Recrystallization Behavior of Cold Rolled Niobium with Varying Initial Grain Sizes

Nicholas Rattigan[1] and Dr. Shreyas Balachandran[2,3]

1. Department of Electrical Engineering, FAMU-FSU College of Engineering 2. Department of Mechanical & Aerospace Engineering, FAMU-FSU College of Engineering
3. Department of Materials Science and Engineering, FAMU-FSU College of Engineering

FSU FLORIDA STATE UNIVERSITY

DEPARTMENT OF MECHANICAL & AEROSPACE ENGINEERING | FAMU-FSU College of Engineering

DEPARTMENT OF MATERIALS SCIENCE & ENGINEERING | FAMU-FSU College of Engineering

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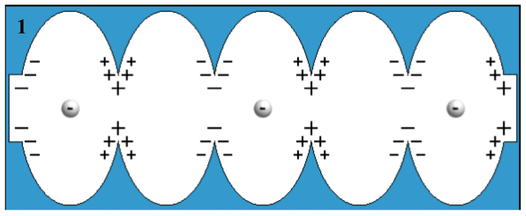
References

Introduction:

- Superconducting radio frequency cavities are widely used in particle accelerators for physics and quantum applications (Padamsee, 2014). These cavities carry high AC current, which accelerates particles to high speeds.
- Research on SRF cavities is focused on making the cavities more efficient. The most important metrics for assessing the efficiency of a cavity are the quality factor (Q_0) and the accelerating gradient (E_{acc}) (Balachandran et al., 2021).
- Altering the grain size, initial microstructure, and heat treatment temperature has been explored by researchers attempting to improve the material's properties (Bennett IV et al., 2025).
- This study aims to relate the initial microstructure to the heat treatment temperature of the material. The deformation strain value will remain constant.



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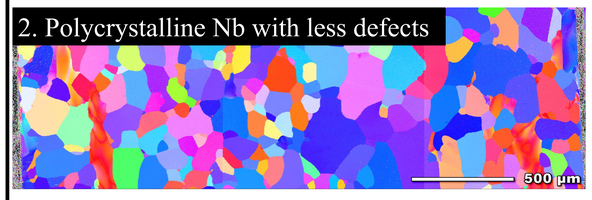
Performance metrics for SRF cavities: Quality factor (Q_0) versus Electric field (E)

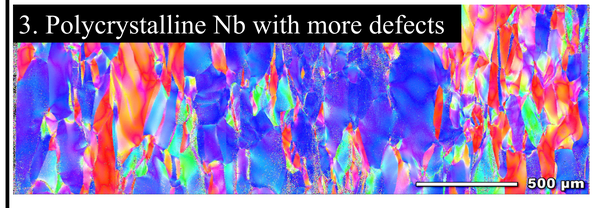
Desired: High Q_0, and High E

Figure 1: A resonant cavity is the high-frequency analog of an RLC resonant circuit. At resonance, RF power builds up high electric fields that accelerate charged particles.
Energy is stored in the electric and magnetic fields.

Q_0 is affected by the microstructure of Niobium (Balachandran et al., 2021).



Microstructure of Nb refers to the crystal structure of Nb (as shown in figures 2 and 3).



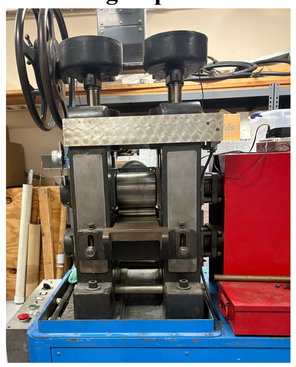
Figures 2 and 3 are from a technique called electron backscatter diffraction. Gradient regions indicate defects.

Methods:

We are investigating the microstructural variations in Nb used for SRF cavities resulting from simple rolling, a processing step used for making all Nb sheets.

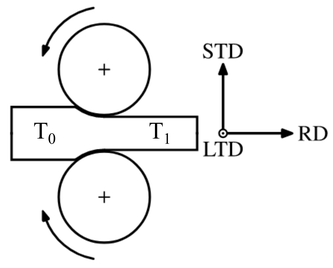
Raw materials: High-purity Nb used in SRF cavities, supplied from Thomas Jefferson National Accelerator Facility. Copper and Aluminum samples are used as starting surrogates.

Processing steps:



1. Rolling

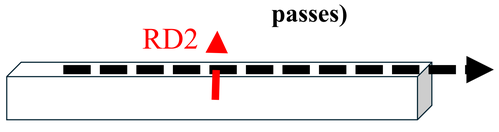
2. Heat Treatment (800° C- 1100° C)



T_0 - Initial thickness
T_1 = Thickness after first rolling reduction

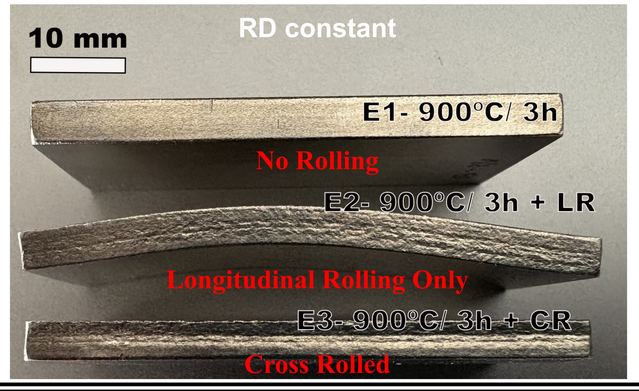
Longitudinal rolling (RD direction does not change)

Cross rolling (RD direction changes 90° between reduction passes)



Preliminary Results:

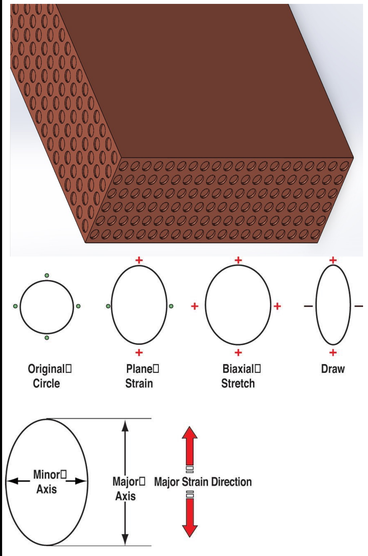
Initial rolling of the Nb samples indicates that how you roll Nb matters. Different rolling variations have different results.



Conclusion:

Minor variation in rolling leads to changes in deformation. It is expected that the microstructure of Nb also gets affected by this variation in deformation between the two rolling schedules.

In the future, we will investigate rolling deformation using Cu and Al samples. A circle grid pattern will be cut into four faces of the samples using a CNC machine. The samples will then be rolled, and the new axes of the resulting ellipses will be measured to calculate the strain of the material that results from rolling.



https://www.thefabricator.com/thefabricator/article/bending/circle-grid-analysis-for-diemakers

- 3D model of circle grid machined into copper block.
- Figure depicting different effects of rolling on circle grid.