Optimization of J_c of MgB_2/Fe sheath wires by varying SiC addition level and sintering temperature

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Pure and nano-SiC added MgB_2/Fe wires were prepared by *in-situ* powder-in-tube method. The nano-SiC addition level varied from 0 to 15 wt%. Samples were sintered at temperatures from 600^{o}C to 1000^{o}C for 30 min. The important finding of this study is that the enhancement in J_c(H) by nano SiC addition can be achieved at different field regions by appropriate compromising of the doping level and sintering temperature.

1. Introduction

The critical current density (J_c) in MgB_2 has been a central topic for extensive research efforts since superconductivity in this compound was discovered [1]. A number of techniques and chemical additives have been used to improve the J_c performance in magnetic fields. The authors' group found that doping of MgB_2 with nano-particle SiC can significantly enhance J_c in high fields with only slight reductions in T_c up to a doping level as high as 30% of B [2]. In the high field region, the J_c for the 10wt% SiC doped sample increased by more than an order of magnitude at all temperatures compared to the undoped sample, that was verified by a number of groups over the past few years [2-9]. However, SiC doping have some negative effect on J_c in the low field region. The J_c for SiC doped MgB_2 was lower than that for undoped MgB_2 below 4 T at 5 K and below 2.5 T at 20 K [3-5]. There are many applications in the low field region, such as open MRI, transformers and electric cables which normally operate at around 1 T to 3 T. Thus, it is important that the enhancement of J_c by SiC doping can be extended to include all the field regions. In this work we will show that the improvement of J_c in SiC added MgB_2 can be achieved in all fields regions by varying SiC addition level and sintering profile.

2. Sample preparation

Fe-sheath MgB2 wires were prepared in-situ using the standard powder-in-tube technique [3, 6]. Powders of magnesium (99%) and amorphous boron (99%) were well mixed for fabrication of pure MgB_2 wire. SiC added MgB_2 wires were prepared from powders with atomic ratios Mg:2B plus 5 wt%, 10 wt% or 15 wt% of SiC additions. The detailed description of wire preparation can be found elsewhere [10].

Table 1. The list of studied pure and SiC added MgB_2 samples.

#	SiC addition level, %	Sintering profile	#	SiC addition level, %	Sintering profile
1	0	650^{o}C×30 min	7	10	650^{o}C×30 min
2	0	825^{o}C×30 min	8	10	825^{o}C×30 min
3	0	1000^{o}C×30 min	9	10	1000^{o}C×30 min
4	5	650^{o}C×30 min	10	15	650^{o}C×30 min
5	5	825^{o}C×30 min	11	15	825^{o}C×30 min
6	5	1000^{o}C×30 min	12	15	1000^{o}C×30 min

The composite wires were sintered in a tube furnace at 650^0C, 825^0C, and 1000^0C for 30 min and finally furnace-cooled to room temperature. A high purity argon gas flow was maintained throughout the sintering process. The description of studied samples is presented in Table 1.

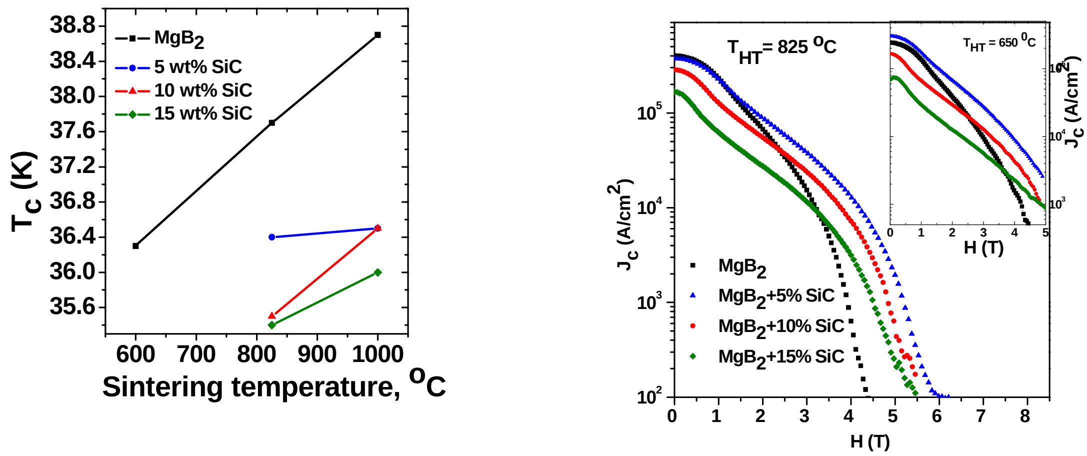
3. Results

3.1 Critical Temperature

The critical temperature values, T_c, were measured by SQUID magnetometer. The T_c values of undoped and SiC doped MgB_2/Fe wires sintered at different temperatures are presented on Fig. 1a. For each sintering temperature in studied samples, the increasing of SiC addition level resulted in more significant T_c suppression due to the reaction between SiC and MgB_2. On the other hand, for both pure and SiC-added wires, the T_c increased with increasing sintering temperature. The increase of T_c can be explained by the improvement of the crystallinity of the MgB_2 core with increasing sintering temperature [11].

