TUPPO043

A Method of Evaluating Multilayer Films for SRF Applications

Daniel Bowring[1] and Larry Phillips[2]

1. Engineering physics program, University of Virginia, Charlottesville, VA 2. Thomas Jefferson National Accelerator Facility

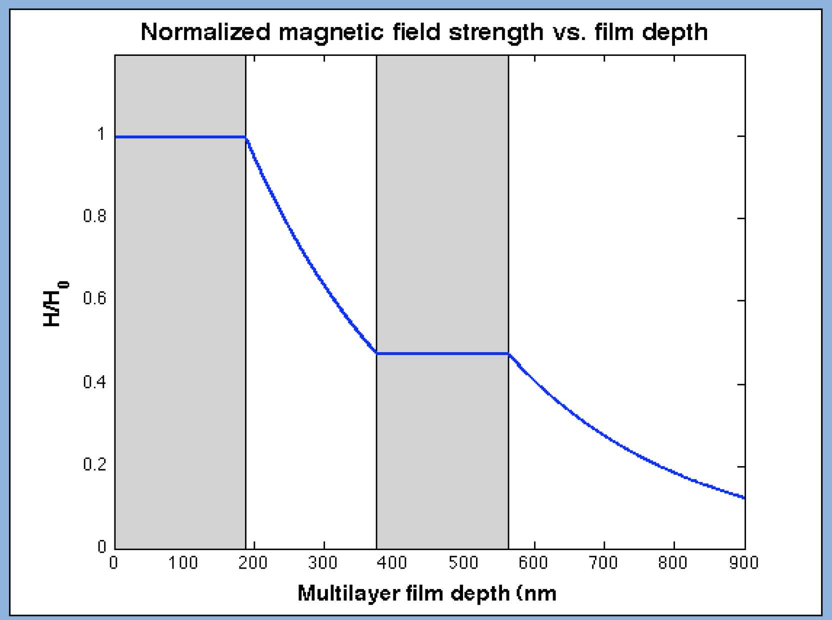
Introduction

The lower critical field H_{c1} of an SRF cavity may be increased by screening interior fields from the cavity bulk. A. Gurevich has proposed a multilayer thin film coating [1] that accomplishes this screening by coating the interior of a cavity with alternating layers of superconducting and insulating films, each of which is thinner than the London penetration depth. Increasing H_{c1} would delay the onset of vortex penetration, leading to higher Q and higher useful gradients.

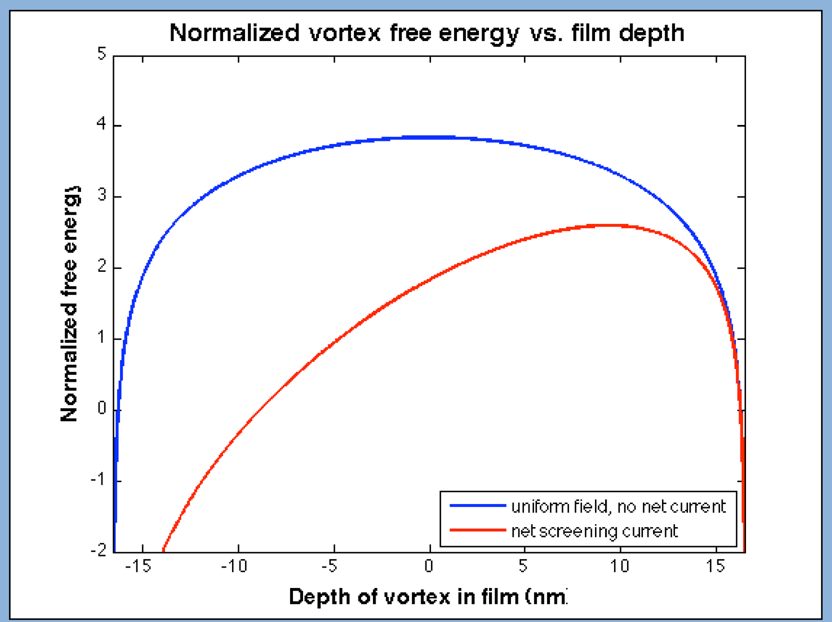
This poster presents the experimental design for a program to evaluate the performance of these multilayer films in comparison with their single-layer equivalents.

Background

- We treat the case of alternating layers of Nb-Ti and aluminum oxide. Then $\lambda \cong 250$ nm and $\xi \approx 7$ Å for films in the dirty limit [2].
- The magnetic field strength decays exponentially in the superconducting layers, as shown in the figure below. Ideally, adding more layers results in more screening and thus a higher H_{c1}. For this structure, the bulk lower critical field of ~ 10 mT means the resonator can operate at ~ 15 mT - a 50% increase.
- The associated Meissner currents in the film alter the free energy of incipient flux vortices and serves as a barrier to flux penetration.
- Since the time required for vortex dissipation is much shorter than an RF period, the problem may be regarded as quasistatic.



