Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Journal of Magnetism and Magnetic Materials 272–276 (2004) 54–55
journal of magnetism and magnetic materials
www.elsevier.com/locate/jmmm

Quantum critical point in ferromagnetic Kondo lattice CePt at high pressure

J. Larrea J[a,*], T. Burghardt[b], A. Eichler[b], M. B. Fontes[a], A. D. Alvarenga[a], E. Baggio-Saitovitch[a]

[a] *Centro Brasileiro de Pesquisas Físicas, Rua Dr. Xavier Sigaud 150, Urca Rio de Janeiro 22 290-180, RJ, Brazil*
[b] *Institut für Technische Physik, Technische Universität Braunschweig, Mendelssohnstr. 2, D-38106 Braunschweig, Germany*

Abstract

We report on measurements of the (AC) magnetic susceptibility and the electrical resistance of the ferromagnetic compound CePt under pressures up to ~14 GPa. The Curie temperature T_C is found to decrease rapidly beyond 11 GPa approaching a quantum critical point (QCP) between 11 and 12 GPa. Close to that QCP the resistance depends linearly on the temperature over two decades indicating non-Fermi liquid (NFL) behaviour. At higher pressures a T^2 power law starts to develop as a hallmark of Fermi liquid (FL) behaviour.

PACS: 75.30.Mb; 75.40.−s; 62.50.+p

Keywords: CePt; Curie temperature; High pressure; Quantum critical point; Resistance

One focus of recent research is the search for materials showing quantum critical points (QCP) and the investigation of concomitant non-Fermi liquid properties. When the ordering temperature of a magnetic phase is driven to zero temperature by means of a control parameter like chemical composition or high pressure, e.g., the materials' properties will be dominated by quantum fluctuations of this phase transition. As a consequence anomalous temperature dependences of macroscopic quantities like specific heat, magnetic susceptibility, and electrical resistivity are found in the vicinity of the QCP. When the control parameter is tuned further away from the critical point the usual hallmarks of Fermi liquid behaviour are increasingly restored [1].

This scenario of a quantum critical point is independent from the type of magnetic order in the magnetic phase. There are just differences in the anomalous temperature laws if the magnetic order is FM or AFM, respectively. But opposite to an overwhelming number of AFM materials, which can be driven close to a QCP there are only few FM examples [1]. Not only that there exist just few FM Kondo lattice systems at all, but often they also have peculiar phase diagrams with competing AFM phases neighbouring or embedding the FM state [2,3]. So, a direct transition from the FM phase to the paramagnetic (PM) state is not frequently observed.

Since long CePt (orthorhombic CrB structure) is known as a FM compound with some Kondo screening [4]. Its Curie temperature $T_C \sim 6$ K was found to increase under pressure up to 3.2 GPa [5] similarly to the behaviour of isostructural $CePt_{1-x}Ni_x$ alloys, where T_C reaches a maximum of 8.8 K before it steeply drops and disappears close to $x \geqslant 0.9$; CeNi is known to be intermediate valent [6,7]. Since the lattice parameters decrease with the Ni content the alloys' behaviour can be at least partially interpreted as a consequence of chemical pressure.

We have performed high pressure experiments on polycrystalline CePt samples prepared by arc melting in purified argon and heat treated at 700°C for one week. Our aim was to find out if $T_C(p)$ will break down in a

*Corresponding author. Tel.: +55-21-25867182; fax: +55-21-25867540.
E-mail addresses: jlarreaj@cbpf.br (J. Larrea J), a.eichler@tu-bs.de (A. Eichler).

0304-8853/$ - see front matter
doi:10.1016/j.jmmm.2003.11.053

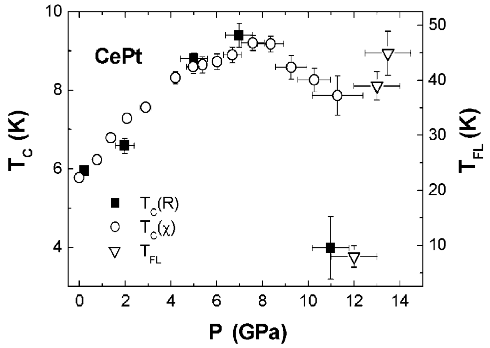

Fig. 1. Pressure dependence of Curie temperature T_C and crossover temperature to Fermi liquid behaviour T_{FL}.

