Available online at www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER
Physica B 359–361 (2005) 278–280
PHYSICA B
www.elsevier.com/locate/physb

Comparison of the effects of chemical and mechanical pressure in $CeCoGe_{3-x}Si_x$ alloys

Anja Rosch[a], S.N. de Medeiros[b], M.B. Fontes[b], E.M. Baggio-Saitovitch[b], A. Eichler[a,*]

[a]*Institut für Technische Physik, TU Braunschweig, Mendelssohnstrasse, 38106 Braunschweig, Germany*
[b]*Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, RJ 22290-180, Brazil*

Abstract

The system $CeCoGe_{3-x}Si_x$ is of special interest since there is evidence that a quantum critical point of the antiferromagnetic phase can be approached by alloying as well as by application of high pressure.

With new results of AC-susceptibility and specific heat measurements on $CeCoGe_{2.1}Si_{0.9}$ under high pressure presented here, we show by comparison with former data that the tuning parameters composition and pressure, respectively, are equivalent. Alloy and pressure data fit in a common phase diagram. The quantitative behavior of c/T under pressure, too, corresponds to that under changes of composition.

PACS: 71.27.+a; 75.30.Mb; 75.40.Cx

Keywords: $CeCoGe_{3-x}Si_x$; Magnetic phase diagram; High pressure

The alloy system $CeCoGe_{3-x}Si_x$ has been extensively studied with respect to its magnetic order [1,2]. In investigations on resistivity, susceptibility, and specific heat of the alloys [2,3] a quantum critical (QC) region with non-Fermi liquid (NFL) properties was made out for $1<x<1.5$. Because of a change to short-range order (SRO) and possible disorder effects [4] no explicit value of a critical concentration was given. Since substituting Ge by Si reduces the lattice constants [2] pressure appears to be another means to reach the QC region. Often, pressure experiments represent the "cleaner" method, as they do not introduce atomic disorder whose influence on the QC point and the NFL properties is not yet well understood. But QCPs often fall into high-pressure regions where quantitative measurements by sophisticated methods like calorimetry e.g. are

*Corresponding author. Tel.: +49 531 3918502; fax: +49 531 3918511.
E-mail address: a.eichler@tu-bs.de (A. Eichler).

0921-4526/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.physb.2005.01.098

very difficult. Tuning both x and p presents itself as an acceptable compromise. If p and x effects turn out to be equivalent, like in $CeCu_{6-x}Au_x$ e.g. Ref. [5], disorder apparently is of minor importance. Former pressure studies on $x = 0.75$ yielded an approach to $T_N = 0$ near 0.8 GPa [6].

Here we present results on the alloy $CeCoGe_{3-x}Si_x$ with $x = 0.9$ which is closer to the critical region but still below the occurrence of SRO [2]. We have studied two slightly different polycrystalline batches ($\Delta x \sim 0.05$ corresponding to $\Delta p \sim$ 0.15 GPa, see below) by AC-susceptibility and specific heat under pressure. The results of $T_N(p)$ are shown in Fig. 1. Since the procedures to extract T_N from c/T and χ lead to systematically differing values, a normalization to χ_{AC} at $p = 0$ was used (similarly as in Ref. [2]). The data follow a phase transition curve $T_N = 5.3(p_c - p)^{2/3}$ (T_N in K, p in GPa), typical for a 3d AFM, extrapolating to $p_c =$ 0.6 GPa. The results on $\chi_{AC}(p)$ of $x = 0.75$ [6] are in accord with this curve if the scaling between p and x is chosen as $\Delta p/\Delta x \sim 3.5$ GPa.

Fig. 2 shows the results of AC calorimetry at some selected pressures. The λ-like singularity at $p = 0$ is rapidly lowered and smeared with p while the low temperature (LT) values of c/T rise as is often observed in approaching a QCP. At 0.5 GPa (not shown) and 0.55 GPa, the highest pressure reached, it is no more possible to extract T_N reliably. Slight bends in the data below 1.5 K remind one of the behavior found by Eom et al. [2,3], attributed to SRO.

