Physica C 235-240 (1994) 2551-2552
North-Holland

PHYSICA C

Superconductivity in RNi_2B_2C (R = rare earth) Compounds

C.V. Tomy, L.J. Chang, G. Balakrishnan and D.M^{c}K. Paul

Department of Physics, University of Warwick, Coventry CV4 7Al, UK.

A series of compounds in the recently discovered RNi_2B_2C family of superconductors have been prepared in order to investigate their magnetic and transport properties. Compounds of the form $(Y_{1-x}A_x)Ni_2B_2C$ (A=Sm, Dy) were examined to study the effects of magnetic pair breaking. Resistance measurements show that the lighter rare earth Sm depresses T_c faster than the heavier rare earth Dy. Solid solutions of the type $(Er_{1-x}Ho_x)Ni_2B_2C$ have also been studied for the possible coexistence of superconductivity and magnetism in these compounds. Even though the magnetic ordering of the rare earth moments can be deduced from our magnetic susceptibility measurements, resistance measurements showed no reentrant behaviour in any of these compounds down to 1.2K.

1. INTRODUCTION

The recently discovered [1] RNi_2B_2C (R=Rare Earth) superconductors are an interesting class of compounds due to the fact that the T_c values are relatively high and superconductivity is observed even for the magnetic rare earth ions (Ho, Er and Tm). The presence of the 3d-tansition element, Ni, and the magnetic ordering of the rare earth moments in the superconducting state add to the interest in these compounds. Superconductivity is observed only for compounds with the heavier rare earth magnetic ions Ho, Er and Tm and T_c decreases on going from Tm to Ho, suggesting the possibility of a pair breaking mechanism. We have studied the nature of pair breaking effects by substituting non superconducting magnetic rare earth ions in YNi_2B_2C. A light rare earth, Sm, and a heavy rare earth, Dy, have been selected for the above purpose.

The new boride carbides also show evidence for the coexistence of superconductivity and magnetism [2], similar to that observed in the past for the RRh_4B_4 compounds [3]. Anomalous behaviour in the upper critical field measurements has been reported in $HoNi_2B_2C$ (T_c~8K) showing a reentrant behaviour at ~5K even in zero field [2]. We have investigated the possibility of coexistence of superconductivity and magnetism in the diluted compounds, $(Ho_{1-x}Er_x)Ni_2B_2$ through resistivity and magnetic susceptibility measurements and the results are presented.

2. EXPERIMENTAL

Samples were prepared by the standard arc-melting technique. The constituent elements, R(99.9%), Ni(99.99%), B(99.7%) and the graphite flakes, were melted in a water cooled copper hearth in flowing argon atmosphere. Weight losses if any, were compensated for during the melting. The resulting buttons were turned over and melted several times in order to ensure homogeneity. These buttons were then wrapped in tantalum foil and annealed in evacuated and sealed quartz tubes at 975-1050C for 12-16 hours. The samples were characterised by X-ray. Very small amounts of impurity peaks were seen in some of the compounds. Resistance measurements (1.2-300K) were carried out on bar shaped samples by the standard four probe method. Magnetic susceptibility measurements (4-300K) were performed using a vibrating sample magnetometer.

3. RESULTS AND DISCUSSION

The variation of T_c with x for Sm and Dy substituted compounds $(Y_{1-x}A_x)Ni_2B_2C$, is shown in Fig.1. It is clear that Sm suppresses T_c faster than Dy when substituted for Y in YNi_2B_2C, bringing out the importance of rare earth ion size in the destruction of superconductivity in these superconductors. For x=0.4, Sm destroys superconductivity completely while the compound is still superconducting for Dy concentrations

