High Field Transport Properties in Ternary and Binary APC type Nb_3Sn Conductors

Sumption, M.D. (The Ohio State University, MSE), Xu X. (FNAL), Peng X. (HTR), Collings, E.W., Rochester, J, (OSU)

Introduction

Our goal is the development and understanding of high field Nb_3Sn strands with artificial pinning centers for enhanced conductor performance in the 15-20 T regime at 4 K for high field particle accelerators and other possible applications[1-3]. Our objective was to demonstrate high B_{c2} (ternary doping levels of > 25 T for B_{irr} and > 27 T for B_{c2}, as seen in RRP conductors) in strands with strongly enhanced APC grain and flux pinning.

Experimental

In this experiment, two 61 filament wires were made, APC-A (0.6% Zr) and APC-B (1%Zr), with 3 and 4 at% Ta respectively, and each including SnO_2 powders to act as the internal oxygen source. Included in the measurement set were two control samples, an RRP strand for the HL-LHC quadrupole magnets reacted at 665°C, and a standard Tube strand. There were two types of measurements performed: (i) R vs B (leading to B_{irr} and B_{c2}), and (ii) J_c vs B at 15 T-25 T. Measurements were performed in a 31 T DC magnet in Tallahassee FL, cell 7.

Results and Discussion

The R-B curves of APC-A and APC-B are shown in Fig. 1, along with the controls RRP and TT. We take 10% as B_{irr} and 90% as B_{c2}. The B_{c2} value of the RRP wire is ~25.8 T. The TT wire has B_{c2} of 26.7 T, ~1 T higher than the measured RRP wire). The B_{c2} values of APC-A and APC-B are 26.9 and 27.6 T, respectively, the latter ~2 T higher than RRP. These results clearly show the anticipated B_{irr} and B_{c2} increases with Ta additions, and are detailed in a recently submitted paper as well as presentations at the ASC 2018. The non-Cu J_cs at 16 T of APC-A and APC-B are 1150 and 1040 A/mm^2, respectively, roughly similar to the RRP, and the 16 T layer J_cs for RRP, APC-A, APC-B are 1850, 3450 and 4710 A/mm^2, respectively. Grain sizes, at 81 -72 nm, were reduced but not yet optimized. From the above measured non-Cu J_cs and separately measured FG area fractions, the Nb_3Sn layer J_cs were calculated and shown in Fig. 2. The 16 T layer J_cs for RRP, APC-A, APC-B are 1850, 3450 and 4710 A/mm^2, respectively, while that of the top-performing RRP wires is ~2200 A/mm^2. Clearly the APC wires have higher advantage at higher fields.

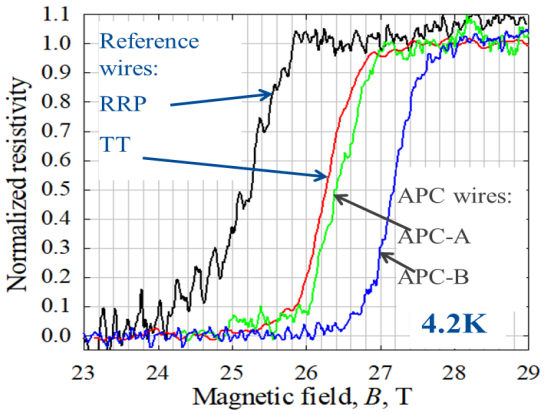

Fig. 1. The R-B curves of the two reference wires and the two APC samples.

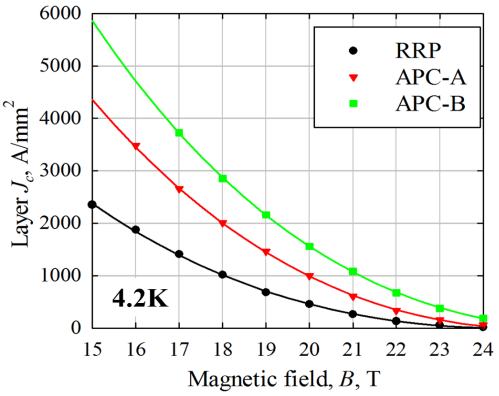

Fig. 2. Nb_3Sn layer J_cs (4.2 K) of RRP, APC-A, APC-B.

Conclusions

Ternary APC Nb_3Sn strands have been demonstrated, with B_{irr} values of 26-26.8 T, and B_{c2} values of 26.9-27.6 T, while layer J_c values reached 4710 A/mm^2 at 16 T.

Acknowledgements

The National High Magnetic Field Laboratory is supported by the National Science Foundation through NSF/DMR-1157490/1644779 and the State of Florida. This work was supported by LDRD program of FNAL as well as DE-SC0013849 and DE-SC0017755 (DOE-SBIR)

References

1. X. Xu, et al, *App. Phys. Lett.* 104, 082602 (2014); doi: 10.1063/1.4866865
2. X. Xu, et al, *Adv. Mater.* 27, 1346–1350 (2015).
3. X. Xu, et al. *IEEE Trans. on Appl. Supercond*. 27, 201706 (2017).