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Superconductivity in $Y(Ni_{1-x}Pt_x)_2B_2C$ compounds

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Abstract. Superconductivity for the $Y(Ni_{1-x}Pt_x)_2B_2C$ compounds is reported. X-ray diffraction patterns of the $Y(Ni_{1-x}Pt_x)_2B_2C$ compounds were indexed on the basis of the modified $ThCr_2Si_2$-type structure. With increasing Pt concentration the lattice parameters a and c and unit-cell volume v increase linearly. The expansion of unit-cell volume for YPt_2B_2C is about 18% compared with that for YNi_2B_2C, whereas the superconducting transition temperature decreases monotonically from 15.2 K for YNi_2B_2C to 10 K for YPt_2B_2C.

Research on superconductivity of the copper-oxide-based superconductors has dominated superconductivity research since 1988 because of their high superconducting transition temperature. In contrast, there has been little research progress in developing new intermetallic superconducting materials. Recently following the discovery of a new family of the R–T–B–C superconducting compounds with R ≡ Y or rare earth, and T ≡ Ni and Pd [1–5], the bulk superconductivity of the new quasi-ternary borocarbides has aroused considerable interest. This is largely because the new superconductors have a significantly higher superconducting transition temperature. The highest T_c reaches 15.6 K for YNi_2B_2C, 16.6 K for $LuNi_2B_2C$ [2], and 23 K for Y–Pd–B–C compounds [4], which are much higher than those of the two-dimensional ternary rare-earth borocarbides where T_c is 3.6 K for YB_2C_3 and 2.4 K for LuB_2C_2 [6]. On the other hand, the presence of the transition metal, generally showing magnetism, in the new quasi-ternary intermetallic borocarbides also makes the mechanism of superconductivity in these materials of particular interest. It has been found [7] that the Ni 3d DOS in YNi_2B_2C is broader than that in FCC Ni metal, and so $N(E_F)$ becomes small enough to make the system non-magnetic and superconducting. Therefore, the superconductivity in the new quasi-ternary YNi_2B_2C can be described by the electron–phonon coupling mechanism.

From the viewpoint mentioned above, the Ni atoms in YNi_2B_2C may be substituted by another non-magnetic or weakly magnetic element, and this substitution does not destroy the superconductivity in the new quasi-ternary borocarbides. In this paper the superconductivity in the $Y(Ni_{1-x}Pt_x)_2B_2C$ compounds has been investigated and the main results are presented.

The samples with nominal composition $Y(Ni_{1-x}Pt_x)_2B_2C$ ($x = 0$, 0.1, 0.2, 0.4, 0.6, 0.8 and 1.0) were prepared by standard arc-melting techniques. The total weight of each target is 5–10 gf. The starting materials were Y (99.9% purity), Pt (99.99% purity), Ni (99.9% purity), B powder (99.995% purity) and C (99.99% purity). First of all, the B powders were pressed into pellets of 8 mm diameter and arc melted under an argon atmosphere on a water-cooled copper hearth. Subsequently, all the constituent elements were mixed thoroughly and arc melted together. The arc-melted buttons were turned over and remelted three times. The total loss of weight of each button upon arc melting is less than 2%. The resulting samples were metallic silver in colour.

The phases present and the lattice parameters for each sample were established by x-ray diffraction with Co Kα radiation on powder samples. The superconducting properties of the polycrystalline materials were measured on a commercial SQUID magnetometer in a field of 20 G down to 5 K, and DC electrical resistivity measurements were carried out using the standard four-probe method down to 4.2 K.