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SSDI 0921-4534(94)01841-3

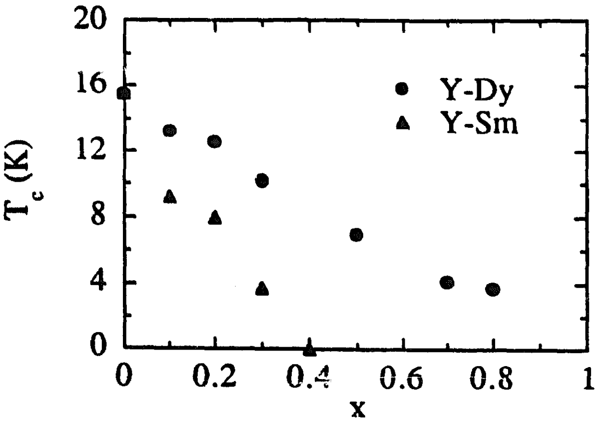

Fig. 1 Variation of T_c with x for $(Y_{1-x}A_x)Ni_2B_2C$ (A=Sm and Dy)

up to x=0.8. The pure Dy compound shows two transitions in its resistance behaviour (Fig.2). The change in slope at ~10.5K is probably associated with magnetic ordering [2], and is seen in our magnetic susceptibility measurements as well [4]. In order to ascertain whether the second transition around 3K is due to the onset of superconductivity, we have measured the resistance of this compound down to 300mK. No superconducting transition was observed down to this temperature. Detailed measurements on this compound will be published elsewhere [4]. It is interesting to see that a small amount of Y (x~0.2) in $(Dy_{1-x}Y_x)Ni_2B_2C$, is sufficient to retain superconductivity.

Fig.3 shows the resistance measurements on the solid solutions $(Ho_{1-x}Er_x)Ni_2B_2C$. All the compounds show superconductivity between 7-10K as expected from the end compounds. Magnetic susceptibility measurements with an applied field of 1.2T (>H_{c2}) confirm that the ordering of the rare earth moments occur in

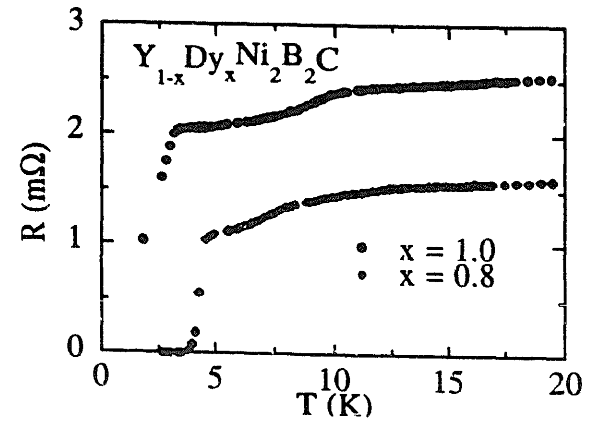

Fig. 2 Temperature dependence of resistance for $DyNi_2B_2C$ and $Dy_{0.8}Y_{0.2}Ni_2B_2C$ compounds.

the superconducting state. However, we have not observed any reentrant behviour in any of these compounds down to 1.2K. In addition, resistance measurements on $HoNi_2B_2C$ compound in a magnetic field [4] did not show any reentrant behaviour. It may be possible that the sample homogeneity plays an important role in bringing about such effects.

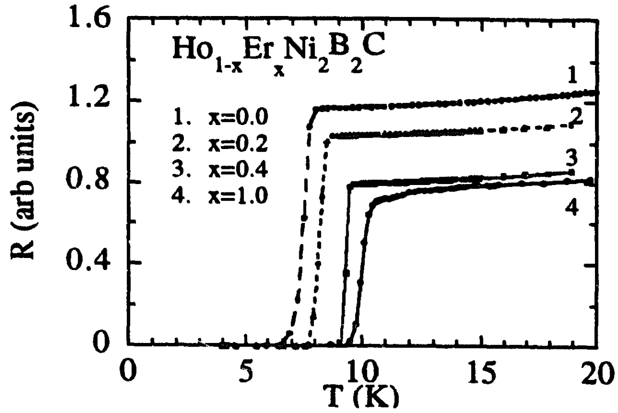

Fig. 3 Resistance vs Temperature plots for the $(Ho_{1-x}Er_x)Ni_2B_2C$ compounds.

In conclusion, our results show that Sm suppresses T_c faster than Dy in $(Y_{1-x}A_x)Ni_2B_2C$, implying the importance of the ionic size along with the magnetic moment of the rare earth ion in pair breaking effects. Even though magnetic ordering of the rare earth moments can be deduced from our magnetic susceptibility measurements in the series $(Ho_{1-x}Er_x)Ni_2B_2C$, no reentrant behaviour is observed in the resistance measurements in any of these compounds down to 1.2K.

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