Magnetic and Superconducting Properties of $R_{1-x}Nd_xNi_2B_2C$ (R=Y and Er) Systems

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Abstract

We investigated Nd concentration dependence of the superconducting transition temperature, $T_C$, and magnetic transition temperature, $T_N$, for the $R_{1-x}Nd_xNi_2B_2C$ (R=Y and Er) systems. $T_C$ and $T_N$ curves against $x$ for the Er=Er system cross over at the substitution concentration $x \sim 0.165$, for which $T_N = 5$ K, but $T_C$ could not be observed. In the meanwhile, $T_C$ and $T_N$ curves for the R=Y system did not cross over. The phase diagram, ($T_C$, $T_N$) against Nd concentration $x$, for the $R_{1-x}Nd_xNi_2B_2C$ systems are given and discussed.

Key words: magnetism and superconductivity, borocarbide

1. Introduction

The recent discovery of superconductivity in borocarbide intermetallic compounds YNi$_2$B$_4$C$^1$ $^2$ and RNi$_2$B$_2$C (R=Lu, Tm, Er, Ho, and Dy)$^3$ has attracted a great deal of attention because of the coexistence of superconductivity and local magnetic moment ordering. Thus, one can expect an interesting intersecting point between the superconducting transition temperature, $T_C(x)$, and the magnetic ordering temperature, $T_N(x)$, curves at some Gd or Nd concentration, $x_C$, in $R_{1-x}R'_xNi_2B_2C$ (R=Y and Er, R'=Gd or Nd) system. Schmidt and Braun $^4$ investigated the superconductivity and magnetism in the system R(Ni$_{1-x}Co_x$)$_2$B$_2$C. According to them, Er(Ni$_{1-x}Co_x$)$_2$B$_2$C system the most interesting feature is the fact if $T_C$ reaches the temperature range of the antiferromagnetic transition $T_N=5.8$K, reentrant behavior occurs similar to that observed in HoNi$_2$B$_2$C. Cao et al. investigated the reentrant behavior in Ho$_{1-x}Nd_xNi_2B_2C$ system. They pointed out that the Nd substitution for Ho in Ho$_{1-x}Nd_xNi_2B_2C$ has the similar effect to break Cooper-pairs as the magnetic field does $^5$. Mori et al. investigated the phase diagram, ($T_C$, $T_N$) against Gd concentration, $x$, for Tm$_{1-x}$Gd$_xNi_2B_2C$ system$^6$. $T_C$, $T_N$ and $T'_N$ curves cross over at the substitution concentration $x \sim 0.23$, for which $T_C=3.7$ K. But $T_N$ and $T'_N$ have been suppressed.

In this study, we report the variations of $T_C$ and $T_N$ against $x$ in the Y$_{1-x}Nd_xNi_2B_2C$ and Er$_{1-x}Nd_xNi_2B_2C$ systems. Thereby we study the coexistence of superconductivity and magnetic order and the interaction between them.

2. Experimental

Polycrystalline samples of Y$_{1-x}Nd_xNi_2B_2C$ ($x=0.1$) and Er$_{1-x}Nd_xNi_2B_2C$ ($x=0.2$) were prepared by a standard arc melting method using a tungsten electrode under an argon atmosphere. Thus obtained samples were examined by powder X-ray diffraction experiment (XRD) and almost shown the single phase. The samples were cut to rectangular for measurements of electrical resistivity and were measured using...
Fig. 1. Specific heat, $C$, vs. temperature for the sample of $Y_{0.2}Nd_{0.8}Ni_2B_2C$.

A standard four-probe technique in the temperature range from 1.8 K to 280 K, and the magnetization measurement was done using a Quantum Designed superconducting interference device magnetometer (SQUID) in the temperature range from 2 K to 300 K. The specific heat was measured by an adiabatic heat-pulse method in the temperature range from 3 K to 15 K.

3. Results and discussion

Figure 1 shows the specific heat variation against temperature for the sample of $Y_{0.2}Nd_{0.8}Ni_2B_2C$. As can be seen in Fig. 1, two magnetic transition peaks are found at $T_N = 8.5$ K and $T'_N = 4.5$ K. $T_N$ and $T'_N$ were also found in the measurement of the magnetization. $T_C$, $T_N$ and $T'_N$ as a function of Nd concentration, $x$, in $Y_{1-x}Nd_xNi_2B_2C$ ($x=0$ to 1) were determined by the electrical resistivity and the magnetization measurements, which are shown in Fig. 2, where the dot lines are guides to the eye. The superconductivity is greatly depressed by Nd substitution and magnetic ordering is also depressed by increasing Y concentration. The interesting point is in the concentration range from $x=0.4$ to $x=0.5$, where the superconducting and the magnetic ordering states do not appear but the paramagnetic state. It was not found that both superconducting and magnetic ordering transitions simultaneously occur at the same temperature.

Figure 3 shows the phase diagram of $T_C$ and $T_N$ against Nd concentration, $x$, in $Er_{1-x}Nd_xNi_2B_2C$ ($x=0$ to 0.2). $T_C$ decreases with increasing $x$, indicating that superconductivity is depressed by Nd substitution for Er. $T_N$ also decreases with increasing $x$, but the values of $T_N$ did not change so much. $T_C$ curve intersects with $T_N$ curve at $x \sim 0.165$. $T_N$ was observed but $T_C$ was not observed for the sample of $x=0.165$ and 0.175. In the case of $Tm_{1-x}Gd_xNi_2B_2C$ [6], $T_C$ curve intersects with $T_N$ curve at $x=0.23$, at which $T_C$ was observed but $T_N$ was not observed.

References


