Prediction of $J_C(B)$ Behavior of Bi-2212 Wires at High Field

Brown, M.D., Jiang, J., Tarantini, C., Bradford, G. (ASC, NHMFL, FSU), Jaroszynski, J. (CMS, NHMFL, FSU), Hellstrom, E.E., Larbalestier, D.C (ASC, NHMFL, FSU)

Introduction

Bi-2212 has evolved into a material with feasible application as a high field magnet conductor. It takes a form similar to the more commonly used LTS conductors as a multifilamentary, twisted, macroscopically isotropic, round wire. These properties and its low magnetization make 2212 a promising candidate for high field solenoids, especially for NMR applications.

2212 is now ready for applications in the 20 to 30 T range, and up to date info on its high field behavior is necessary. Over the last decade, we have received a variety of wires with a large range of $J_C(B)$ at 5 T and 15 T. which we believe is due to connectivity between grains in the 2212 filaments. We wished to test this hypothesis at high field (up to 31 T).

Experimental

The sample set was comprised of 17 samples (10 wire types, 2 architectures, and 5 powder types from 3 powder manufacturers) with the same Bi-2212 powder composition which were produced over the last decade by OST/B-OST and whose $J_C(15\ T)$ values vary over a factor of 5.

Short samples (15 cm in length) were heat treated using a standard overpressure heat treatment (OPHT) [1] and were cut to 3.5 cm in length for measurement up to 31 T at 4.2 K in the NHMFL's DC magnet facility.

Magnetization was measured for temperatures from 4.2 K to 20 K sweeping field from -2 T to 14 T in a VSM for wires with the two newest powder types. Samples were cut to 5 mm in length with their axes orthogonal to the field direction.

Results and Discussion

The $J_C(B)$ curves for all samples are very similar when normalized by $J_C(15\ T)$ (Fig 1a). When plotted in log-log (Fig 1b), a power law relation ($J_C \propto B^{-\alpha}$) is clear for all samples between ~3 T and ~19 T, above which J_C begins to fall for all wires but one (W8-2). The fall in J_C is believed to be a consequence of a trapped He bubble in the sample space above ~19 T due to the diamagnetism of gaseous He [2]. The average value of α for all samples when fit between 3 T and 15 T is 0.28 (σ = 0.015) which indicates that the flux pinning mechanism does not change wire to wire and is more likely a consequence of connectivity between grains within the 2212 filaments which alters the effective filling factor of each wire. Close alignment of the bulk pinning force, F_P, with respect to field when normalized by F_{Pmax} and the Kramer field, H_k, derived from magnetization curves of W8-2 and W10-1, supports this conclusion that the physical properties remain unchanged wire to wire. Due to the high irreversibility field of 2212, predicted to fall well above 30 T [3], we believe that all wires should follow the power law relation to larger fields if unperturbed by the He bubble problem. This assumption is bolstered by the W8-2 wire, which was unaffected by the He bubble, and obeys up to 31 T.

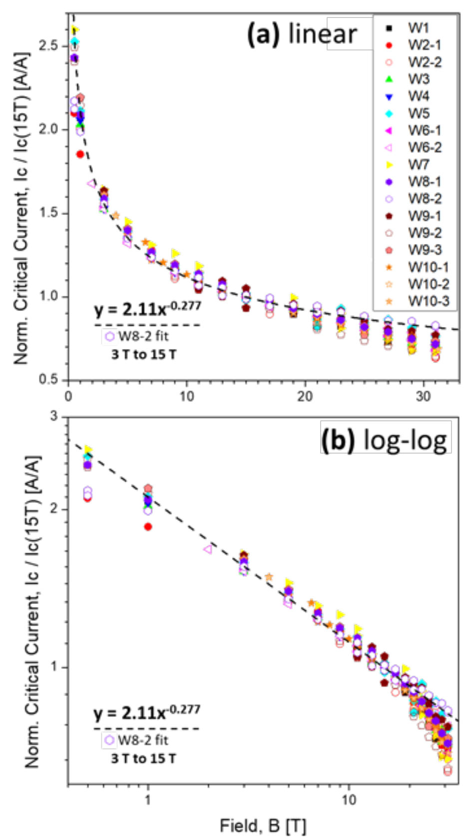

Fig. 1: Plots of $J_C(B)$ for Bi-2212 wires up to 31 T, normalized to $J_C(15\ T)$. Plot (a) is in linear scale and plot (b) in log-log scale. Both contain a power law fit from 3 T to 15 T of W8-2 which works well up to 31 T.

Conclusions

Measurements of $J_C(B)$ up to 31 T were taken for various 2212 wires produced over the last decade. We find that all wires obey a power law relation from 3 T to 19 T above which most wires show diminished values of J_C due to a He bubble phenomenon. Values of α, are similar indicating that variations in $J_C(15\ T)$ are not due to differences in pinning mechanism. A comparison between bulk pinning force curves of W8-2, which obeys they power relation up to 31 T, and W10-1, which does not, indicates that vortex pinning is unchanged between them indicating that, without the He bubble, J_C variation is largely due to grain connectivity. We conclude that a power law fit from 3 T to 15 T is a feasible method for estimating $J_C(31\ T)$ and possibly above.

Acknowledgements

The National High Magnetic Field Laboratory is supported by the National Science Foundation through NSF/DMR-1157490/1644779 and the State of Florida. In addition, this work was supported by a grant from the US Department of Energy, Office of High Energy Physics (DE-SC0010421).

References

[1] Jiang, J., *et al.*, *IEEE Trans. Appl. Supercond.*, **27**, no. 4, 1–4 (2017)
[2] Bai, H., *et al.*, *IEEE Trans. Appl. Supercond.*, **25**, no. 3, 1–4 (2015)
[3] Larbalestier, D. C., *et al.*, *Nat. Mater.*, **13**, no. 4, 375–381 (2014)