Revista Mexicana de Física S **58** (2) 164–166 DICIEMBRE 2012

Transport and Magnetic Properties of Dy_2CoGa_8

N.O. Moreno[a], M.F. Hundley[b], and J.L. Sarrao[b]
[a]*Departamento de Física, Universidade Federal de Sergipe, São Cristovão, SE, 49100-000, Brazil.*
[b]*Los Alamos National Laboratory, Los Alamos, NM 87545, USA.*
e-mail: nomoreno@ufs.br

Recibido el 25 de junio de 2010; aceptado el 8 de abril de 2011

The magnetic susceptibility, the specific heat and the electrical resistivity of the single crystal Dy_2CoGa_8 have been measured. That compound crystallizes in a tetragonal structure with space group P4/mmm. It is found at ambient pressure that Dy_2CoGa_8 presents an antiferromagnetic order below the Néel temperature, T_N = 16 K. The electronic specific heat coefficient is about 180 mJ/K^2. A strong uniaxial anisotropy is observed of the magnetic susceptibility, χ. At higher temperatures above 150 K both χ_a and χ_c follows the Curie-law with an effective magnetic moment of 10.94 μ_B/Dy that is close to the expected value of for a Dy^{3+} free ion. Crystalline electric field levels were derived from the magnetization and specific heat data.

Keywords: Dy_2CoGa_8; intermetallic compounds; antiferromagnetism.

La susceptibilidad magnética, el calor específico y la resistencia eléctrica de un mono cristal de Dy_2CoGa_8 fue medida. El compuesto cristaliza en una estructura tetragonal con grupo espacial P4/mmm. Se encuentra a la presión ambiente que Dy_2CoGa_8 presenta un orden antiferromagnético por debajo de la temperatura de Néel, T_N = 16 K. El coeficiente electrónico del calor específico es de unos 180 mJ/K^2. Un fuerte anisotropía uniaxial se observa de la susceptibilidad magnética, χ. A temperaturas altas por encima de 150 K tanto χ_a y χ_c siguen la ley de Curie con un momento magnético efectivo de 10.94 μ_B/Dy que está cerca del valor esperado del íon libre Dy^{3+} . Los niveles del campo eléctrico cristalino se derivaron de los datos de la magnetización y calor especifico.

Descriptores: Dy_2CoGa_8; compuestos intermetálicos; antiferromagnetismo.

PACS: 78.20.-e; 75.20.-g; 75.47.Lx

1. Introduction

In the past few years, considerable interest has developed in the heavy fermions family systems $CeTIn_5$ and Ce_2Tin_8. [1,2] These compounds belong to the more general family R_nTGa_{3n+2} compounds with the Ho_2CoGa_8 type structure are abundant due to their robust structure and the interesting physical properties that result from the ability of this structure to adopt different elements with various atomic sizes. The physical properties of this family of materials are also quite interesting and often display strongly correlated electron behavior especially for Ce. In particular, Ce_2TIn_8 (n = 2) can be described as bilayer variants of the single-layer $CeTIn_5$ with a tetragonal structure in which 2 layers of $CeIn_3$ units are stacked sequentially along the c axis with intervening monolayer of TIn_2 [3]. The n = 2 materials possess similar Sommerfeld coefficients to that of their n = 1 counterparts. At atmospheric pressure the bilayer T = Rh material is shown to order antiferromagnetically below Néel temperature (T_N) $\approx$ 2.8 K while the T=Ir material remains a heavy-fermion paramagnet to 50 mK, with no evidence for a phase transition [4,5].

This paper, concerning the magnetic properties and transport study of Dy_2CoGa_8 single crystal. For this compound the exchange interactions and crystalline electric field (CEF) are two factors that influence the stability of the magnetic ordering of the rare-earth magnetic moments. Competition between these two interactions leads to a large variety of magnetic structures being observed in ternary rare-earth intermetallic compounds. Because of the large interatomic distances, the exchange interactions between the localized $4f$electrons are indirect and are probably mediated via the conduction electrons (Ruderman Kittel Kasuya Yosida (RKKY) model).

2. Experimental details

X-ray powder diffraction (XRD) patterns were obtained in a Rigaku diffractometer at room temperature. Magnetization measurements have been taken in a Quantum Design superconducting quantum interference device (SQUID) MPMS-7T dc-magnetometer. Specific heat and electrical resistivity measurements were performed in a PPMS quantum design system.

Single crystalline samples of Dy_2CoGa_8 were grown by gallium self-flux technique. The starting materials used for the preparation of Dy_2CoGa_8 single crystals were high purity metals of Dy (99.95%), Co (99.9%), and Ga (99.999%) The crystals grew as plates (6$\times$5$\times$3 mm) with the $c$axis perpendicular to the large face. The compound Dy_2CoGa_8 crystallizes in a tetragonal unit cell, space group123, P4/mmm. The unit cell parameters determined by X ray powder diffraction are a= 4.219(5) Å and c= 10.991(2) Å and are in good agreement with the results found by Joshi *et al.* [6].

