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Possible coexistence of superconductivity and magnetic order in $NdPt_2B_2C$

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Abstract. Coexistence of superconductivity and magnetic order has been one of the exciting aspects of the quaternary borocarbide superconductors. So far, RNi_2B_2C (R = Tm, Er, Ho and Dy) are the only known magnetic superconductors in this family. Here, we present our resistivity, magnetization and heat capacity studies on $NdPt_2B_2C$ (nominal composition, $NdPt_{1.5}Au_{0.6}B_2C$ and $NdPt_{2.1}B_{2.4}C_{1.2}$). We find superconductivity in both samples with $T_{c,onset} \sim 3$ K. Bulk magnetic order is found to occur below 1.7 K. We suggest that $NdPt_2B_2C$ is a possible magnetic superconductor.

Keywords. $NdPt_2B_2C$; quaternary borocarbide; magnetic superconductor.

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1. Introduction

One of the attractions of quaternary borocarbide superconductors [1–3] is the coexistence of superconductivity and magnetism found in some of the members at relatively elevated ($\gtrsim$ 5 K) temperatures [4]. So far, RNi_2B_2C (R = Tm, Er, Ho and Dy) ($T_c \sim 11$ K, 10 K, 8 K, 6 K and $T_N \sim 1.5$ K, 6 K, 8 K, 11 K, respectively) are the only known magnetic superconductors in this family. Amongst the other members of the family which contain magnetic ions, superconductivity has been observed only in $PrPt_2B_2C$ [5]. However, as it has been recently shown by us, Pr ions have a non-magnetic singlet ground state in this compound [6]. While $NdPt_2B_2C$ forms in the $LuNi_2B_2C$-type, tetragonal structure [5], it has been reported that in order to obtain single phase samples, one either has to partially substitute Pt with Au ($NdPt_{1.5}Au_{0.6}B_2C$) [7] or have off-stoichiometry such as $NdPt_{2.1}B_{2.4}C_{1.2}$ [8]. In these single phase samples, no superconductivity has been reported so far. While Cava *et al* [5] do not find magnetic order down to 1.8 K, Buchgeister *et al* [8] do report a magnetic transition at 9.5 K. In the light of these results, we have investigated single phase samples of $NdPt_{1.5}Au_{0.6}B_2C$ and $NdPt_{2.1}B_{2.4}C_{1.2}$. We find that bulk magnetic order occurs in the system but below 1.7 K. Surprisingly, we also find superconductivity in the system with $T_c \sim 3$ K. Preliminary results are presented in the following sections.

2. Experimental

Samples of $NdPt_2B_2C$ with nominal composition, $NdPt_{1.5}Au_{0.6}B_2C$ and $NdPt_{2.1}B_{2.4}C_{1.2}$ were prepared by arc-melting technique under flowing argon atmosphere. The samples were sealed in evacuated quartz capsules and annealed at 1100°C for 7 days. Two batches were made to check the reproducibility of results. Phase purity was checked by powder X-ray diffraction. Magnetic measurements (1.8–300 K) were performed using a SQUID magnetometer and resistivity measurements (1.5–300 K) were carried out by standard four-probe method. Heat capacity measurements (1.5–25 K) were performed by semi-adiabatic, heat pulse method using a home-built apparatus.

3. Results and discussions

Powder X-ray diffraction results showed that the samples are essentially single phase with expected $LuNi_2B_2C$-type structure. Maximum intensity of non-indexable peak was $< 5\%$ of 100% intensity peak in the Au containing sample. The lattice constants were a=3.834 Å, c = 10.799 Å, and a = 3.826 Å, c = 10.732 Å for $NdPt_{1.5}Au_{0.6}B_2C$ and $NdPt_{2.1}B_{2.4}C_{1.2}$, respectively. These values are in reasonable agreement with those reported in literature [7,8]. In our further discussions we shall refer to these samples as $NdPt_2B_2C$ with and without Au.

