IMPROVED $H_{c2}$ IN BULK-FORM MAGNESIUM DIBORIDE BY MECHANICAL ALLOYING WITH CARBON


Introduction

Recent studies of magnesium diboride thin films by Braccini et al.\(^1\) found $H_{c2}(0K)|| > 50T$ for C-doped MgB\(_2\) films. Such critical field properties exceed those of any Nb-base conductor at any temperature, suggesting that MgB\(_2\) could be a viable replacement for Nb\(_3\)Sn as a high field magnet conductor. Untextured carbon-doped filaments fabricated by a CVD method can achieve upper critical fields in excess of 30T at 4.2K\(^2\).

The present document discusses the ex-situ synthesis of alloyed MgB\(_2\) powder using high energy ball milling of MgB\(_2\) with C. Since a major goal of MgB\(_2\) technology is the fabrication of high critical current density, multifilament wire suitable for magnet applications, we need a scalable bulk process capable of producing carbon-doped precursor powder. One such method is provided by this work.

Experimental

MgB\(_2\) powder was mixed with powdered graphite in several proportions and high energy ball milled for tens of hours, then made into pellets. Pellets were hot isostatic pressed (HIP) at 1000°C and >30ksi for 200 minutes, then exposed to Mg vapor at 900°C for 5 hours. Properties were then measured by various techniques. High field electrical properties were measured at NHMFL – Los Alamos using the 65T pulsed magnet.

Results and Discussion

Figure 1 shows measured $H_{c2}$ for our samples, plotted alongside data from the literature, where $x$ is the carbon content given by Mg(B\(_{1-x}\)C\(_x\))^2. Our analyses showed that while our X=0.0525 sample had near total carbon incorporation into the lattice, our nominally X=0.17 sample had a lattice composition of only about X=0.69. While the X=0.0525 sample had $J_c>10^6 \text{ A/cm}^2$ as well as excellent $H_{c2}$, the nominal X=0.17 sample had $J_c$ reduced by nearly two orders of magnitude. Normal state resistivity was also much higher for the more heavily doped sample.

Conclusions

We have shown that milling C with MgB\(_2\) can produce $H_{c2}(0K)$ equal to that obtained for single crystals and CVD filaments. Lattice disorder introduced in the milling process is indicated by weakened XRD patterns, high normal state resistivity, and a low-temperature upturn in $H_{c2}(T)$. Excess carbon not incorporated into the crystal lattice can result in detrimental effects such as grain boundary obstruction (causing reduced $J_c$), reduced $T_c$, and reduced $H_{c2}$.

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References