Experimental report

16/09/2015

Proposal: 5-31-2346 **Council:** 4/2014

Title: Evolution of magnetism and superconductivity in the solid solutions Dy(CoxNi1-x)2B₂C and Er(CoxNi1-x)2B2C systems.

Research area: Physics

This proposal is a new proposal

Main proposer: **Mohammed EL MASSALAMI**

Experimental team: Adriana JIMENEZ
Mohammed EL MASSALAMI

Local contacts: Bachir OULADDIAF

Samples: Dy(CoxNi1-x)2B2C
Er(CoxNi1-x)2B2C

Instrument	Requested days	Allocated days	From	To
D2B	5	3	19/09/2014	22/09/2014

Abstract:

The Ni-based titled compounds are anti-ferromagnetic superconductors while the Co-based ones are normal magnetic (DyCo2B2C is ferromagnetic while ErCo2B2C is a collinear antiferromagnetic). We intend to follow the evolution of their magnetic and electronic properties when Co is substituted for Ni. We have already synthesized twelve ^{11}B enriched samples (x=0. 0.2, 0.4, 0.6, 0.8, 1 for each) of these two solid solutions and found out, as expected for these borocarbides, the ThCr2Si2;-type single phase is formed across the whole concentration range. Thermodynamic (magnetization, resistivity, specific heat) studies are underway to follow the evolution of their magnetic and electronic (in particular superconducting) properties. We are interested in mapping out the magnetic structure of these solid solution to see the evolution of the magnetic modes with the Co concentration: this is expected to shed light on the influence of Co substitution (mainly through the variation of the electron count) on the interplay between superconductivity and magnetism in these layered magnetic superconducting borocarbides.

Magnetic modes in $Dy(Co_xNi_{1-x})_2B_2C$: from an antiferromagnetism (coexisting with superconductivity) to a simple normal-conducting ferromagnet.

$DyNi_2B_2C$ orders antiferromagnetically at T_N ≈10 K.[1–4] Superconductivity is observed to coexist with such an antiferromagnetic state below $T_c \approx 6$ K.[1–3] On the other hand, the isomorphous $DyCo_2B_2C$ orders ferromagnetically below T_C ≈6 K.[5] Such a wide variation in the electronic and magnetic ground state is quite surprising considering the similarity in both the electronic structure and the crystalline-electric-field single-ion properties. This variation was observed as well in both $Tb(Co_xNi_{1-x})_2B_2C$,[6,7] and $Ho(Co_xNi_{1-x})_2B_2C$.[8] To understand this evolution of the electronic and magnetic properties, we followed the structural, thermodynamic, electronic and magnetic properties of the solid solution $Dy(Co_xNi_{1-x})_2B_2C$, particular attention has been paid to map out the evolution of the magnetic structure of the intermediate solid solutions.

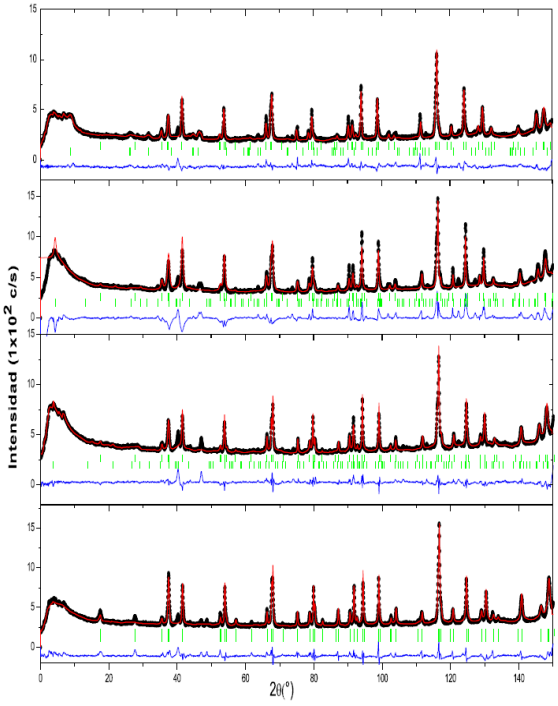

FIG. 1. Neutron diffractograms of $Dy(Co_xNi_{1-x})_2B_2C$ (from top to bottom x=0.2,0.4,0.6 and 0.8) measured at T=1.5 K. The solid line represent the Rietveld refinements parameters as given in Table 1.

Conventional arc-melt was used for the synthesis of a series of ^{11}B enriched $Dy(Co_xNi_{1-x})_2B_2C$ wherein x=0, 0.2, 0.4, 0.6, 0.8, 1. Structural (XRD and neutron) and elemental (EDAX,..etc.) analysis were used to evaluate the single-phase character as well as the structural and elemental properties of these samples. Magnetoresistivity, magnetization, specific heat characterizations were extensively used for thermodynamical characterization. Magnetic modes were probed by neutron diffraction analysis.