Magnetic field screening
Reproduction of a plot in [1], showing magnetic field screening for the Nb-Ti / Al2O3 layering scheme. The magnetic field strength in the bulk is 30% its strength at the resonator surface.

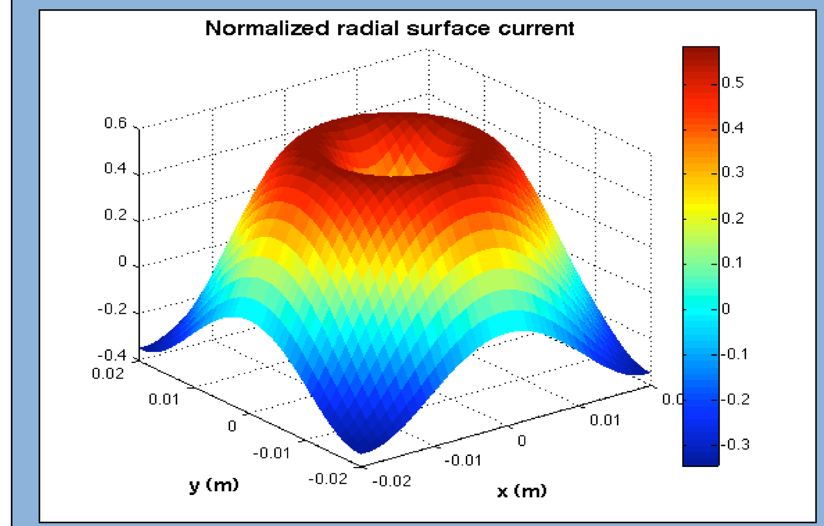


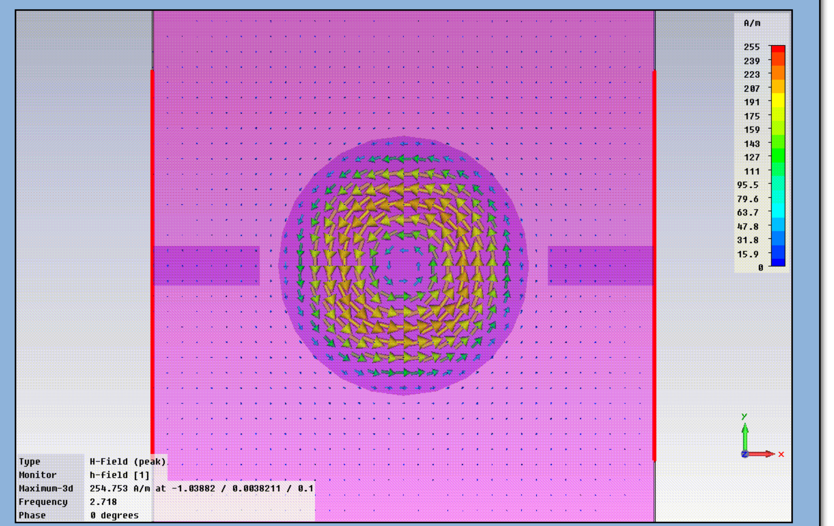
Effect of current screening on vortex free energy
The difference in current strength across the thin film results in an asymmetric free energy for vortex motion. As the Meissner current strength increases, it becomes energetically favorable for vortices to leave the film.

Design requirements

- For thin films, H_{c1} is significantly higher when the applied magnetic field is parallel to the film surface. We therefore require a resonator mode whose magnetic field is everywhere parallel to the multilayer sample surface. (This also mimics the accelerating mode of an elliptical cavity.)
- The onset of flux penetration in the sample should be the only impact on resonator performance. We therefore require the magnetic field to be strongest on the sample surface. Consequently, H_{c1} must be lowest on the sample surface.
- Sample deposition should be straightforward to facilitate film quality control and analysis. That is, a flat sample geometry is ideal.
- Multipacting should be minimized.

To satisfy the above requirements, we have designed a microstrip disk resonator that operates in the TM_{01} mode.

