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STRUCTURE AND SUPERCONDUCTIVITY OF $Mg(B_{1-x}C_x)_2$ COMPOUNDS*

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In this paper, we report on the structural properties and superconductivity of $Mg(B_{1-x}C_x)_2$ compounds. Powder X-ray diffraction results indicate that the samples crystallize in a hexagonal AlB_2-type structure. Due to the chemical activity of Mg powders, a small amount of MgO impurity phase is detected by X-ray diffraction. The lattice parameters decrease slightly with the increasing carbon content. Magnetization measurements indicate that the non-stoichiometry of MgB_2 has no influence on the superconducting transition temperature and the transition temperature width. The addition of carbon results in a decrease of T_c and an increase of the superconducting transition width, implying the loss of superconductivity.

Keywords: superconductivity, magnesium diboride, carbon substitution
PACC: 7470

I. INTRODUCTION

The discovery of superconductivity at about 39 K in magnesium diboride by Akimitsu *et al.*[1] has resulted in common excitement for scientists investigating in the field of solid-state physics, due to its relatively high superconducting transition temperature. Its superconducting transition temperature seems to be at or above the limit of the Bardeen–Cooper–Schrieffer (BCS) theoretical model.[2] This novel discovery may open a new route towards the search for high-temperature superconductors. In order to investigate the effect of electron concentration on T_c, Slusky *et al.*[3] have synthesized the solid solutions of $Mg_{1-x}Al_xB_2$ and investigated its structural transition and superconductivity. It was found that the superconducting transition temperature decreases with increasing Al concentrations, and the superconductivity disappears at $x > 0.4$. Up until now, the contribution of B layers to the superconductivity has not been well known. The substitution of carbon for boron may give an insight into the understanding of the contribution of the boron layer to the superconductivity. In this paper, the effect of carbon substitution on the superconductivity of MgB_2 is investigated.

II. EXPERIMENTAL DETAILS

The samples were prepared from powdered magnesium (98.5% purity), mixed with boron (99.99% purity) and carbon (99.99% purity) powders. The powders were well mixed in an appropriate ratio and pressed into pellets, which were sealed in a quartz tube and sintered at 950 K for 2 h. Powder X-ray diffraction (XRD) was carried out on an X-ray diffractometer with Cu $K\alpha$ radiation over a 2θ ranging from 20° to 90° with a step of 0.02°. The temperature dependence of the magnetization of the samples was measured in a Quantum Design MPMS-7 SQUID magnetometer in an applied field of 1600 A/m.

III. RESULTS AND DISCUSSION

Figure 1 illustrates the XRD patterns of MgB_2 and $Mg(B_{1-x}C_x)_2$. The XRD indicates that the main diffraction lines can be indexed by a hexagonal lattice of $Mg(B_{1-x}C_x)_2$. A small amount of impurity phase MgO was also detected due to the chemical activity of the Mg powders. The crystal structure of $MgB_{1.8}C_{0.2}$ consists of alternating hexagonal layers of Mg atoms and graphite-like honeycomb layers of B and C atoms along the c-axis direction. With

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the introduction of carbon, the lattice parameters (a=0.3070nm, c=0.3523nm) are slightly smaller than those of MgB_2 (a=0.3086nm, c=0.3524nm).

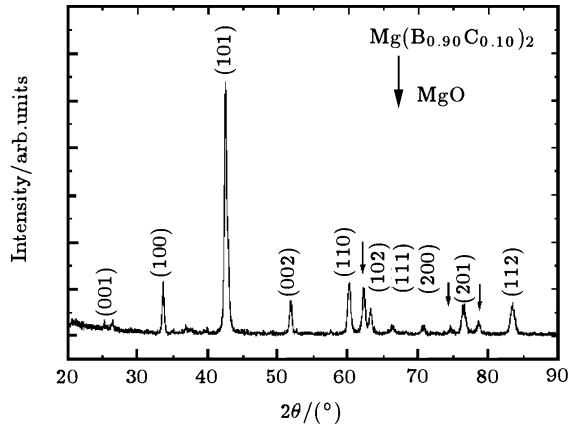


Fig.1. Cu $K\alpha$ powder X-ray diffraction pattern of $Mg(B_{1-x}C_x)_2$ with x=0.10.

