of Kondo effect and RKKY interactions in the framework of a Doniach diagram, knowing the large Kondo temperature values, $T_K = 35$ and 100 K, deduced from inelastic neutron scattering [15] and NMR experiments [16], respectively. Thus, more work is still needed to get a full understanding of the properties of $CeRh_2Si_2$.

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