Low field magnetization (10 Oe) measurements of our samples of $NdPt_2B_2C$ (with and without Au) show diamagnetism below 2.8 K, indicating occurrence of superconductivity. The strength of the signal in the sample containing Au is comparable to that observed in a bulk superconductor. Resistivity measurements confirm superconductivity in the sample with Au with $T_{c,onset}$ of 3.2 K and $T_{c,0}$ at 2.8 K (figure 1). In the case of the sample without Au, the transition is broad with $T_{c,onset}$ at 3 K, nearly the same as that for the Au sample.

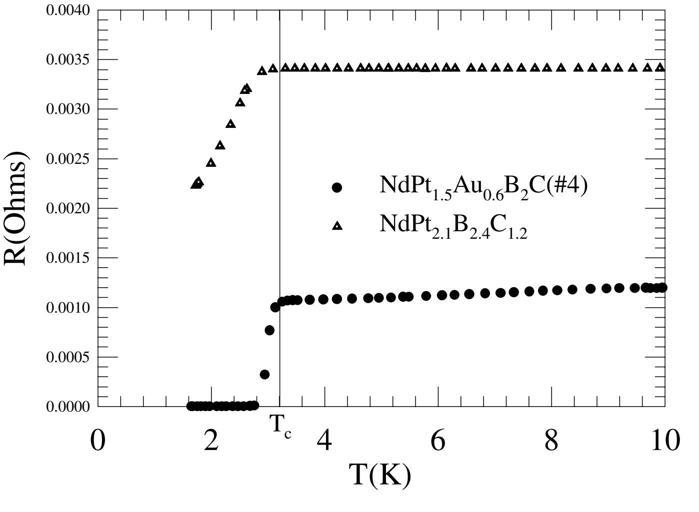

Figure 1. Resistivity, R, of $NdPt_{1.5}Au_{0.6}B_2C$ and $NdPt_{2.1}B_{2.4}C_{1.2}$ showing superconducting transition.

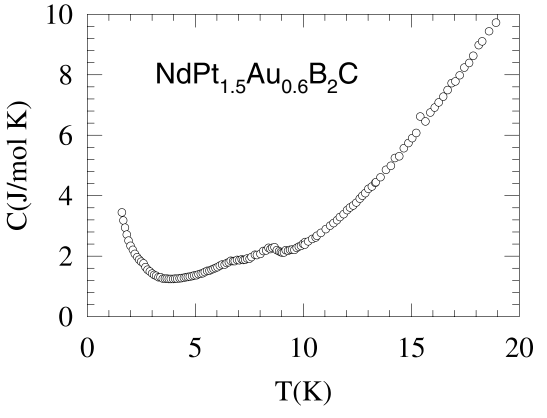

Figure 2. Low temperature heat capacity, C, of $NdPt_{1.5}Au_{0.6}B_2C$.

Magnetic susceptibility at high temperatures exhibits Curie–Weiss behavior with $\mu_{\text{eff}} = 3.55\ \mu_{\text{B}}/\text{Nd}$ which is nearly equal to the free ion value and $\theta_p = -20$ K. Heat capacity of the sample with Au is shown in figure 2. The data of the sample without Au are similar, but do not show the anomaly around 9 K. The large increase in heat capacity below 2 K indicates the onset of bulk magnetic order in the material at lower temperatures. Since, the paramagnetic Curie temperature is negative, we anticipate the magnetic order to be antiferromagnetic. Since it is known that antiferromagnetism and superconductivity coexist in the Ni-borocarbides, we suggest their coexistence in $NdPt_2B_2C$ too. We attribute the small anomaly around 9 K to NdB_2C_2 impurity, which is known to order magnetically around the same temperature. We believe that the earlier reported magnetic order at 9.5 K based on magnetic susceptibility, may be due to the same impurity and was erroneously attributed to $NdPt_2B_2C$ [8].

4. Conclusions

We have observed for the first time, the occurrence of superconductivity in $NdPt_2B_2C$ system ($T_c \sim 3$ K). Contrary to an earlier report, we did not observe any bulk magnetic order around 9 K. Our heat capacity studies conclusively show existence of magnetic order, but below 1.7 K. The data suggest possible coexistence of superconductivity and magnetism below 1.7 K.

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