STRUCTURAL, TRANSPORT, MAGNETIC AND SUPERCONDUCTING PROPERTIES OF THE PSEUDO-QUATERNARY INTERMETALIIC SYSTEM $(Y_{1-x}Gd_x)Ni_2B_2C$

M.El Massalami, S.L.Bud'ko, B.Giordanengo, M.B.Fontes, J.C.Mondragon and E.M.Baggio-Saitovitch.
CBPF, R.Xavier Sigaud 150, 22290-180, Rio de Janeiro, Brazil

The superconducting and the magnetic phase diagram (in x-T plane) of the pseudo-quaternary $(Y_{1-x}Gd_x)Ni_2B_2C$ series is obtained. Superconductivity is observed to be montonically degraded with Gd-concentration for $x < 0.25$. For higher x , two magnetic transitions are observed. The nature of these transitions and their influence on the measured physical properties will be discussed.

Superconductivity in the RNi_2B_2C series, with $ThCr_2Si_2$-type structure, was reported, so far, for R=Y,Lu,...,Ho systems[1-5]. Further, due to the competition between magnetism and superconductivity in the R=Tm,Er,Ho,Dy compounds, T_c was found[2-5] to scale approximately with the de Gennes factor indicating a modest interaction between the R-moments and the conducting electrons. An indirect exchange coupling between the R-moments (generalizing to the non-superconducting R-members), leads eventually to a 3-D long range order, which is found[4] for e.g. R=Tm, to be antiferromagnetic and to co-exist with superconductivity below T_N=1.5K. In this communication, we report how does the controlled addition of the Gd-moments (R=Gd is a non-superconductor down to 1.5K) to the YNi_2B_2C superconductor (T_c=15.6K) influence its structural, transport, magnetic and superconducting properties.

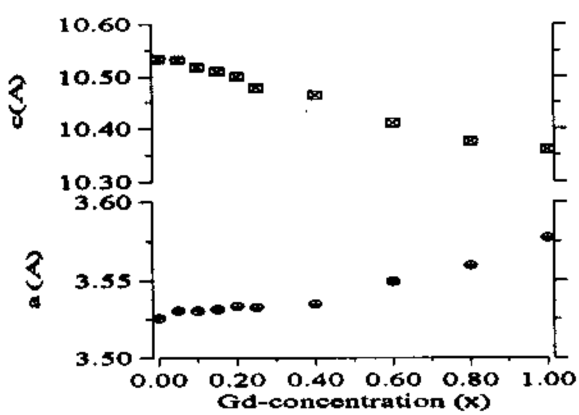

Fig.1. Lattice parameters of the tetragonal unit cell of the pseudo-quaternary system $(Y_{1-x}Gd_x)Ni_2B_2C$.

Pellets from stoichiometric mixtures of high purity elements were arc-melted under argon in a conventional argon arc-melt furnace. Some, but not all, of our data below are reported on as-prepared samples. X-ray Cu-Kα diffraction patterns were analyzed by the standard Rietveld method assuming the reported structural model[3]. The lattice parameters (Fig.1) depend montonically on the Gd-concentration. Consistent with the behavior of the RNi_2B_2C series[3], the a-parameter reflects the Lanthanide-contraction (Vegard's law), however, the c-parameter behaves oppositely. This can be seen as follows: while the introduction of the larger Gd-ion increases the length of the C-Gd bond (hence effectively increasing the a-parameter), it does open the tetrahedral angle facing the Gd-planes and thus gives an effective decrease in the c-parameter.

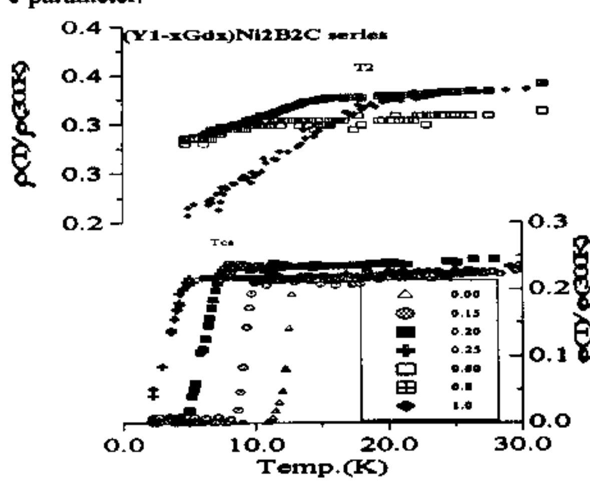

Fig.2 Representative room-temperature-normalized ρ vs. T curves for $(Y_{1-x}Gd_x)Ni_2B_2C$ compounds.

