THE INFLUENCE OF CRISTALLINE ELECTRIC FIELD AND OTHER MAGNETIC INTERACTIONS ON *RNiBC* COMPOUNDS (*R* = Er, Ho, Dy, Tb AND Gd)

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ABSTRACT

The quaternary intermetallic compounds $(RC)Ni_2B_2$, has been studied by several techniques because the members of this family show exotic superconductivity and magnetic properties. This compounds, belong to the quaternary family of compounds $(RC)_m(NiB)_n$ with m = 1, 2 and n = 2. In spite, compounds $(RC)_2\ Ni_2B_2$ was not very intensively studied although they show a similarities in their structural features. The magnetic ordering temperatures T_M, as obtained from AC susceptibility measurements, do not show a simple linear scaling with the de Gennes factor as it was observed for the RNi_2B_2C series. The maximum temperature achieved corresponding to DyNiBC ($T_M \sim 17K$). TbNiBC exhibits a complicated behavior: for T > 15K paramagnetic state is established. Below this temperature is ferromagnetic, and for T = 12K an antiferromagnetic behavior is detected. The anomalous behavior of RNiBC compounds can be attributed to strong crystalline electric field effect, however, an evaluation of another facts as a unusual RKKY interaction between RC layers and the other short range magnetic interactions can be considered.

INTRODUCTION

The quaternary intermetallic family of compounds $(RC)_n(BNi)_2$ con n = 1 o 2 has been studied the last years[1,2]. This materials present a layered structure consisting of alternating RC and $(NiB)_2$ layers. Some of the compounds of the series $(RC)(NiB)_2$ show superconductivity and different magnetic behavior at low temperatures[3,4]. However in the close related series $(RC)_2(NiB)_2$, only the LuNiBC show superconductivity at 2.9K[5], and for the Er, Ho, Dy, Tb and Gd compounds, different ways of magnetic ordering was detected at low temperatures[6,7]. Magnetic behavior at low temperatures are different in the this series, for example for ErNiBC a ferromagnetic transition at T = 4.5K are detected[6], but in the series RNi_2B_2C this magnetic behavior is not observed. Also, magnetic ordering temperatures follow the de Gennes scaling for the series RNi_2B_2C, but no for RNiBC[7]. This behavior was observed in other families of intermetallic compounds[8].There are several facts that explain this behavior like as: crystalline electric field (Thereafter CEF) effects, short range interactions, etc.

The compounds RNi_2B_2C show different forms of antiferromagnetic ordering at low temperatures. This temperatures are scaling with the de Gennes factor, however with a small deviation for Er and Ho compounds. In spite, the ordering temperatures of RNiBC

compounds do not show a simples relation with the de Gennes factor, this is attributed to additional layer of R-C which modifies magnetic interactions between R-C layers, CEF enhanced and other short range magnetic interaction between R ions.
In this paper we show experimental evidences for explain the behavior of RNiBC. Neutron diffraction measurements was does in the samples of DyNiBC and TbNiBC. In this samples one singular behavior was detected at low temperature: below T = 17K the samples are ferromagnetic, but at T = 13K one antiferromagnetic behavior was observed [9]. At low temperatures, however, the samples exhibit a ferromagnetic behavior. This behavior was detected through ^{57}Fe Mössbauer Spectroscopy measurements in TbNiBC with 1% of ^{57}Fe at the Ni site[10]. We calculate the influence of CEF and estimated the possible influence of dipolar interaction between rare earth ions.

RESULTS AND DISCUSSION

Samples was prepared by standard arc-melting method, wrapped in Ta-foil and homogenized by annealing at 1000 ^{0}C during two days, and quench at liquid nitrogen. Purity of samples was tested by X-ray diffraction at room temperature and AC susceptibility measurements. Samples for neutron diffraction measurements were prepared using ^{11}B isotope.