3.2 Magnetic Characterization

Fig. 1b shows magnetic J_c vs H curves at 20 K for the undoped and SiC added MgB_2 wires sintered at 825^oC for 30 minutes. As can be seen, in self-field and 20 K J_c for 5 wt% SiC added MgB_2 wire reached the same value of 400,000 A/cm^2 as pure MgB_2 wire. At low fields the J_c values for the 10 wt% and 15 wt% SiC added wires were lower than those of the undoped sample. All SiC added samples showed more than one order of magnitude increase in J_c values at higher field regions. The J_c(H) behavior for all these samples sintered at 650^oC (see insert in Fig.1b) showed the same trend as that for samples sintered at 825^oC, but the J_c values in self field were lower than those obtained for the samples sintered at 825^oC. It is evident that for low field applications 5 wt% SiC doping gives the best performance in J_c(H), without any degradation even in self-field.



a b

Figure 1. a) Critical temperature of studied samples vs sintering temperature; b) critical current density of pure and SiC added MgB_2 samples sintered at 825^0C and 650^0C (insert).

Fig 2a,b presents transport J_c(H) measured at 4.2 K in the field range of 5 T to 15 T for the doped and undoped wires sintered at 650^oC and 825^oC. First, there was a clear distinguishable difference in J_c(H) for the undoped and SiC doped wires, the J_c value for the doped wires at all three doping levels being significantly higher than that of undoped one.

Furthermore, there were a cross over of the best $J_c(H)$ from 5 wt% SiC doped wire in the low field range (0 T to 5T) to 10 wt% SiC doped wire in the high field range (8 T to 15 T). Higher doping level results in larger amount of Mg_2Si impurities that act as effective pinning centers improving $J_c(H)$ performance in high field region [10].

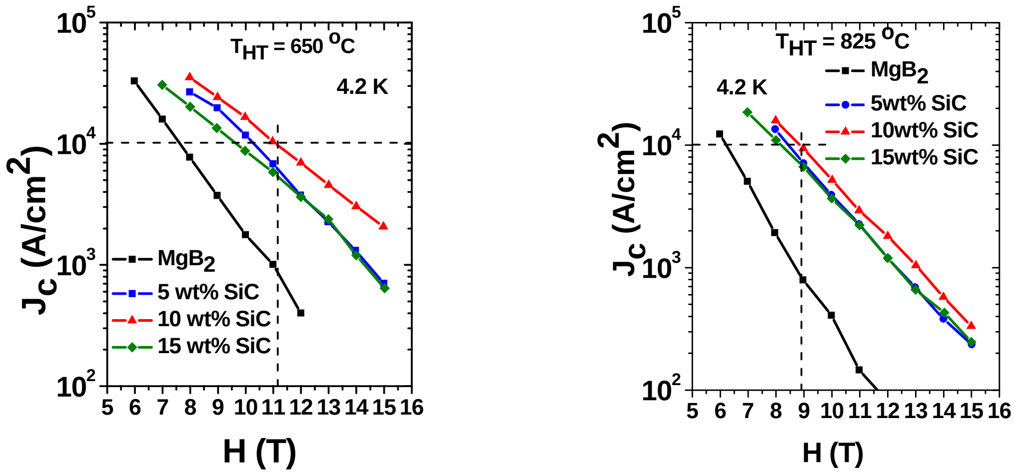


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Fig. 2. Transport critical current densities of samples sintered at 650^0C (a) and 825^0C (b).

Another important thing is the effect of sintering profile on J_c value. One can see, that only reducing of sintering temperature from 825^0C to 650^0C allowed increasing working field by 2T. For example, the J_c level of 10^4 A/cm^2 was reached at 9T for sample with 10wt% SiC addition sintered at 825 ^{o}C (see Fig. 2b) and at 11T for sample sintered at 650 ^{o}C (see Fig.2a).

4. Conclusion

We have shown that the $J_c(H)$ in MgB_2 samples can be optimized for different field regions by varying the SiC doping level and sintering temperature. To achieve a high critical current in low fields region, a low doping level of 5wt% SiC and higher sintering temperature (825^{o}C) should be used. For high field regions of 8-15 T addition level of 10wt % SiC and sintering temperature of 650^{o}C resulted in the best J_c value.

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