A metallic behavior is observed in the dc resitivity (ρ) down to 30K, below which, it saturates with $\rho(300K)/\rho_{sat}$= 3 ~10. Both ρ (Fig.2) and χ_{ac} (500Hz, 1Oe) (Fig.3) show that superconductivity is being degraded montonically with x; with an eventual quenching for x≥0.25. This is argued to be due to a combination of the size effects (similar to the T_c drop in R=Y relative to R=Lu) and the introduction of pair-breaking centers. The latter is more effective and can be fitted successfully to the Abrikosov-Gor' kov theory.

For higher x values, a remarkable anomalous lowering of $\rho(T)$ is observed, Fig(2), indicating a decrease in the electronic scattering due to the onset of an antiferromagnetic transition with weak ferromagnetism at T_2: the Zero-field cooled and field-cooled magnetization confirmed its partial ferromagnetic character(Fig.3). M-H curves at 1.7K shows that magnetization saturates only for H >10T; indicating a strong antiferromagnetic coupling.

In Fig.4, we show the phase diagram as constructed from the results of the ρ, χ_{ac} and magnetization measurements. For the Gd-limit, above 40K , μ_{eff}=8.1, reflecting the paramagnetism of the Gd-moments. Below 30K, two magnetic transitions are observed and with characteristic temperatures that are decreasing with the decrease of Gd-concentration. In particular, the weak ferromagnetism line may act as an additional parameter for destroying superconductivity when they cross near x ~ 0.25.

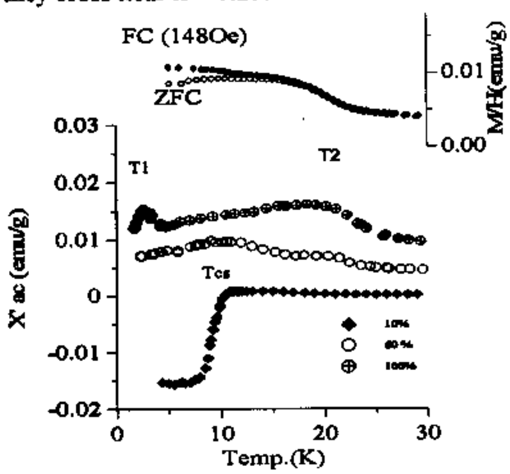

Fig.3. Lower curves:- representative curves of χ_{ac} - T with different concentrations. Upper curve:- Zero Field cooled and Field Cooled M/H -T for x=1.

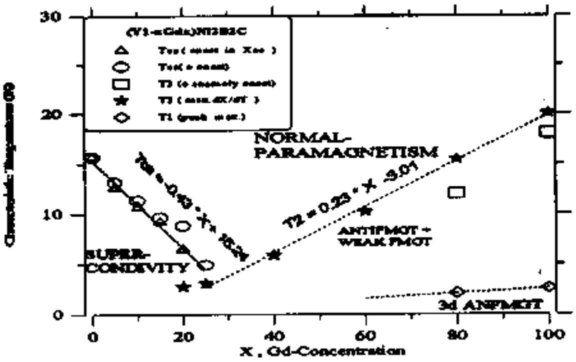

Fig.4. The concentration dependence of the magnetic and superconducting transition temperatures of $(Y_{1-x}Gd_x)Ni_2B_2C$. The solid line represents the Abrikosov.-Gor'kov relation. The dashed lines shows the linear dependency of the magnetic transition temperatures on the magnetic dilution.

As a summary, a preliminary phase diagram is reported about the magnetic and superconducting behavior of the $(Y_{1-x}Gd_x)Ni_2B_2C$ system. From our preliminary results on M(T,H) measurement, and considering the results[4] of the C_p on the isomorphous R=Tm and the results of Ref.5, we argued that, the Gd-moments are antiferromagnetically coupled, however, with weak ferromagnetism (thus the observed FC and ZFC features at T_2 for x=1, and the quenching of superconductivity at x=0.25) while this ferromagnetic component is antiferromagnetically coupled at low temperatures (thus, for x=1, the antiferromagnetic order at T_1). More details on the magnetism and superconductivity and their interplay in this system, will be published elsewhere.

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