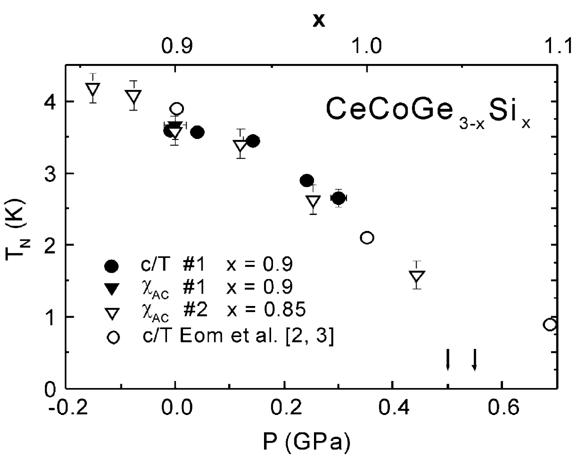

Fig. 1. Néel temperatures of $CeCoGe_{3-x}Si_x$ close to $x = 0.9$ as a function of pressure p or Si-concentration x. At 0.5 GPa and 0.55 GPa (arrows) no ordering transition could be seen in the c/T data. Results on alloys by Eom et al. at $x = 1$ and 1.1 are taken from the kink in $\chi(T)$ which is believed to be a sign of SRO [3].

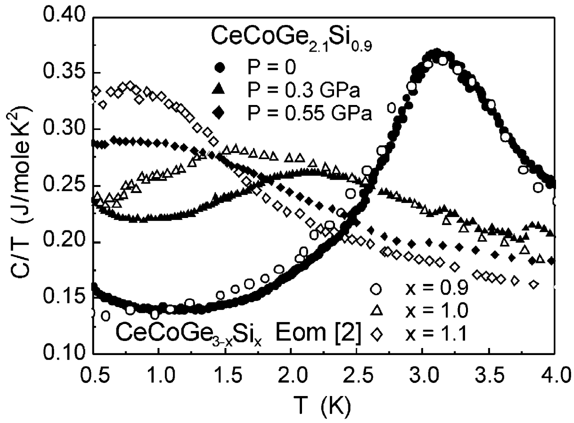

Fig. 2. Specific heat of $CeCoGe_{3-x}Si_x$ alloys at zero pressure (open symbols [2]) and under pressure (full symbols). For clarity the data points at 0.55 GPa are shifted downward by $\Delta c/T = 0.025\,J/mol\,K^2$.

Fig. 2 also shows c/T data on alloys taken from Ref. [2]. The similarity between selected p and x data confirms our scaling $\Delta p/\Delta x = 3.5$ GPa. Differences in the absolute values may result from the AC calorimetry used. A LT upturn in our data develops which is not uncommon in systems close to a QCP but cannot be explained at the time. The question if the correspondence continues to higher pressures (or Si-concentrations, respectively) is still open. In the alloys the electronic specific heat γ reaches a distinct maximum (which is often correlated with a QCP) at $x = 1.25$ [2]. Starting from $x = 0.9$ pressures of about 1.3 GPa are required to get into this state. As a preliminary attempt to "extend" our limited pressures we have applied additional magnetic fields $\leqslant 2$ T. A continued increase of γ is observed even beyond the maximum value of Eom [2], not being understood at present.

In summary we have found a close correspondence between pressure data on $CeCoGe_{2.1}Si_{0.9}$ and results on different alloys $CeCoGe_{3-x}Si_x$ for $x \leqslant 1$ representing a good argument for the equivalence of chemical and mechanical pressure in these materials. This gives reason to reconsider the assumption that beyond $x = 1$ only SRO is observed [2]. Our results would mean that SRO can also be induced by pressure and is not a mere result of increasing site disorder by alloying. To explore this question in more detail experiments at higher pressures combined with magnetic fields are planned.

References

[1] V.K. Pecharsky, et al., Phys. Rev. B 47 (1993) 11839.
[2] D. Eom, et al., J. Phys. Soc. Japan 67 (1998) 2495.
[3] D.H. Eom, et al., Physica B 281&282 (2000) 369.
[4] V.V. Krishnamurty, et al., Physica B 289–290 (2000) 47.
[5] B. Bogenberger, H.V. Löhneysen, Phys. Rev. Lett. 74 (1995) 1016.
[6] S.N. de Medeiros, et al., Physica B 281&282 (2000) 34.