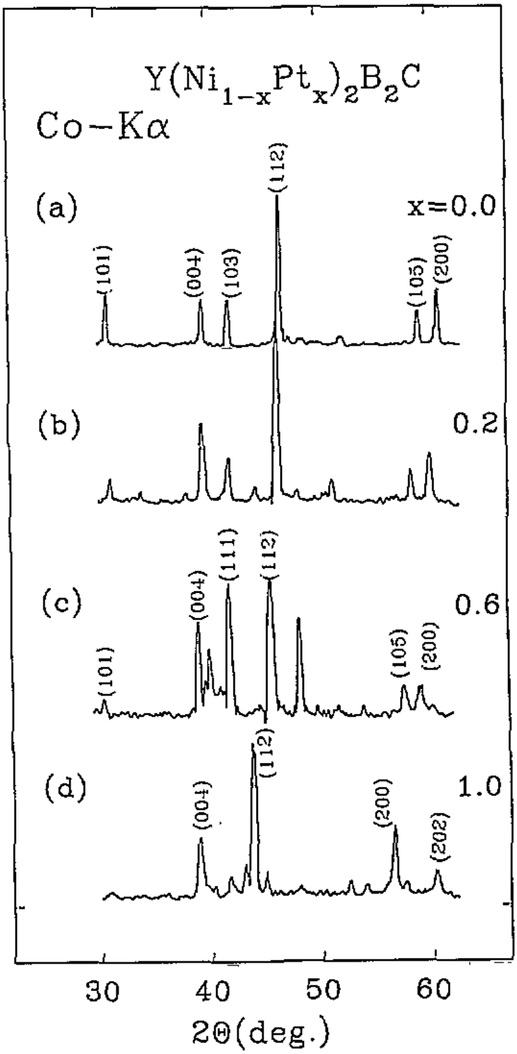

Figure 1. X-ray diffraction patterns of the $Y(Ni_{1-x}Pt_x)_2B_2C$ compounds for (a) $x = 0$, (b) $x = 0.2$, (c) $x = 0.6$ and (d) $x = 1.0$.

Powder x-ray diffraction patterns of the $Y(Ni_{1-x}Pt_x)_2B_2C$ compounds are shown in figure 1 for several Pt concentrations. All the investigated compounds crystallize in a

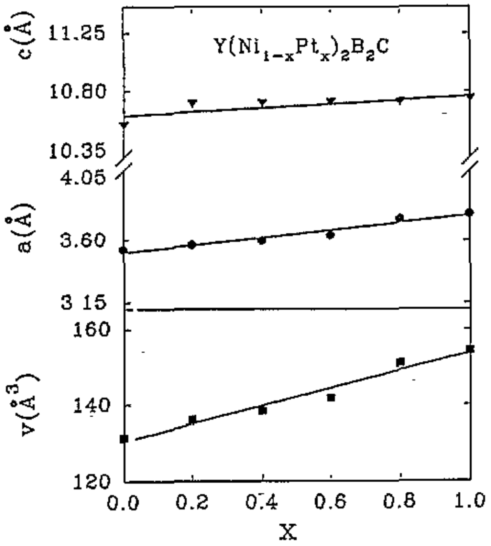

Figure 2. Lattice parameters a and c and unit-cell volumes v of the $Y(Ni_{1-x}Pt_x)_2B_2C$ compounds as functions of Pt concentration.

modified $ThCr_2Si_2$-type structure [3]. It can be seen that YNi_2B_2C is single phase, as shown in figure 1(a). The lattice parameters are derived to be $a = 3.53(1)$ Å and $c = 10.54(1)$ Å and the unit-cell volume $v = 131(1)$ Å^3. With increasing Pt concentration the main peaks in the x-ray diffraction pattern of YNi_2B_2C are shifted towards smaller angles, as shown in figure 1(b). When the Pt content reaches 0.6, the main diffraction peaks were indexed on the basis of a modified $ThCr_2Si_2$-type structure, but there are some peaks of the second phase left. $YNi_{0.8}Pt_{1.2}B_2C$ becomes multiphase, as shown in figure 1(c). YPt_2B_2C is almost a single phase but still with a small amount of the second phase. The lattice parameters were derived to be $a = 3.79(1)$ Å and $c = 10.71(1)$ Å and the unit-cell volume $v = 154(1)$ Å^3. Figure 2 shows the structural parameters of the $Y(Ni_{1-x}Pt_2)_2B_2C$ compounds as functions of Pt concentration. It can be seen that the lattice constants a and c and the unit-cell volume v of the $Y(Ni_{1-x}Pt_x)_2B_2C$ compounds increase linearly with increasing Pt concentration. The expansion of the unit-cell volume of YPt_2B_2C reaches 18%, compared with that of YNi_2B_2C. Such a large expansion of the unit-cell volume may be associated with the larger Pt^{2+} ionic radius of 1.06 Å compared with 0.78 Å for the smaller Ni^{2+} ion and may have a considerable influence on the electron–phonon interaction. The temperature dependences of the magnetization measured in a low field of 20 G with a SQUID magnetometer for as-melted YNi_2B_2C and YPt_2B_2C are shown in figure 3. The data were obtained both for warming after zero-field cooling and for cooling in a field as denoted by the arrows. The large zero-field-cooled shielding signal of -1.4×10^{-2} emu g^{-1} G^{-1} for YNi_2B_2C and -8.4×10^{-3} emu g^{-1} G^{-1} for YPt_2B_2C at 5 K indicates a bulk superconductivity effect in these compounds. The onset of superconductivity was found to be 15.2 K for YNi_2B_2C, which is in good agreement with the value reported in [2], and 10 K for YPt_2B_2C. Figure 4 shows the Pt concentration dependence of the onset temperature of the $Y(Ni_{1-x}Pt_x)_2B_2C$ compounds, derived from the temperature-dependent magnetization. It can be seen that with increasing Pt concentration the onset temperature of the superconductivity decreases monotonically.

