Simple and Economical Method to Prepare $Mg_{1-x}Mn_xB_2$ Superconductor

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Abstract. The polycrystalline samples of $Mg_{1-x}Mn_xB_2$ ($0 \le x \le 0.03$) have been synthesized by using the solid state reaction method. The properties of the samples depend on the method of preparation. Generally, Tantalum foil is used for the preparation of MgB_2 superconductor to reduce the formation of MgO phase. Here, we have reported a very simple and economical method for the preparation of $Mg_{1-x}Mn_xB_2$ ($0 \le x \le 0.03$) samples by using the stainless steel sheet instead of Ta foil. These results are well in agreement as prepared by using the Ta foil. All the samples were sintered at 850 °C for 2 hrs in the presence of high purity argon flow. The structural and electrical properties were studied by using the X-Ray diffraction and four-probe resistivity measurement techniques, respectively. The XRD patterns revealed the formation of MgB_2 as the major phase. The superconducting transition temperature (T_c) decreases with increasing the Mn concentration. The Mn doping suppresses the transition temperature sharply as compared to the other doping like Al, Cu and Ag. This abrupt suppression in transition temperature is due to the pair breaking by the introduction of magnetic ions.

Keywords: MgB_2, Doping, Phase formation, Transition temperature.Enter Keywords here.
PACS: 74.70.Ad, 74.25.Fy, 74.25.62.Dh

INTRODUCTION

The discovery of superconductivity in MgB_2 [1] evoked a new enthusiasm among the experimentalists and theoreticians to understand the mechanism of superconductivity in this material. This discovery offers a new era in the field of superconductivity and as a guide to search the superconductivity in simple binary compounds. Unlike high temperature superconductors (HTS), MgB_2 has lower anisotropy, larger coherence length, high critical current density and transparency at grain boundaries to the current flow. This makes MgB_2, promising material for practical applications. This superconductor has the wide range of operating temperature, approximately twice the value of the present application of Nb_3Sn and Nb-Ti superconductors, which can be easily attained by cryogen/cryocoolers and more economical than the liquid helium. The density of this new intermetallic superconductor is very less (2.6 g/cm^3). Therefore, this superconductor is very useful in the applications where light material is preferable, like space science. The MgB_2

CP1004, *Thermophysical Properties of Materials and Devices-NCTP'07*,
edited by P. Predeep, S. Prasanth, and A. S. Prasad

wire has been used in X-ray spectrometer in 'Suzaku' satellite launched by Japan on July 10, 2005 [2]. Also MgB_2 has the prospects to make high field superconducting magnet [3].

The other groups prepared MgB_2 by different methods using the sealed tube method and vacuum furnace etc. The major problem to prepare MgB_2 is the formation of MgO phase. Generally, Tantalum foil is used for the preparation of MgB_2 superconductor to reduce the formation of MgO phase. We have already optimized the processing parameters for the preparation of Cu doped MgB_2 [4]. Our group has also studied the thermodynamical properties of this superconductor [5, 6]. Here, we have reported a very simple and economical method for the preparation of $Mg_{1-x}Mn_xB_2$ ($0 \leq x \leq 0.03$) samples by using the stainless steel sheet instead of Ta foil. The preparation, phase formation and electrical properties of $Mg_{1-x}Mn_xB_2$ ($0 \leq x \leq 0.03$) are discussed systematically in the following section.

EXPERIMENTAL PROCEDURE

We have used the standard solid-state reaction method for the synthesis of polycrystalline $Mg_{1-x}Mn_xB_2$ ($0 \leq x \leq 0.03$) samples. For this purpose, the stoichiometeric amount of Mg, B and Mn powders were taken and thoroughly ground in an agate mortar for 4 hrs and compacted into the circular pellets of 12 mm diameter by applying hydraulic pressure. We have made a boat of commercially available stainless steel sheet and put the pellets in the above said boat and heated the same in a quartz tube at 850°C for 2 hrs in the presence of high purity argon gas flow followed by the furnace cooling. These samples were characterized by X-Ray diffractometer (Cu K_α radiation) in the range $20° \leq 2\theta \leq 80°$ for identifying the phase formation. The low temperature electrical resistivity was measured by the standard four-probe method in the range of 30 K to 300 K by closed cycle refrigeration equipment (CTI Cryogenics).

