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Pressure dependence of the superconducting transition temperature of $MgCNi_3$

G. Garbarino [a,b], M. Monteverde [b], M. Núñez-Regueiro [a,1], C. Acha [b,*], R. Weht [c], T. He [d], K.A. Regan [d], N. Rogado [d], M. Hayward [d], R.J. Cava [d]

[a] Centre de Recherches sur les Très Basses Températures, C.N.R.S., 25 Avenue des Martyrs, BP 166, 38042 Grenoble cedex 9, France
[b] Lab. de Bajas Temperaturas, Depto. de Física—FCEyN—UBA, Ciudad Universitaria, PAB I (C1428EHA) Buenos Aires, Argentina
[c] Departamento de Física, CNEA, Avda. General Paz y Constituyentes, 1650 San Martin, Argentina
[d] Department of Chemistry and Materials Institute, Princeton University, Princeton, NJ 08544, USA

Abstract

The new superconductor $MgCNi_3$ with a $T_C \sim 8$ K is an interesting candidate for non-conventional superconductivity as it is in the borderline of ferromagnetism. We have performed a systematic study of several samples of this compound under pressures up to 25 GPa, measuring the electrical resistivity between 1 and 300 K. We observe a slight increase of the critical superconducting transition temperature at high pressures. Our results are compared with the evolution under pressure of the calculated electronic band structure.

Keywords: Pressure effects; Superconductivity

The recent discovery [1] of superconductivity at 8 K in the intermetallic perovskite $MgCNi_3$ has raised questions about the origin of superconductivity in this material. First, it has to be remarked that this compound has the same perovskite structure as many interesting oxides. Also, as it has a large proportion of Ni per unit cell, magnetic fluctuations can be expected to play a role. Most interesting is the fact that the Fermi level lies in the vicinity of a large peak of the electronic density of states suggesting that this material is near a ferromagnetic state, as has be predicted for a hole doping [2]. The question of unconventional superconducting is then relevant, though the evidence gathered up to now is not definitive. In this note we report measurements of the electrical resistivity and the variation of the superconducting transition temperature (T_C) under pressure.

Four probe d.c. electrical resistivity measurements were performed in a sintered diamond Bridgman anvil apparatus. Samples were fabricated as described elsewhere [1], and different stoichiometries were measured: S1 a polycrystal, S2 a powder, S3 a polycrystalline sample with an excess of Ni and S4 similar to S3 but without Ni.

On Fig. 1 we have plotted the evolution of T_C. We observe a different value of T_C at ambient pressure for each sample, that can be attributed to a different carbon concentration [3]. For a lower T_C sample a small decrease followed by an increase above 2 GPa has been reported [4] and related to a possible phase transition. Starting at higher pressures, we observe in our samples a monotonous increase of T_C with pressure. We note that for all the samples at high pressure $\mathrm{d}\ln T_C/\mathrm{d}P$ is practically the same.

It is known that the standard behavior for *s–p* superconductors is a decrease of T_C with pressure due to the pressure stiffening of the lattice. While the

* Corresponding authors. Fax: +54-1145763357.
E-mail addresses: nunez@grenoble.cnrs.fr (M. Núñez-Regueiro), acha@df.uba.ar (C. Acha).
[1] Fax: +33-476-875060

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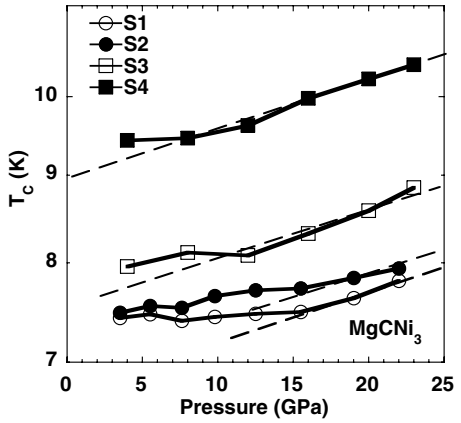

Fig. 1. Pressure dependence of the superconducting transition temperature T_C (in logarithmic scale) for different samples.

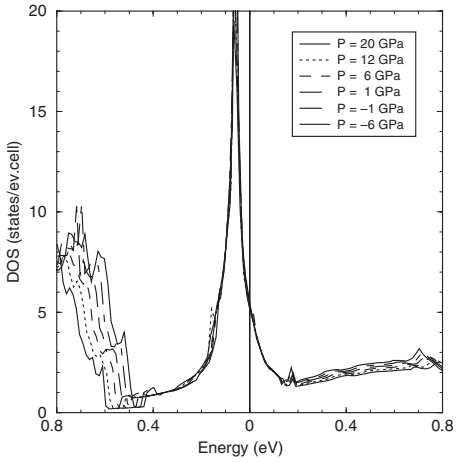

Fig. 2. Evolution of the density of states of $MgCNi_3$ with pressure. Note that there is no visible change at the Fermi level.

peculiarities of transition metals can yield an increase of T_C with pressure. In particular, an increase of the density of states at the Fermi level with pressure. We have done preliminary Hall constant measurements under pressure. We have found that the Hall constant seems to be rather insensitive to pressure with an apparent small increase of the density of carriers of a few percents [5]. However, the important parameter for T_C is the density of states at the Fermi level. Thus, electronic density of state calculations as a function of compression were done using the method described in Ref. [2]. The results are shown in Fig. 2. It is clear from the calculations that no sensible variation of the density of states is expected under pressure. We conclude that the increase of T_C does not follow from a variation in the density of states at the Fermi level. Due to the neighborhood of the ferromagnetic state suggested by the band structure calculations, we can speculate that the increase of T_C could be due to a reduction of the magnetic character of this material, i.e. pressure suppression of spin fluctuations, with the concomitant strengthening of the superconducting state. Another possible origin of the increase of T_C could be the vicinity of a structural transition at higher pressures inducing a phonon softening that would increase the electron–phonon interaction. In fact, it has been reported from EXAFS measurements that the compound shows below 70 K a distortion from the perfect cubic lattice [6]. And ab initio calculations have shown that numerous phonons can render the cubic perovskite structure unstable [6]. A study of the evolution of the structure with pressure is then necessary to clarify this point.

References

[1] T. He, Q. Huang, A.P. Ramirez, Y. Wang, K.A. Regan, N. Rogado, M.A. Hayward, M.K. Haas, J.S. Slusky, K. Inumaru, H.W. Zandbergen, N.P. Ong, R.J. Cava, Nature 411 (2001) 54.
[2] H. Rosner, R. Weht, M.D. Johannes, W.E. Pickett, E. Tosatti, Phys. Rev. Lett. 88 (2002) 027001.
[3] T.G. Amos, Q. Huang, J.W. Lynn, T. He, R.J. Cava, Sol. State Comm. 121 (2001) 73.
[4] T. Geetha Kumary et al., Phys. Rev. B 66 (2002) 064510.
[5] G. Garbarino, et al., in press.
[6] A. Yu. Ignatov, T.A. Tyson, S.Yu. Savrasov, communication presented at the American Physical Society March Meeting 2003, abs. K21.010.