Temperatures as a function of the de Gennes factor do not show a linear behavior (see fig. 1) as expected for compounds with ***f***-ions. We take the temperature of Gd as a maximum value and scaling with the de Gennes factor, to compare experimental values of temperature. We observe, that there a significant difference between this scaling to and experimental values of temperature. We can be considered several facts to explain this behavior: The influence of CEF, because there is an important effect. The CEF effect can be examined by Hamiltonian:

$$H_{CEF} = -2\Im(g_J - 1)^2 J_Z \langle J_Z \rangle + B_2^0 \left[3J_z^2 - J(J+1)\right] \qquad (1)$$

with $\Im$ exchange parameter, g_J landé factor, J_Z magnetic moment along z-axis, B_2^0 is the dominant term in the CEF.

$$T_M = 2\Im(g_J - 1)^2 \sum_{J_z} J_z^2 \exp(-3B_2^0 J_z^2 / T_M) x \left(\sum_{J_z} \exp(-3B_2^0 J_z^2 / T_M \right)^{-1} \qquad (2)$$

To examination the influence of CEF we put the transition temperature for Gd compound (free of CEF effects) and scaling with respect to this temperature (see fig. 1 -filled circles-). Temperature under only exchange interaction can be expressed by:

$$T_0 = 2\Im(g_J - 1)^2 J_Z \langle J_Z \rangle \qquad (3)$$

Then we can compare T_M and T_0 by ratio of $\frac{T_M}{T_0}$ which can be expressed as:

$$\frac{T_M}{T_0} = \frac{3}{J(J+1)} \frac{\sum_m m^2 \exp\left[\frac{-m^2}{T_M/T_0}\frac{9(B_2^0/\Im)}{2(g-1)^2 J(J+1)}\right]}{\sum_m \exp\left[\frac{-m^2}{T_M/T_0}\frac{9(B_2^0/\Im)}{2(g-1)^2 J(J+1)}\right]} \quad (4)$$

when m = J, J-1,..-J. This equation can be solved for each rare earth and determine the influence of CEF. In the figure 2 we can observe the theoretical behavior of $\frac{T_M}{T_0}$ on the $B_2^0/\Im$ for each rare-earth.

The other hand, we can evaluate a fictitious temperature related with a dipolar interaction, for this purpose we evaluate this interaction for rare earth ion in the plane R-C taking account only the eight nearest neighbor ions, according to this expression:

$$k_B T_M = \left(\frac{m_0}{4p}\right)\sum_n \frac{m_n^2}{r_n^3} \quad (5)$$

with m_n is the effective free ion moment and r_n is the nearest neighbor distance. We note which the influence of this interaction are most noticeable for Er and Ho compounds compared with other compounds

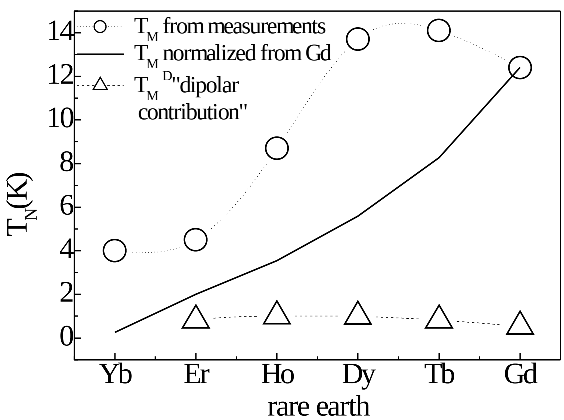

Fig. 1 a) Order temperature as a function of Rare earth ion (empty circles); b) scaling temperatures with respect to Gd compounds and (line); c) fictitius temperature of dipolar interactions (empty triangle).

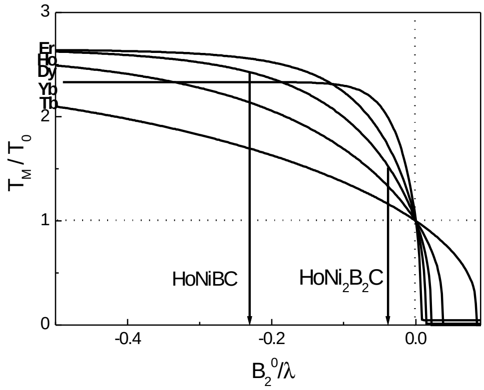

Figure 2. Critical transition temperatures (with and without influence of CEF effects) rates T_M/T_0 for different R as a function of the $B_2{}^0 / \lambda$ parameter.

CONCLUSION

We can conclude that in this compounds an strong CEF can be influence the interaction between rare earth ions. Also other interactions as a dipolar interaction between rare earth ions, may be considered to explain anomalous behavior respect to scaling temperatures with the de Gennes factor. On the other hand superconductivity in this compounds is observed only for LuNiBC at 2.9K. This can be explain for a very low density of states at the Fermi level. Against the $LuNi_2B_2C$ show a superconducting transition at T= 16K. D.R. Sanchez, et al. report and differences between RNiBC and RNi_2B_2C with respect to B_4Ni tetrahedral[11], this difference reflect into density of states at Fermi level.

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