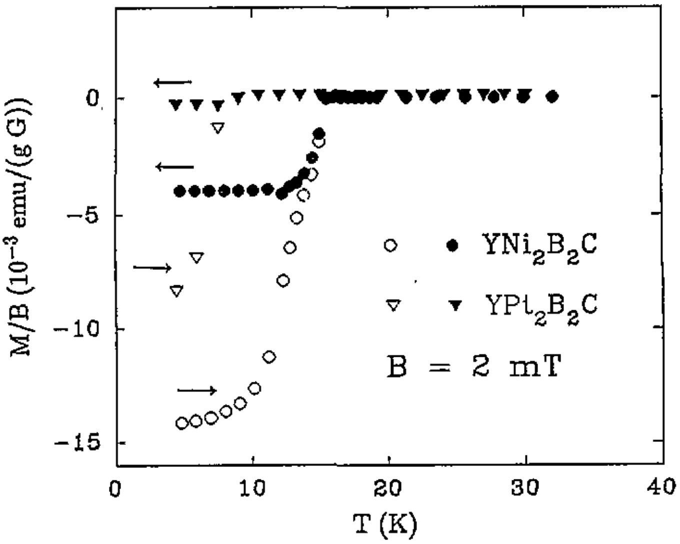

Figure 3. Temperature dependence of the magnetization *M*, in an applied field of 20 G, for YNi_2BC and YPt_2B_2C. The data were obtained both for warming after zero-field cooling and for cooling in the field, as denoted by the arrows.

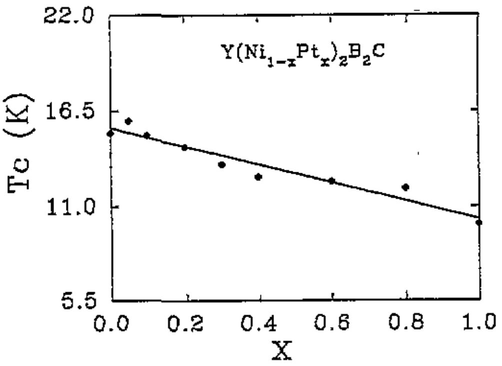

Figure 4. Onset of superconductivity derived from the temperature-dependent magnetization as a function of Pt concentration for the $Y(Ni_{1-x}Pt_x)_2B_2C$ compounds.

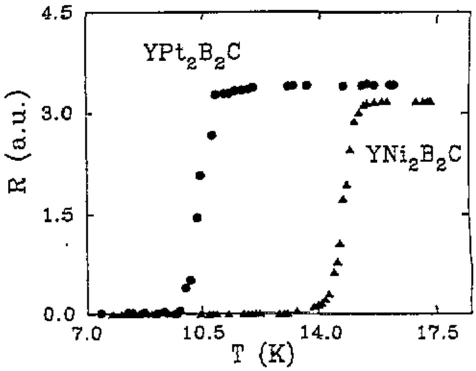

Figure 5. Temperature dependences of resistance *R* for YNi_2B_2C and YPt_2B_2C.

The temperature dependence of the DC resistivity also shows a superconducting transition for all the $Y(Ni_{1-x}Pt_x)_2B_2C$ compounds, and even for pure YPt_2B_2C. Figure 5 shows the temperature dependences of the electrical resistances of the as-melted samples of the YNi_2B_2C and YPt_2B_2C. Slight S-shaped temperature dependences of the resistance were observed. The onset and zero-resistivity temperatures of the superconducting transition were derived to be 15.4 K and 14.0 K, respectively, for YNi_2B_2C, and 11 K and 10 K, respectively, for YPt_2B_2C. The 10–90% transition widths are 0.8 K for YNi_2B_2C and 0.6 K for YPt_2B_2C.

In conclusion, we have found that YPt_2B_2C, which is isostructural to YNi_2B_2C, is a new superconducting quasi-ternary borocarbide. The appearance of superconductivity in the present YPt_2B_2C compound indicates that magnetism may be irrelevant to the superconductivity of this system. The T_c of 10 K for the present YPt_2B_2C compound is lower than those of YNi_2B_2C and Y–Pd–B–C compounds, which may be associated with the expansion of the unit-cell volume upon substitution of Pt for Ni. The influence of the transition-metal magnetism on the superconductivity in this system is not yet fully understood. It is best to await a detailed interpretation of $T_c(x)$ for the $Y(Ni_{1-x}Pt_x)_2B_2C$ compounds until experimental results on single crystals have been obtained.

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