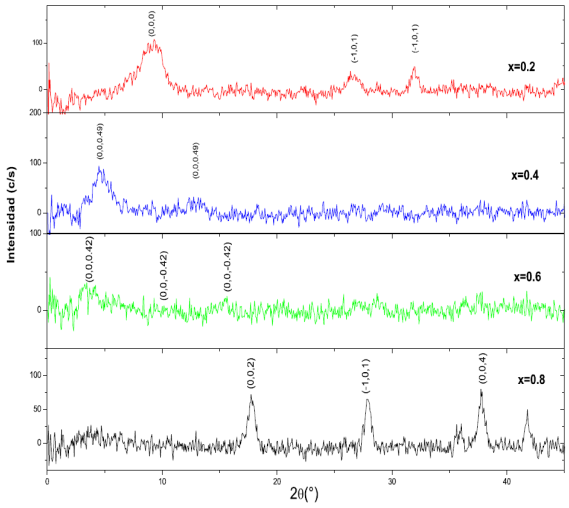

FIG. 2. Principal magnetic peaks of $Dy(Co_xNi_{1-x})_2B_2C$ as determined from the neutron diffrtactograms measured at T= 1.5 K.

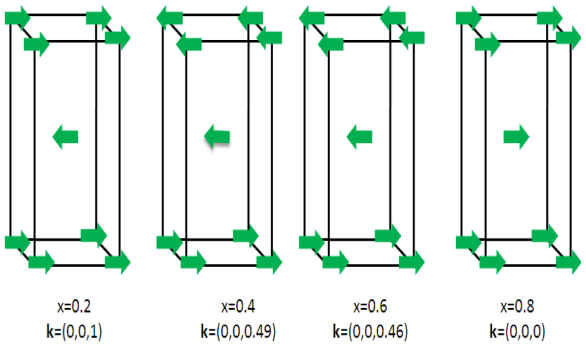

FIG. 3. Magnetic structure of $Dy(Co_xNi_{1-x})_2B_2C$ as determined from neutron diffraction analysis.

The crystal structure, across the whole concentration range, was confirmed to be the single $ThCr_2Si_2$-type tetragonal ($I4/mmm$) phase (see Fig.1 and Table 1). Thermodynamic investigations indicate that while the compositions with x= 0.2, 0.4 manifest an antiferromagnetic behavior, the ones with x=0.6, 0.8 exhibit a ferromagnetic character. These conclusions are confirmed by neutron diffraction analysis which reveals (see Figs. 2-3) an antiferromagnetic order $k_{0.2}$=(0,0,1) for x=0.2 and, furthermore, helicoidal modes for both x=0.4 and

TABLE I. Basic crystallographic parameters of $Dy(Co_{2x}Ni_{2(1-x)})B_2C$ obtained from the Rietveld refinement of diffractograms of Fig. 1. z represents the z-position of the B atom: the only variable component in the occupied atomic positions of the space group $I4/mmm$.

x	$a = b$ (Å)	c (Å)	V(Å^3)	z (B)
0.0	3.534(2)	10.4878	130.998	0.3583
0.2	3.523(9)	10.461(4)	129.90(9)	0.358(0)
0.4	3.521(6)	10.445(7)	129.55(1)	0.360(5)
0.6	3.518(7)	10.434(4)	129.19(7)	0.357(1)
0.8	3.512(4)	10.452(9)	129.53(1)	0.357(0)
1.0	3.509(9)	10.5268	129.683	0.34585

x=0.6 with $k_{0.4}$=(0,0,0.49) and $k_{0.6}$=(0,0,0.46), respectively. Finally, a ferromagnetic order, $k_{0.8}$=(0,0,0), is confirmed for x=0.8. A possible mechanism behind this alloying-dependent evolution of the magnetic modes is discussed along the same lines of reasoning as the ones observed in the isomorphous $Tb(Co_xNi_{1-x})_2B_2C$,[6,7] and $Ho(Co_xNi_{1-x})_2B_2C$.[8]

[1] K.-H. Müller and V. N. Narozhnyi, Rep. Prog. Phys. **64**, 943 (2001).
[2] P. C. Canfield, P. L. Gammel, and D. J. Bishop, Phys. Today **51**, 40 (1998).
[3] L. C. Gupta, Adv. Phys. **55**, 691 (2006).
[4] J. W. Lynn, S. Skanthakumar, Q. Huang, S. K. Sinha, Z. Hossain, L. C. Gupta, R. Nagarajan, and C. Godart, Phys. Rev. B **55**, 6584 (1997).
[5] M. ElMassalami, R. Moreno, H. Takeya, B. Ouladdiaf, J. W. Lynn, and R. S. Freitas, J. Phys.: Condens. Matter **21**, 436006 (2009).
[6] M. ElMassalami, H. Takeya, B. Ouladdiaf, R. Maia Filho, A. M. Gomes, T. Paiva, and R. R. dos Santos, Phys. Rev. B **85**, 174412 (2012).
[7] M. ElMassalami, A. Gomes, T. Paiva, R. dos Santos, and H. Takeya, J. Mag. Magn. Mater. **335**, 163 (2013).
[8] M. ElMassalami, A. Gomes, T. Paiva, R. dos Santos, and H. Takeya, J. Mag. Magn. Mater. **372**, 74 (2013).