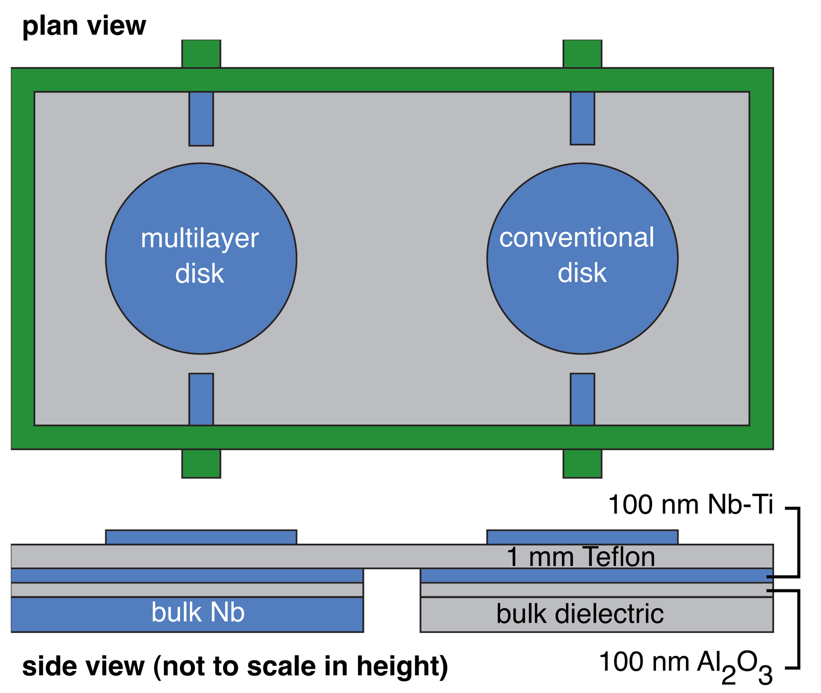




The resonator itself is a bulk Nb disk with high RRR. Since bulk Nb has a lower critical field roughly 20 times larger than H_{c1} for Nb-Ti, multilayer sample performance will not be compromised by flux penetration in the disk.

To minimize variations in applied fields for different samples, the disk resonator is positioned separately on a movable dielectric film. The same resonator and coupling structure may then be applied to all samples.

Below H_{c1} we calculate Q for an ideal multilayer resonator to be roughly $6{\times}10^7$, a 50% improvement over an equivalent conventional disk resonator.



Sample schematic
The diagram shows the basic layout for each multilayer sample. Two bulk Nb disk resonators (high-RRR) are positioned side-by-side on a movable Teflon sheet with fixed SMA-type RF connectors. This ensures that the frequency and RF coupling of the resonators stays constant between each sample.

Only one half of each sample is a true multilayer structure. The other half has a conventional disk resonator configuration. These are deposited simultaneously on the same substrate, allowing each multilayer film to be compared with a "control" sample of identical grain structure, RRR, mean free path, etc.

Onset of flux penetration

The onset of flux penetration in these multilayer samples can be measured via two related phenomena:

- Observe **flux flow voltages in the thin film** [3]. A transport current on the film surface generates a Lorentz force on flux vortices. This, in turn, induces a dissipative electric field - a flux flow voltage. We can observe propagating flux flow voltage signals in the thin dielectric layer of the samples. These signals can be correlated with the Q of the resonator.
- Measure the **Q of the resonator**. Above H_{c1} for the multilayer film, the entrant vortices dissipate power, lowering the Q. The extent of Q degradation can be calculated directly using the thermal feedback model, as shown in [1,2]. This approach requires knowledge of the surface resistance of the multilayer film, for which the surface impedance characterization facility presented in [4] will be used.

Current and future work

- The cryostat insert is being assembled and sample production has already begun.
- Calculations for this poster were made assuming a perfectly flat film surface. We are examining the effect of surface roughness on, for example, the vortex image problem.
- Film quality and thickness heavily influence Q, field strength, and critical field values. Although *a priori* estimates of these quantities are presented in this poster, precise values can be obtained only through direct measurement of actual films. These quantities can be measured at Jefferson Lab using, for example, the new surface impedance characterization facility [4].

Literature cited

[1] A. Gurevich. *Appl. Phys. Lett.* **88**, 012511 (2006).
[2] G. Stejic *et al. Phys Rev. B.* **49** (2) 1994.
[3] Y.H. Kim, C.F. Hempstead, A.R. Strnad. *Phys Rev.* **139**, 4A (1965).
[4] B. Xiao *et al.* Proc. SRF 2009.

Acknowledgements

The authors would like to thank Jean Delayen, Tom Goodman, and Anaïs Miodek for their helpful contributions.

This work is supported by the United States Department of Energy, by Jefferson Science Associates, and by a student travel grant from SRF 2009.

University of Virginia School of Engineering and Applied Science · Jefferson Lab, Thomas Jefferson National Accelerator Facility · SRF09 Berlin-Dresden, 14th International Conference on RF Superconductivity

Further information

Please contact *dbowring@jlab.org*.