Doping of MgB_2 Thin Films and Wires with C, Diborides, and Rare Earth Compounds

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Introduction

A 35 T resistive magnet at the National High Magnetic Field Laboratories (NHMFL) in Tallahassee, FL was used to perform resistive measurements of B_{irr} and B_{c2} for MgB_2 thin films and wires. The samples included (i) ZrB_2-doped MgB_2 thin films, (ii) C-doped MgB_2 PIT wires, and (iii) rare earth oxide-added MgB_2 PIT wires.

Experimental

Thin film MgB_2 was made using a PLD located at OSU. A ZrB_2 target was used along with an MgB_2 target to form a superlattice of MgB_2 and ZrB_2. In-process and during subsequent annealing the Zr was expected to diffuse into the MgB_2 layers. The superlattice structures and films are described in Table 1. Monofilamentary PIT wires were by a commercial collaborator (Hyper Tech Research) with different levels of C doping, as described by Table 2. Similar wires were made with 0.5 wt% Dy_2O_3 and the results compared to a control sample, both with 2% C doping. For the wires, B was $\perp$ to J, and B_{irr} and B_{c2} were measured resistively as the 10% and 90% points, with a 10 mA excitation current. For the films, B was applied in the force-free direction, extracting B_{c2} only.

Table 1. ZrB_2/MgB_2 ratios, resistive $T_{c,\,onset}$, and B_{c2} (in-plane) data for 3 mm x 10 mm PLD samples.

Sample Name	ZrB_2/MgB_2	Nominal %ZrB_2
MgB_2-182A	0	0
MgB_2-190	5/200	2.4
MgB_2-189	10/200	4.8
MgB_2-188	20/200	9.1
MgB_2-192	30/200	13.0
MgB_2-194	50/200	20.0

Table 2. Sample properties for C-doped MgB_2 wire specimens

Sample Name	SC fraction[b]	Expected x in $MgB_{2-x}C_x$[d]	Actual x in $MgB_{2-x}C_x$[e]
MgB_2-00	0.252	0	0
MgB_2-01	0.115	0.038 ± 0.001	0.039 ± 0.001
MgB_2-02	0.152	0.063 ± 0.001	0.063 ± 0.001
MgB_2-03	0.131	0.095 ± 0.005	0.076 ± 0.009
MgB_2-04	0.183	0.130 ± 0.002	0.120 ± 0.003

Results and Discussion

The results for the Zr-doped films are shown in **Figure 1**, those for the C-doped wires in **Figure 2,** and those for the Dy_2O_3 wires in **Figure 3**.

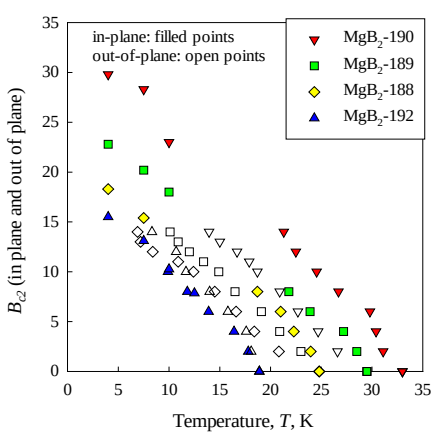

Figure 1. T dependency of B_{c2} for MgB_2 thin films with ZrB_2 doping

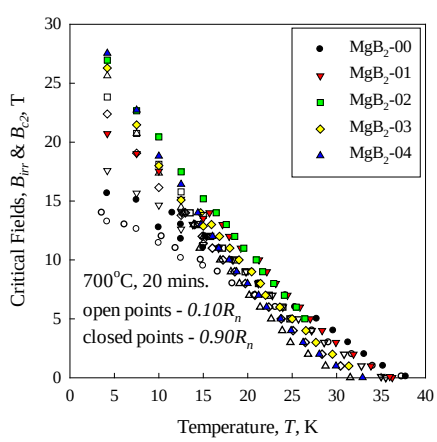

Figure 2. T dependency of B_{c2} and B_{irr} of MgB_2 strands with various C doping in the B

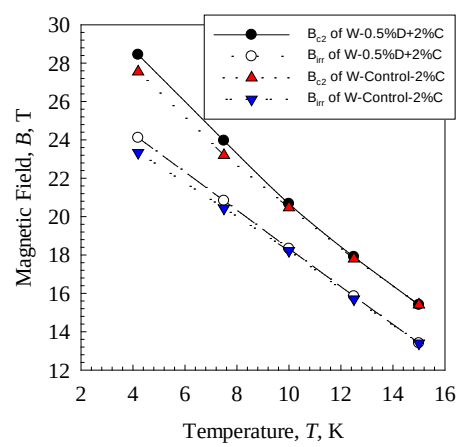

Figure 3. T dependency of B_{c2} and B_{irr} of W-0.5%D+2%C and control W-Control-2%C

Conclusions

ZrB_2 additions (seen to enter the MgB_2 grains via subsequent STEM) were seen here to affect B_{c2} in a systematic way. C doping, long known to increase B_{c2}, was studied systemically here for C directly added to the B. Finally, Dy_2O_3 was seen not to increase B_{c2}. Although not displayed here, this clarifies the cause of substantial high field J_c increases to be due to flux pinning, rather than B_{c2} increases.

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