An Investigation of the Influence of Grain Boundaries on Flux Penetration in High Purity Large Grain Niobium for Particle Accelerators

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Introduction

Grain boundaries (GBs) may be a source of degradation in the performance of superconducting radio frequency (RF) Nb cavities for particle accelerators. In our 2007 work we measured J_b and investigated the microstructure at grain boundaries in order to better understand whether and how grain boundary weakness can affect SRF cavity performance.

Experimental

To measure *inter* and *intra*-J_b we applied transport current as a function of perpendicular magnetic field on chemically polished single and bi-crystals on as-received, high-purity (RRR>250), large-grain niobium sheet [1]. After measurement, we were able to use magneto-optical imaging to observe preferential flux penetration at some Nb grain boundaries, and finally we observed the microstructure of the GB in the same sample by scanning transmission electron microscopy (STEM), using EELS (Electron Energy Loss Spectroscopy) for oxygen analysis. The TEM sample was prepared using a FIB (Focused Ion Beam) tool, which can create cross sectional TEM lamellae and preserve the topmost layer of the sample. The STEM and EELS study was accomplished at ORNL as part of a SHaRE collaboration [2].

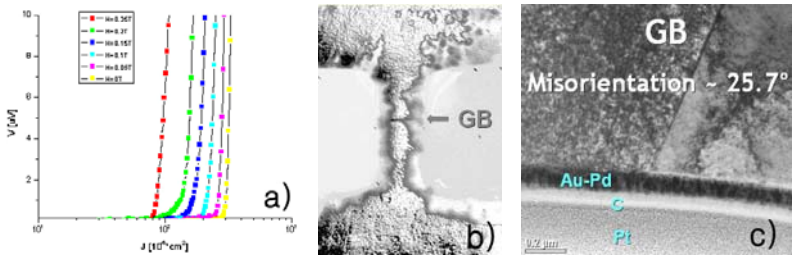

Fig. 1 (a) V [μV] vs J [10^{-4}cm²] curve for bi-crystal with external field from 0 T to 250 mT. (b) Magneto optical (MO) image of flux penetration, which is superimposed on surface morphology. (c) TEM bright field image of grain boundary regime; Au-Pd, C, and Pt are protection layers for the FIB cutting process.

Results and Discussion

Unlike the single crystal that shows only flux flow in grains, the bi- crystal of Fig. 1 shows preferential flux penetration by vortices lying in the GB, as shown in Fig.1 (a). However, our voltage vs. critical current curves do not clearly provide evidence of depinning flux flow behavior by Abrikosov-Josephson vortices in the GB as we observe in low angle HTS GBs. The MO image (Fig.1. (b)) shows preferential flux penetration at the GB, but the influence of other defects (e.g. steps) induced during sample preparation also is under consideration. In TEM cross-section we observe a variation in the thickness of niobium oxide over the GB, which appears as a white line between Au-Pd layer and Nb matrix, as shown in TEM bright field image (Fig.1.c).

Conclusions

J_C (H) measurement with MO imaging reveals some Nb grain boundary weakness, while atomic-scale analysis has been used to reveal the topology and structure of the topmost layers of SRF niobium cavities. Now that we have set up this complex experiment, we will be repeating it to understand the generality of our result.

Acknowledgements

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References

[1] P. Bauer, *et al*., Argonne National Laboratory Report ANL-05/10, March 2005, pp. 84-93.
[2] Shared Research Equipment (SHaRE) user facility program, ORNL, Knoxville, TN.