Abstract

Transport current values of $7.5 \times 10^4$ A/cm$^2$ at 4.2 K and self-field are reported for MgB$_2$-based tapes. MgB$_2$ strands were formed by directly filling commercially available MgB$_2$ powder into Nb-lined, monel tubes and then wire drawing. The wires were then rolled into tapes $2.56 \times 0.32$ mm$^2$, with a total superconducting cross section of 0.2319 mm$^2$. Transport measurements were performed using a standard four-point technique at $T = 4.2$ K (in liquid helium) and at self field. Three samples were prepared, with heat treatments of 900°C for 1, 2, and 3 h under 1/3 at Ar. Measured values of transport current were 4.7, 7.5, and $1.1 \times 10^4$ A/cm$^2$, respectively, at 4.2 K and self field. M-H loops taken on the sample HT for 1 h showed magnetic $J_c$s of $4.2 \times 10^4$ A/cm$^2$ at 4.2 K and 1 T, indicating that the material had reasonably well connected grains.

Keywords: MgB$_2$, transport current
Introduction

The recent announcement of the discovery of MgB$_2$ [1] has triggered a great deal of interest in the research community. The origin of its transition has been described in terms of an electron-phonon coupling [2] with its associated isotope effect [3]. Alternatively, it has been described in terms of a hole-carrier-based pairing mechanism [4]. The crystal structure of MgB$_2$ is the AlB$_2$ structure, with honeycomb layers of boron atoms alternating with hexagonal layers of Mg atoms. MgB$_2$ decomposes peritectically, with the phase diagram given in [4]. Even though this makes formation of single crystals difficult, polycrystalline MgB$_2$ can be easily formed. In fact, MgB$_2$ powder is commercially available, and has been successfully sintered into a reasonably well connected pellets by heat treatment (HT) under pressure at 1000°C [5]. It is also possible to start with sufficiently small elemental powders and sinter to form high quality MgB$_2$ by reaction at similar temperatures [6].

A number of groups have now fabricated the powders in pellet or similar form and have reported $B_{c2}$ and magnetically derived $J_c$ properties [5-7]. Takano et al. [5] starting with -100 Mesh MgB$_2$ powders, sintered them at 775, 1000, and 1250°C under pressure. They find some level of MgO (present in the powder as-received) and MgB$_4$ impurity phases (at higher temperatures). The powders are seen to sinter together during the 1000°C HT, leading to 20 K, 1 T magnetic $J_c$s of approximately $10^5$ A/cm$^2$ for the powder and $4 \times 10^4$ A/cm$^2$ in the sintered bulk. On the other hand Larbalestier et al. have started with elemental Mg and B powders. They pressed them into pellets, placed them on Ta foil on Al$_2$O$_3$ boats and fired them under Ar for 1 h at 600°C, 800°C, and 900°C.
The powders were then lightly ground, pressed into pellets and HT under pressure at temperatures between 650°C and 800°C for times between 1 and 5.5 h. They obtained $10^4$ A/cm² at 20 K and 1 T, and also $4 \times 10^4$ A/cm² at 4.2 K 1 T. Recent results from Dou et al., using again elemental powders gives $10^5$ A/cm² at 4.2 K, 1 T for the $J_c$ of currents flowing across the whole of the slab 3 x 3 x 2 mm [8].

Larbalestier et al. [6] give values of 17.5 T for $B_{c2}(0)$, similar to the estimates from [5]. The level of intrinsic anisotropy has not been determined. The grain to grain link properties seem good in view of results from [5-7] and also [8]. In fact the macroscopic $J_c$ was sufficiently high in [8] that flux jumping was seen.

The properties of MgB₂ are increasing rather quickly, suggesting that this system will be much easier to work with than “high Tc” materials. The next step is to make the material in wire form. Below some initial progress in that direction is shown.

