Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

LINAC GENEVA 14

Nb_3Sn – Present Status and Potential as an Alternative SRF Material

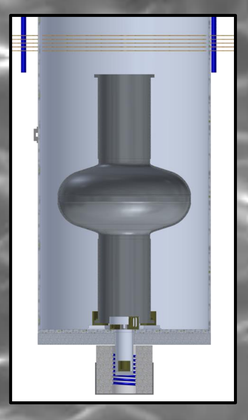
Sam Posen and Matthias Liepe

Introduction

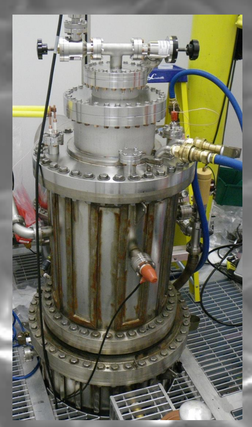
Nb_3Sn is a material that has the potential to have a transformative impact on superconducting RF. Due to its large T_c of approximately 18 K, Nb_3Sn cavities can have far smaller R_s values at a given temperature than standard T_c ~ 9 K Nb cavities. This could significantly reduce the costs for infrastructure and power in cryoplants for large CW linacs. The predicted B_{sh} of Nb_3Sn is 400 mT, approximately double that of Nb, potentially doubling the maximum energy gradient. This would significantly decrease the size and cost of high energy linacs.

In this work, we present recent progress in preparation methods for this novel material. We show the benefits observed after annealing during coating, and we show the effect of two standard material removal methods, HF rinse and centrifugal barrel polish.