Figure 2 illustrates the temperature dependence of magnetization of $Mg(B_{1-x}C_x)_2$ intermetallic compounds measured in the applied field of 1600A/m. A sharp superconducting transition is observed in MgB_2 compound. With the increasing carbon content, the transition temperature becomes less sharp. The superconducting transition temperature determined from the onset temperature of 2% of the full diamagnetic signal at low temperature is found to decrease from 36 K for x=0.00 to 34 K for x=0.20. The superconducting transition width for a 10–90% drop, ΔT_c increases from 1 to 3 K with the introduction of carbon atoms.

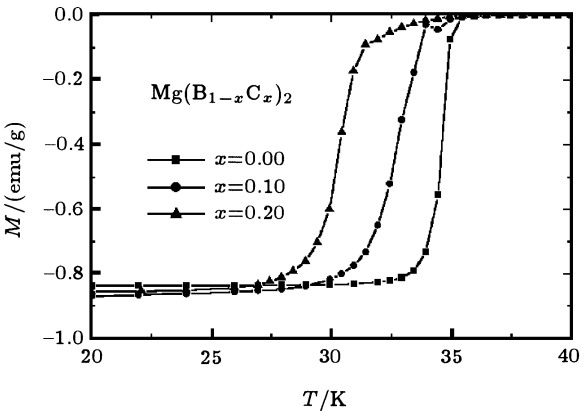


Fig.2. Normalized magnetization data of $Mg(B_{1-x}C_x)_2$ compounds with x=0.00, 0.10 and 0.20 as a function of temperature measured in an applied field of 1600A/m. The samples were cooled down to 5K without a magnetic field (ZFC).

The superconducting transition temperature of our sample MgB_2 is slightly lower than 39K, as reported in Refs.[1] and [3]. One possible reason for the lower T_c is related to the non-stoichiometry of MgB_2. It is well known that boron and carbon have high melting points and high boiling points; the only possible loss is Mg powders due to its evaporation at high temperatures. In order to exclude the possibility of the deficiency of Mg, we have investigated the non-stoichiometry of MgB_2 by adding an excess of Mg with 10at%, 20at% and 30at% Mg, respectively. Figure 3 presents the magnetization temperatures of $Mg_{1+x}B_2$ (x=0.00, 0.1, 0.2 and 0.3) compounds. In order to compare these easily, the magnetization data are all normalized to one at low temperatures. The plot shows that they have identical superconducting transition temperatures and transition widths regardless of Mg contents. Therefore, the lower value of T_c for our samples possibly comes from the low purity of Mg powders (98.5% purity), rather than the non-stoichiometry of the MgB_2 compound.

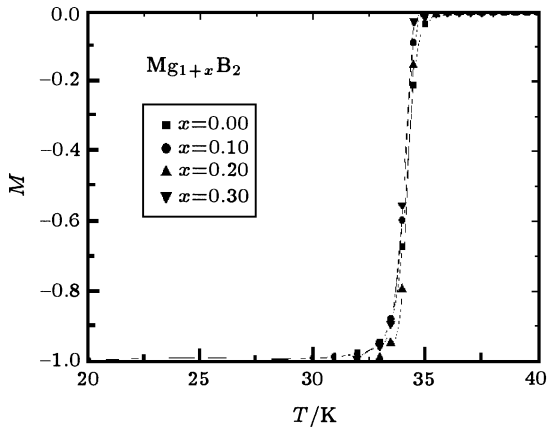


Fig.3. The temperature dependence of normalized magnetization of $Mg_{1+x}B_2$ compounds measured in an applied field of 1600A/m. The samples were cooled down to 5K in a zero magnetic field.

IV. CONCLUSION

The structural properties and superconductivity of $Mg(B_{1-x}C_x)_2$ were investigated by means of powder XRD patterns and magnetization measurements. It was found that the non-stoichiometry of MgB_2 has no influence on the superconducting transition temperature and its width. This result suggests that once MgB_2 forms, it has specific T_c. The deficiency or excess of Mg only results in the formation of the second phase, which has no effect on T_c. The addition of carbon leads to the decrease of the superconducting transition temperature.

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