Niobium Electropolishing in an Aqueous, Non-Viscous HF-Free Electrolyte: A New Polishing Mechanism

M. Inman, T. Hall, E.J. Taylor, Faraday Technology, Inc., Clayton, OH 45315, U.S.A.
C.E. Reece, O. Trofimova, JLAB, Newport News, VA 23606, U.S.A.

Need

- Superconducting radio frequency cavities are fabricated from pure niobium
- Processing of the cavities requires polishing of the interior surface to a mirror finish
- State-of-the-art polishing technology for the Nb cavities uses either buffered chemical polishing or conventional electropolishing
- However, these process employ hydrofluoric acid, which is an "environmental insult" and hazardous to workers
- Ideally, a polishing process for superconducting RF Nb cavities will have attributes that include the following:
  - Electrolyte free of hydrofluoric acid
  - Control of surface roughness to a microscale finish, Ra < 0.1 μm
  - Surface free from contamination after polishing
  - Current distribution control that enables uniform polishing across the entire cavity surface
  - Minimization of the absorption of hydrogen into the bulk material
  - Controlled removal of at least 100 μm of Nb during polishing

Development of Chemical-Mechanical Polishing for Superconducting Cavities, S. Mishra, M.J. Oreglia, C. Spiro, ANL-FNAL-UofC Collaboration Meeting

Objectives, Approach, and Key Advantages

Overall Objective:

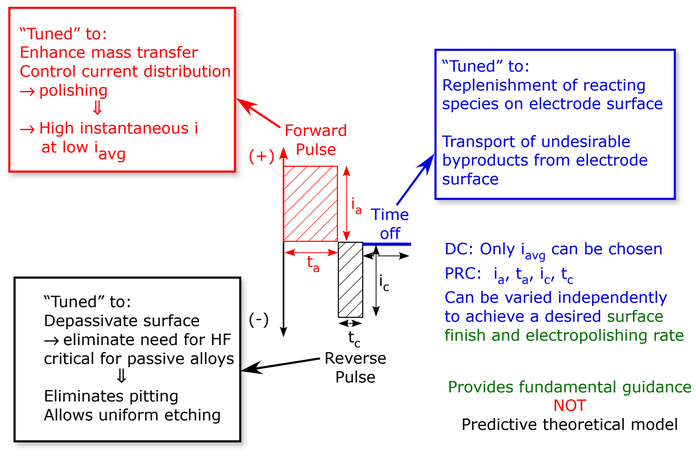
- Development of the FARADAYIC HF-Free Electropolishing Process for polishing alloys used in the manufacturing of cavities
- Understand the interactions between polishing parameters, surface finish, microstructure, oxide formation and 2K RF test performance

Approach:

- Reduce the oxide film by an electrochemical process instead of relying solely on aggressive chemicals (e.g HF)

Key Advantages:

- Eliminate need for aggressive chemical baths, and the high cost associated with waste disposal
- Improve process control (constant driving force)
- A cost-effective and environmentally benign manufacturing process

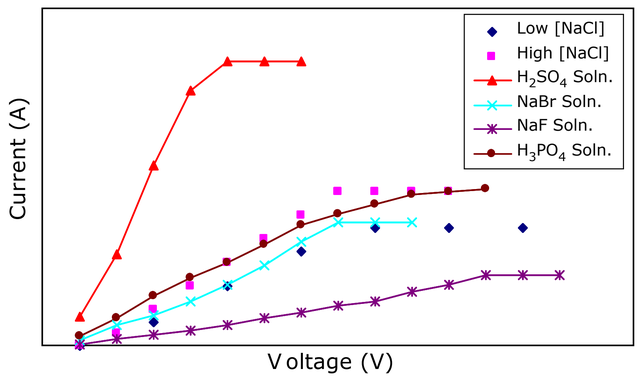


Sample Preparation

- 99.9% Nb foil
- Waterjet cut into coupons 25.4 mm x 25.4 mm x 3 mm
- SiC grinding paper used to prepare a consistent finish