3. Results

The temperature dependence of the magnetic susceptibility of Dy_2CoGa_8 is displayed in Fig. 1. An antiferromagnetic transition occurs at T_N= 18 K, as can seen in Fig. 1. In the paramagnetic state, the inverse susceptibility was fitted to the Curie–Weiss law with effective moment μ_{eff}= 10.4 μ_B/Dy and Curie temperature θ= =-45 K and -6 K in plane and along the c-axis, respectively. The effective moments are close to the theoretical value μ_{eff}= 10.63 μ_B/Dy

In Dy_2CoGa_8 intermetallic , the easy axis of magnetization lies along the [001] direction. The anisotropic behavior of the magnetization in both the paramagnetic and antiferromagnetically ordered states arising due to the influence of crystal electric fields (CEF) The ratio and $\chi c/\ \chi a$ taken at T_N is mainly determined by the tetragonal CEF.

For Dy^{3+} in a tetragonal environment, the CEF Hamiltonian can be written as

$$H_{CEF} = B_2^0 O_2^0 + B_4^0 O_4^0 + B_4^4 O_4^4 + B_6^0 O_6^0 + B_6^4 O_6^4, \quad (1)$$

where the B_l^m are the CEF parameters and the O_l^m are the Stevens operator equivalents.

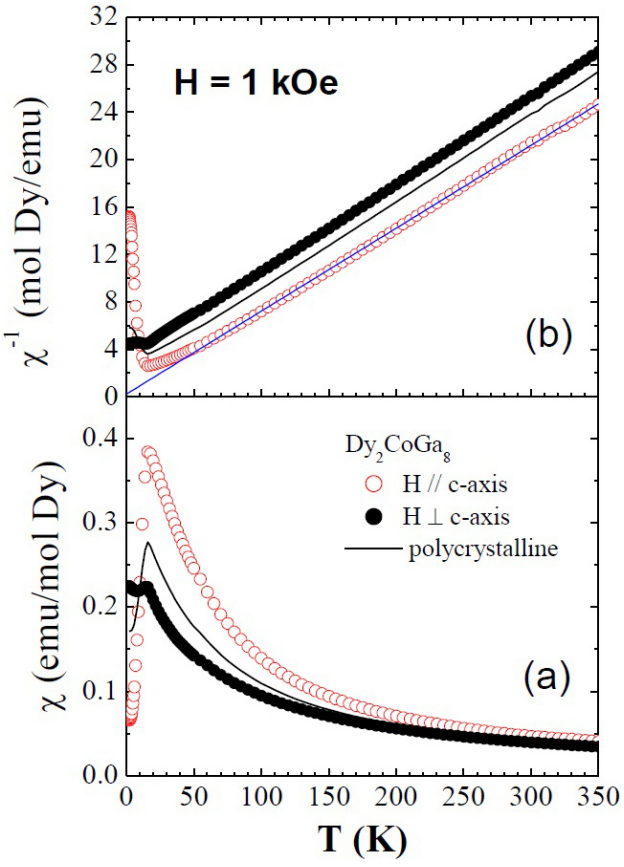

FIGURE 1. (a) The temperature dependence of magnetic susceptibility, χ and (b) χ^{-1} vs. T for Dy_2CoGa_8 under a magnetic field of 1 kOe. The solid line through the data point indicates the CEF fit.

The inverse magnetic susceptibility including the molecular field contribution λ is given by

$$\chi^{-1} = \chi_{CEF}^{-1} - \lambda,$$

The inverse susceptibility of the Dy_2CoGa_8 as shown in Fig. 1b, was fitted to the above discussed CEF model. The values of the CEF parameters obtained of the fit are presented in Table I

The temperature dependence of the electrical resistivity for Dy_2CoGa_8 is plotted in Fig. 2. The inset shows the low-temperature resistivity data. The room-temperature value of the electrical resistivity is about 50 $\mu\Omega$cm and the high temperature data show a weak metallic behavior for this compound. The resistivity for the current J along the [100] direction shows peaks at 9 and 6 K, both below T_N estimated of susceptibility peak

The temperature dependence of the electrical resistivity clearly reveals that the electrical resistivity has two peaks around 9 K and 6 K, and starts to decrease rapidly below to lower temperatures. Such a feature of the resistivity agrees with the notion of the presence of the CEF effect in this sample.

The temperature dependence of the specific-heat divided by temperature is plotted in Fig. 3. To calculate the magnetic entropy, the phonon contribution was estimated from the specific-heat data of Lu_2CoGa_8 and subtracted from the total specific heat of the former. The magnetic contribution is plotted in Fig. 3 (square solid) The peak not sharp marks the Néel temperature in agreement with the magnetic measurements. The magnetic entropy recovered at the antiferromagnetic transition is $8R\ln 2$.