RESULTS AND DISCUSSION

The XRD patterns of $Mg_{1-x}Mn_xB_2$ ($0 \leq x \leq 0.03$) samples are shown in fig.1. These patterns are indexed in P6/mmm space group by using PowderX program. In fig. 1, we have also introduced the XRD patterns of pure MgB_2 sample, which we have prepared by using the Tantalum foil for the reference purpose. It is clear from fig. 1 that all the peaks are indexed according the P6/mmm space group. The XRD patterns of pure MgB_2 by using the Tantalum foil and stainless steel sheet (fig. 1) are similar. In both the cases there is small impurity peak of MgO at $2\theta = 62.36$. The presence of this peak is also seen in other reports [7-10]. The small MgO peak is also observed near the major peak of MgB_2 in the case of 2% and 3% Mn concentration. There is no trace of Mn impurity.

The variation of normalized electrical resistivity of $Mg_{1-x}Mn_xB_2$ ($0 \leq x \leq 0.03$) in the temperature range 30 K to 300 K is shown in fig. 2. All the samples show metallic to superconducting transition. The superconducting transition temperature decreases as we increase the Mn concentration. The transition onset temperature of 1% Mn doped sample is 35 K, which is 3 K less than that of pure MgB_2. This decrease in transition

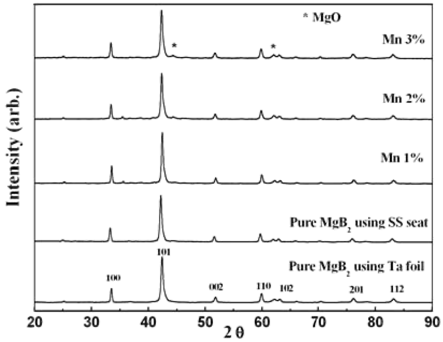

FIGURE 1 XRD patterns of $Mg_{1-x}Mn_xB_2$ $(0 \leq x \leq 0.03)$ superconductors

temperature is due to the substitution of magnetic Mn atoms at Mg site, which breaks the cooper pairing. Although the Mn doping suppresses the transition temperature but does not affects the transition width. The transition width in all the samples is very less

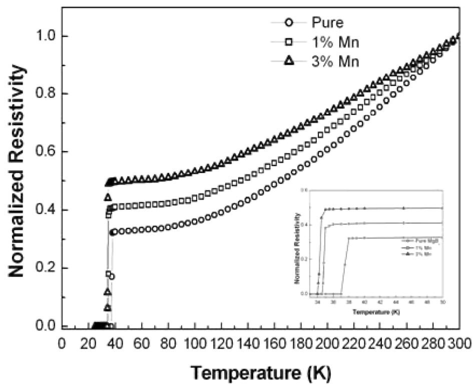

FIGURE 2. The variation of normalized resistivity with temperature of samples prepared by using the stainless steel sheet, inset shows the clear variation of transition temperature.

TABLE 1. Transition temperatures (onset and zero resistivity) and transition width of prepared samples

Sample	$T_{c\ onset}$ (K)	$T_{c\ zero}$ (K)	Transition width (K)
Pure MgB_2	38	37	1
1% Mn	35	34.50	0.50
3% Mn	35	34.10	0.90

(<1 K), which also support the monophasic nature of the prepared samples.

The variation of transition temperature is clearly seen from the inset of fig. 2. The normal state resistivity also increases with Mn doping. The variation of transition temperature with Mn doping is given in Table I.

CONCLUSION

We have synthesized $Mg_{1-x}Mn_xB_2$ ($0\leq x\leq 0.03$) superconductors through solid state reaction method by using the stainless steel sheet instead of Tantalum foil. On the basis of above discussion, we can conclude that the prepared samples (using stainless steel sheet) show the same properties as we obtained by using the Tantalum foil. Thus, our method of preparation of MgB_2 is economical and simple because the Tantalum foil is very costly as compared to the stainless steel sheet. Although the Mn doping decreases the transition temperature abruptly but no impurity traces of Mn is observed in the MgB_2 matrix. This decrease in transition temperature is due to substitution of magnetic Mn atoms at Mg site, which breaks the cooper pairing.

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