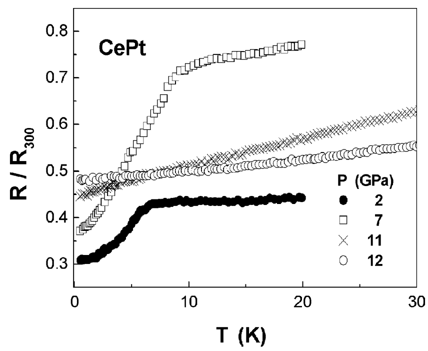

Fig. 2. Temperature dependence of the resistance of CePt at different selected pressures.

similar rapid way as $T(x)$ and to study—if possible—the behaviour of CePt near a QCP, if it exists.

The electrical resistance R of CePt was measured in a Bridgman anvil cell using steatite as transmitting medium and a lead strip as an internal manometer. Temperatures extended from ~40 mK to room temperature. In addition we have determined T_C by AC-susceptibility measurements in a diamond anvil cell using a non-magnetic CuBe gasket filled with a liquid transmitting medium. Again lead was used as manometer.

Both experiments agree well in showing an increase of T_C under pressure up to 9.3 K around 8.5 GPa (Fig. 1), the slope being not as steep as found by Itoh et al. [5]. Beyond that pressure the decrease of T_C sets in as shown by the susceptibility data. The amplitude of the AC-signal has already diminished by one order of magnitude at 8.5 GPa signaling a decrease of the ordered moment as an obvious consequence of the augmented Kondo interaction. Since the shape of the AC-signal does not alter to the highest pressure, there is no evidence that the type of magnetic order has changed. The susceptibility measurements have not been extended beyond 11.4 GPa, which is close to the stability limit of our rather soft gasket. At this pressure the T_C-values as determined by χ (7.8 K) and R (4 K), respectively, differ markedly. We take this as evidence for a very steep drop of T_C between 11 and 12 GPa. The pressure deviations between the two techniques using different pressure media thus may lead to large differences in the T_C-values measured. It is in this pressure range where the QCP has to be located.

In the $R(T)$ dependence T_C shows up with a clear-cut bend which becomes weak at 11 GPa and definitely disappears at higher pressures. In the FM phase at low temperatures $R(T)$ can be fitted exponentially indicating the presence of a spin wave excitation gap in a FM ordered system [8]. There, too, we have found no indications for a change in the type of magnetic order. The pressure dependence of this gap parallels that of T_C (Fig. 2).

While at 11 GPa $R(T)$ above T_C varies linearly with T over two decades of the temperature, at higher pressures a T^2 Fermi liquid behaviour develops. Its upper temperature limit T_{FL} increases from 9 K at 12 GPa to ~45 K at 13.5 GPa indicating that the system is being tuned away from the quantum critical region. At the same time the prefactor A of the T^2 law decreases by an order of magnitude as it is expected for moving away from a QCP.

In summary, we have shown that the FM order in CePt can be quenched under high pressure, too. A QCP near 12 GPa separates the FM from the PM state. Close to that pressure $R \propto T$ is found, as typical for NFL behaviour. At higher pressures a Fermi liquid state is developing T_C.

We wish to thank F. Vollrath for the assistance in preparing the material and M.A. Continentino for many helpful discussions. The support of this collaboration by CAPES, CNPq, and DAAD is gratefully acknowledged.

References

[1] G. Stewart, Rev. Mod. Phys. 73 (2001) 797.
[2] H. Wilhelm, et al., Sol. State Commun. 106 (1998) 239.
[3] T. Burghardt, et al., Physica B 259–261 (1999) 99.
[4] B.J. Holt, et al., Physica B 107 (1981) 255.
[5] Y. Itoh, et al., J. Phys. Soc. Jpn. 56 (1987) 1159.
[6] D. Gignoux, J.C. Gómez Sal, Phys. Rev. B 30 (1984) 3967.
[7] J.A. Blanco, et al., Phys. Rev. B 49 (1994) 15126.
[8] M.A. Continentino, et al., Phys. Rev. B 64 (2001) 012404.