TABLE I. CEF parameters for Dy_2CoGa_8 obtained from the inverse susceptibility fit.

T_N(K)	B_2^0(K)	B_4^0(K)	B_4^4(K)	B_6^0(K)	B_6^4(K)	λ mol/emu
18	-0.6	0.004	0.001	8.0×10^{-8}	2.0×10^{-4}	-2,4

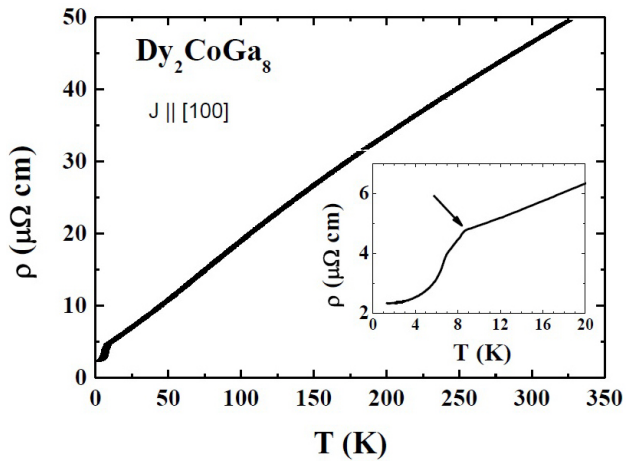

FIGURE 2. Temperature dependence of the electrical resistivity for Dy_2CoGa_8 The current has been applied parallel in the *ab* plane. The inset shows the low-T range.

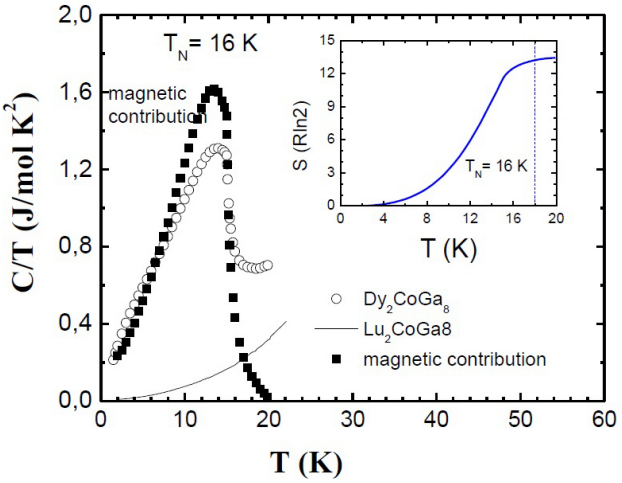

FIGURE 3. The specific heat data as a function of temperature. Inset is shown the magnetic entropy.

4. Conclusions

Measurements of magnetic susceptibility, heat capacity, and electrical resistivity in single crystal Dy_2CoGa_8 are reported. This compound orders antiferromagnetically with a $T_N = 16$ K, and the strong anisotropic magnetic susceptibility is higher for the field applied along the c axis. The anisotropic behavior of the susceptibility below the Néel temperature shows the c-axis as the easy axis of magnetization. Unfortunately we cannot synthesize the relative $DyCoGa_5$ to compare its T_N with of Dy118. It is observed that density of states at the Fermi level decreases on replacing In by Ga in these R_2CoX_8 R = rare earth; X=In and Ga) series of compounds, it should result in a weaker conduction electron mediated RKKY magnetic interactions between the rare-earth ions in R_2CoGa_8 compounds.

A detailed CEF study including fits to the existing data and additional experiments and inelastic neutron scattering experiments for a more direct determination of the CEF scheme of level for this compound is desirable.

Acknowledgements

N.O. Moreno wishes to thank the Brazilian funding agencies CNPq, CAPES and FAPITEC/SE for financial support. Work at Los Alamos was performed under the auspices of the DOE

1. H. Hegger *et al.*, *Phys. Rev. Lett.* **84** (2000) 4986.
2. P.G. Pagliuso *et al.*, *Physica B* **312** (2002) 129.
3. N.O. Moreno *et al.*, *Physica B* **312** (2002) 274.
4. J.D. Thompson *et al.*, to appear in *J. of Magn. Magn. Mat.* (2001).
5. W. Bao, P.G. Pagliuso, J.L. Sarrao, J.D. Thompson, and Z. Fisk, *Phys. Rev. B* **64** (2001) R020401.
6. D.A. Joshi, R. Nagalakshmi, S.K. Dhar, and A. Thamizhavel, *Phys. Rev. B* **77** (2008) 174420.
7. M. Nicklas *et al.*, *Phys. Rev. B* **67** (2003) 020506.
8. G. Chen *et al.*, *J. Phys. Soc. Jpn.* **71** (2002) 2836.
9. N.O. Moreno *et al.*, *Phys. Rev. B* **72** (2005) 035119.