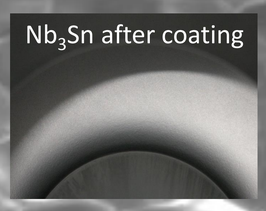
Nb_3Sn Cavity Treatment at Cornell


Cross Section


Commissioning


In UHV Furnace


Coated Cavity




Acid Etch

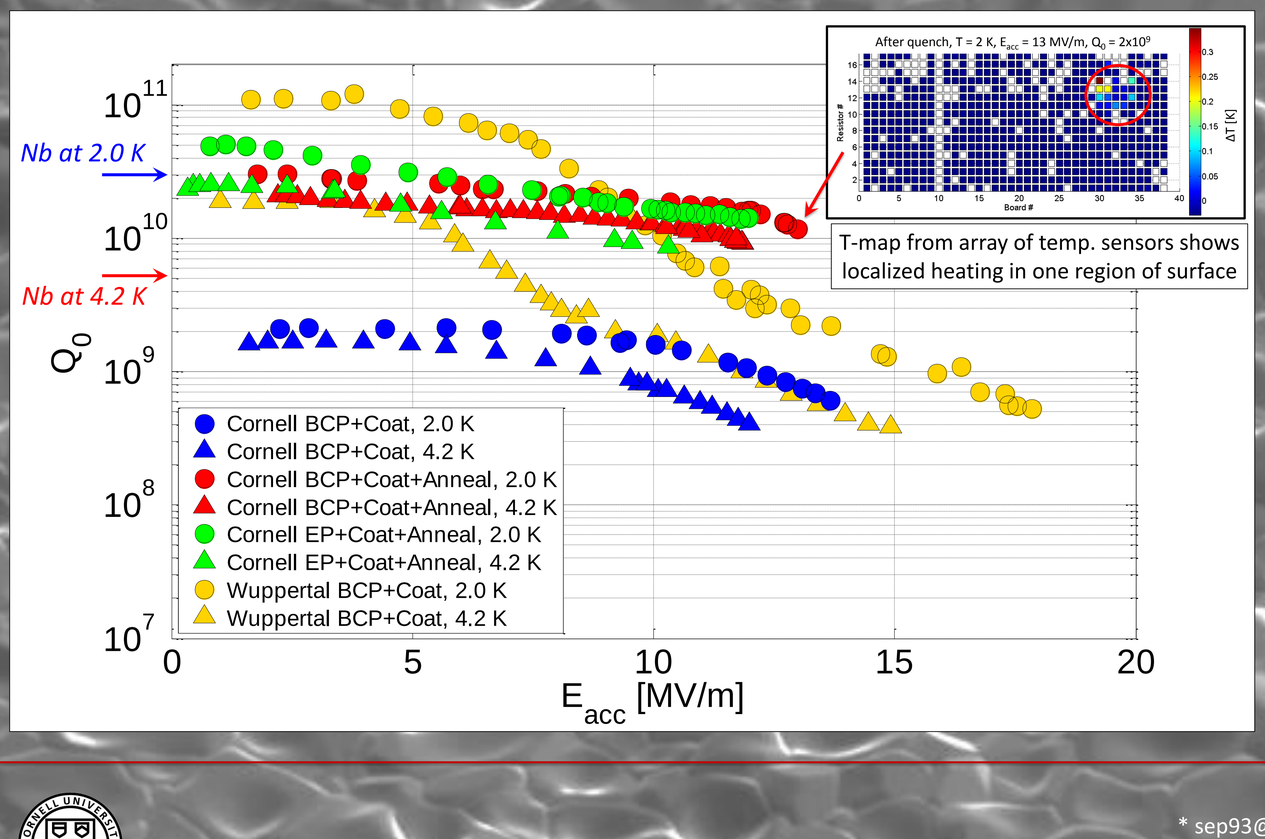

Centrifugal Barrel Polish


Polishing Media

Inside Cavity

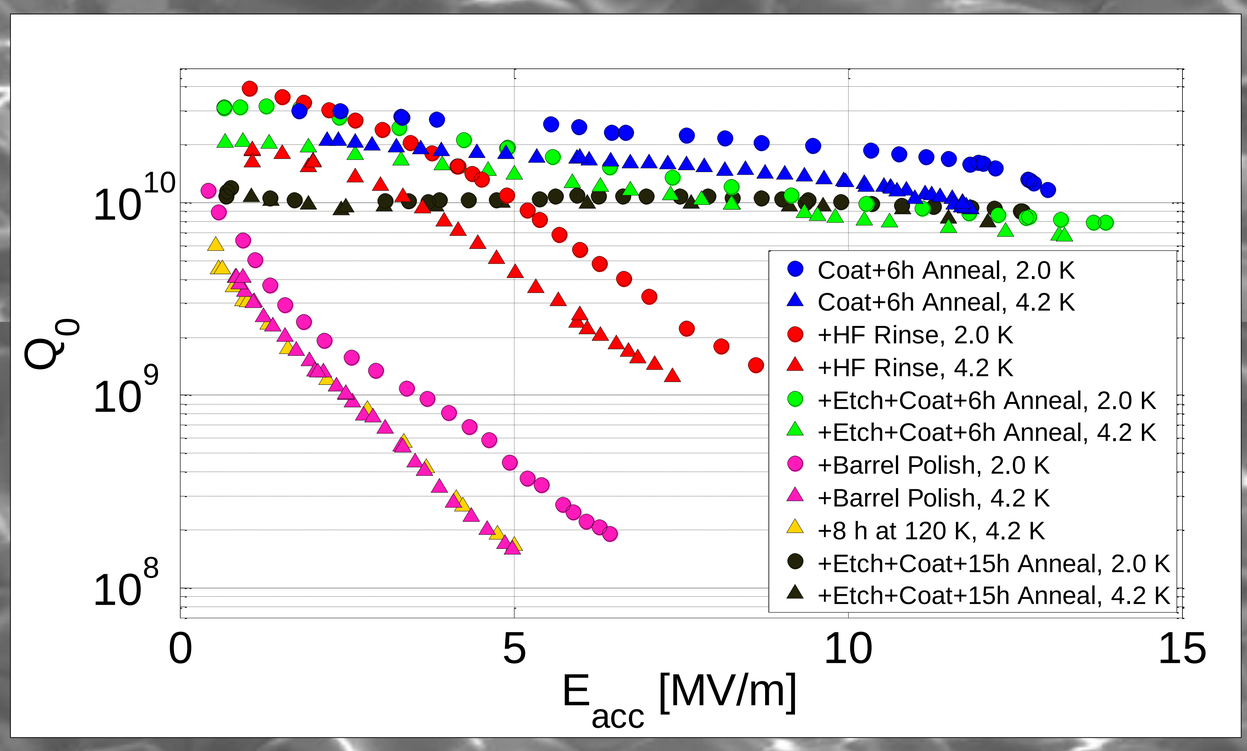
Comparing Cavities

Three cavities have been coated and tested at Cornell. The two that received a 6 h annealing step had minimal Q-slope, achieving $Q_0>10^{10}$ at 4.2 K at useful fields >10 MV/m. R_{res} at low fields is as small as ~6 nΩ. Medium field performance does not seems sensitive to pre-coating chemistry (EP vs BCP). Cavities that were not annealed exhibit strong Q-slope.



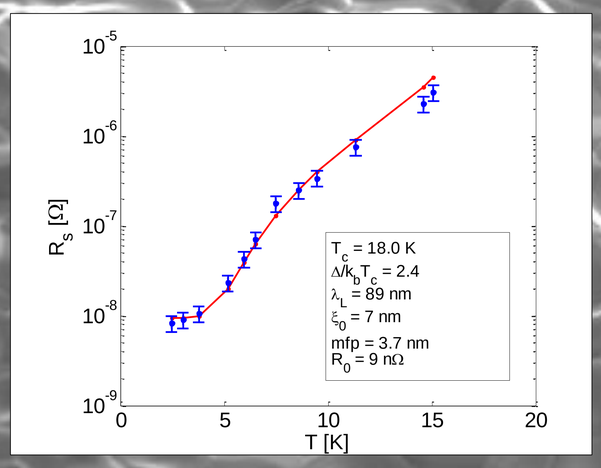
Comparing Removal Methods

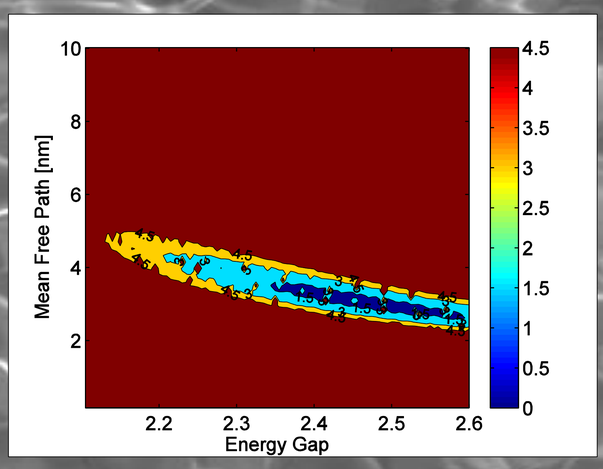
While the performance of the annealed cavities is already useful for some applications, the gradient was quench-limited at ~13 MV/m. To excise any gradient-limiting defects, two removal methods were attempted on one of the cavities after coating with annealing: 5 cycles of HF rinsing and barrel polishing. High pressure water rinsing was applied before each test. Strong Q-slope was observed after each of the removal methods.



Material Parameters

R_s vs T and f vs T measurements were fit simultaneously to extract material parameters (see TUPP018 for details). Calculated critical fields from the fits showed that the annealed cavities far exceeded H_{c1} without strong Q-slope. H_{c2} agreed with the literature value within uncertainty.





Conclusions

While still far below the ultimate potential of the material, Nb_3Sn cavities are now outperforming Nb cavities at useful gradients at 4.2 K. This opens up the possibility of the use of SRF cavities in low energy industrial applications without the need for superfluid liquid helium.

A strong performance is observed after the addition of an annealing step to the coating process. Results are also presented for the first time for accelerator cavities that were treated with EP prior to coating with Nb_3Sn, and for cavities that were treated with centrifugal barrel polishing after coating with Nb_3Sn, but they did not provide additional strong improvement. Nevertheless, we are just beginning to understand this material and its limitation mechanisms, and these tests provide valuable information in this respect. Future work will focus on studying the cause of the post-removal Q-slope and finding preparation methods to push the quench field without inducing Q-slope.

* sep93@cornell.edu

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