Performance of Carbon and Titanium Doped Magnesium Diboride Wire


Introduction

When carbon is added to boron in a plasma synthesis process, the carbon atoms form point defects replacing boron in the MgB$_2$ which material that is subsequently made. These point defects, in turn shorten the electronic mean free path and raise the upper critical field, H$_{c2}$, at a rate of about 4 T per atomic percent carbon in pressed pellet material. When titanium atoms are added, they form TiB$_2$ precipitates in the boron powder and flat plate precipitates in the subsequent MgB$_2$ material that are reasonably effective pinning sites for superconducting vortices. The goal of this work is to determine whether MgB$_2$ wire made from these same plasma synthesized powders show the same performance characteristics as pellet material.

Experimental

Plasma synthesized doped boron powder was made in an rf argon plasma torch by introducing gas streams of appropriate amounts of H$_2$, BCl$_3$, CH$_4$. If needed, TiCl$_4$ molecules are entrained with the H$_2$ gas by bubbling it through liquid TiCl$_4$. This powder was made into wire at Hyper Tech Inc. by a continuous tube filling and forming process.

Results and Discussion

The upper critical magnetic field, H$_{c2}$, of wires manufactured from plasma synthesized carbon doped boron powder were shown to have an upper critical field over 30 tesla for samples doped with 4% carbon. This is the same performance as found in pellet samples. These same wires in other experiments had shown critical current densities over 10,000 A/cm$^2$ at 20 K and 1 T.

The H$_{c2}$ values of the Ti doped boron powder wires were essentially unchanged from the H$_{c2}$ values of pure MgB$_2$. The TiB$_2$ precipitates were in the 10 to 100 nm size range and the critical current density, J$_c$, was comparable to undoped boron powder samples. It looks like grain boundary pinning dominates the pinning in these wires. Further experiment is required at different reaction temperatures to determine whether Ti doping will be an effective way to enhance J$_c$.

Conclusions

Wires prepared from carbon and titanium doped MgB$_2$ give the same H$_{c2}$ and J$_c$ values as pellet samples made from the same doped boron powder. Conversion of the powders to wire enhances J$_c$ while retaining the same enhancement of H$_{c2}$ as is found in pellet samples. This is very encouraging for the enhancement of the performance of wire material.