**Experimental**

MgB₂ powder (-100 mesh) was filled into a Nb-lined monel tube 6 mm in diameter. The tube was then drawn through conical dies to form a wire 50 mils in diameter which was subsequently rolled. The samples were then encapsulated under Ar and reacted at 900°C for 1 and 2 hours. Transport $J_c$ measurements were made in liquid helium at self field using the standard four-point technique. M-H loops were measured using an EG&G PAR vibrating sample magnetometer with a 1.7 T iron core magnet.
Results

Transport measurements were made for two samples, listed in Table 1, below. Sample MGB1, heated treated 1 had an $I_c$ of 108 A and $J_c$ of 4.7 x $10^4$ A/cm$^2$, while sample MGB2 had an $I_c$ of 173 A and a $J_c$ of 7.5 x $10^4$. MGB2 went normal via quench, indicating that the intrinsic transport $J_c$ is higher, and the practical $J_c$ will be improved with proper stabilization. M-H loops were performed on MGB1, and the result is shown in Fig. 1. Here the loop has a ferromagnetic component due to the monel which causes the unusual looking asymmetry, and a peak at low fields due to Nb. However, we have extracted the resulting 1 T $\Delta M$ and it is listed in Table 2. Magnetic $J_c$ was extracted using the expression $\Delta M = (0.2/3\pi)J_cd$, where $d$ is the width perpendicular to the applied field. For the present measurements the field was applied perpendicular to the sample. The resulting magnetic $J_c$ of 4.2 x $10^4$ A/cm$^2$ at 4.2 K and self field is close (somewhat less) than the transport $J_c$ for this sample. The slightly lower magnetic $J_c$ is due to a slight drop in $J_c$ between self field and 1 T.

Summary

Transport current values of 7.5 x $10^4$ A/cm$^2$ at 4.2 K and self-field were shown for MgB$_2$-based tapes. MgB$_2$ strands were formed by directly filling commercially available MgB$_2$ powder into Nb-lined, monel tubes and then wire drawing. The wires were then rolled into tapes 2.56 x 0.32 mm$^2$, with a total superconducting cross section of 0.2319 mm$^2$. Transport measurements were performed using a standard four-point technique at $T = 4.2$ K (in liquid helium) and at self field. Three samples were prepared, with heat treatments at 900°C for 1, 2, and 3 h under 1/3 at Ar. Measured values of transport
current were 4.7, 7.5, and $1.1 \times 10^4$ A/cm$^2$, respectively, at 4.2 K and self field. M-H loops taken on the sample HT at $900^\circ$C/1 h showed magnetic $J_s$ of $4.2 \times 10^4$ A/cm$^2$ at 4.2 K and 1 T, indicating that the material had reasonably well connected grains.

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Table 1. Transport $J_c$ values for MgB$_2$ samples at 4.2 K and self field

| Sample Name | Heat Treatment | Superconductor Area, mm$^2$ | $I_c$ (4.2 K, self field), A | $J_c$ (4.2 K, self field), A/cm$^2$ |
|-------------|----------------|------------------------------|-------------------------------|----------------------------------|
| MGB1        | 900$^\circ$C/1h | 0.23                         | 108                           | 4.7 x 10$^4$                     |
| MGB2        | 900$^\circ$C/2h | 0.23                         | 173                           | 7.5 x 10$^4$                     |
| MGB3        | 900$^\circ$C/3h | 0.23                         | 25                            | 1.1 x 10$^4$                     |

Table 2. Magnetic $J_c$ values for MgB$_2$ samples at 4.2 K and 1 T

| Name  | Superconductor, w x t x L mm$^3$ | $\Delta M$, emu/cm$^3$, 1 T, 4.2 K | Magnetic $J_c$, A/cm$^2$, 4.2 K, 1 T |
|-------|----------------------------------|------------------------------------|-------------------------------------|
| MGB1  | 2.26 x 0.103 x 10.0              | 400                                | 4.2 x 10$^4$                        |
Figure 1. M-H loops for MgB$_2$ sample MGB1 at 4.2 K
