Upper Critical Field Study of CH$_4$ HPCVD Carbon-doped MgB$_2$

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Introduction

Carbon doping of MgB$_2$ has been the most successful method of enhancing the upper critical field $H_{c2}$ by introducing impurity scattering. Several methods of combining carbon with magnesium diboride have been employed by sample growers with varying degrees of effectiveness at enhancing its superconducting properties. The PSU group of Xi has had success growing films by HPCVD with the metalorganic bis(methylcyclopentadieny)magnesium (C$_6$H$_7$)$_2$Mg as a source of carbon. Subsequent films grown at PSU by HPCVD of tri-methyl boron have shown that TMB is a more uniform dopant than the previously used (C$_6$H$_7$)$_2$Mg. Our latest study of carbon doped MgB$_2$ is focused on films grown at Peking University by HPCVD with methane CH$_4$ as the carbon source.

Experimental

The $H_{c2}(T)$ of a set of four carbon-doped MgB$_2$ films grown on both SiC and Al$_2$O$_3$ substrates at CH$_4$ flow rates from 7 to 10 sccm were measured in fields up to 65T using the 45T Hybrid and 65T Pulsed Magnet systems. The low-current four point magnetoresistance measurements were supplemented by HRTEM to investigate correlations between the microstructure of these films and characteristics of the $H_{c2}(T)$ behavior.

Results and Discussion

Compared to early metalorganic C sources which generated high $H_{c2}(0)$, these films have much lower resistivities and higher connectivities. CH$_4$ as C source produces higher $H_{c2}$ than TMB. Resistive transitions appear similar to metalorganic films with similar $T_c$ ~ 35K. HRTEM by Zhu and Voyles revealed a two-layered structure in the films.

Conclusions

The curvature of $H_{c2}(T)$ shows upturn at low temperatures, which is consistent with the dominance of $\pi$-band scattering in the theory of dirty two-gap superconductivity. $H_{c2}(0) > 60T$ is close to the paramagnetic limit of ~ 66T for the 10 sccm film on SiC, though still a little lower than for the previously used metalorganic (C$_6$H$_7$)$_2$Mg. Differences in the $H_{c2}(T)$ behavior between films grown on the two substrates are attributed to variations in strain fields produced by the substrate coupled to the film at growth.

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References