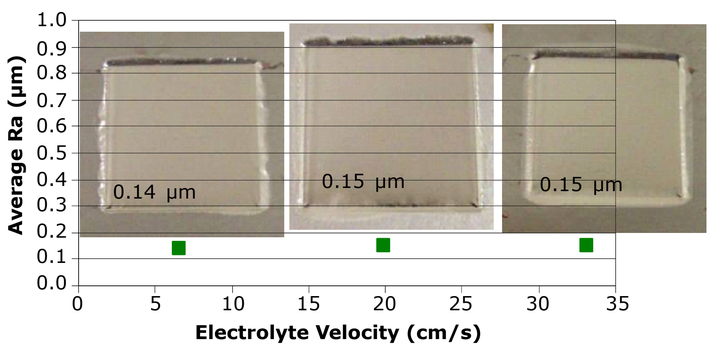
Polarization Curves

- 2-electrode polarization curves of Nb in various electrolytes
- Breakdown of the Nb was not observed
- Current measured assumed to be associated with water electrolysis and Nb anodization (Nb_XO_Y)
- This data demonstrated the tenacity of the Nb oxide film under DC conditions



Effects of Flow Velocity on Ra

- There did not appear to be a significant effect of electrolyte velocity when electropolishing Nb
- However, results at an electrolyte velocity of 0 cm/s suggested that there must be some degree of agitation in order to achieve uniform, smooth polishing of the Nb surface



Patents Filed

- Filed a utility patent (U.S. and International) on the Eco-Friendly polishing technology:
  - Title: Electrochemical System and Method for Machining Strongly Passivating Metals
  - U.S. Patent Application No. 10240426
  - Foreign (PCT) Application No. PCT/US11/39354

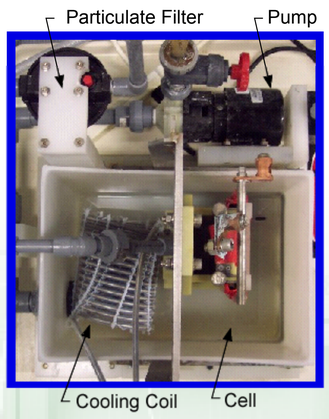
Surface Finish/Polishing Rates

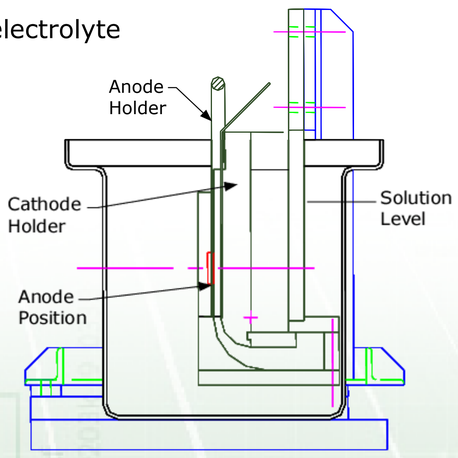
- Polishing rates range from 0.8 to 6 μm/min
- Ra as low as 0.05 μm assessed over 12 mm length
- JLab assessed surface finish on coupon using AFM
  - Ra of < 1 nm over 10 x 10 μm area
  - Extremely clean surface noted

Scan Size μm	Scan Number	R_{max} nm	R_a nm	RMS nm
50x50	1	35.00	2.71	3.34
	2	37.30	3.54	4.73
	3	69.66	3.74	4.69
10x10	1	22.59	2.25	2.87
	2	16.16	0.41	0.54
2x2	1	9.42	0.36	0.46

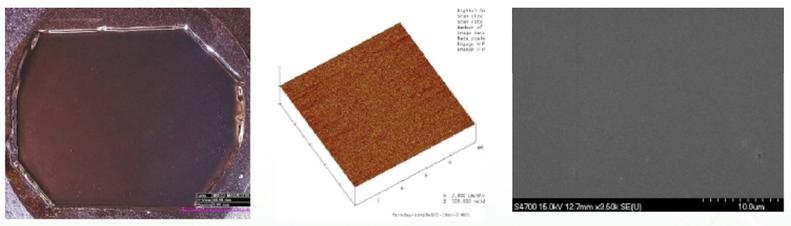
Electropolishing Cell

- Controlled flow
- Anode-cathode gap adjustable
- Flow meter device
- Filtration system included
- 30% wt H_2SO_4 selected as electrolyte

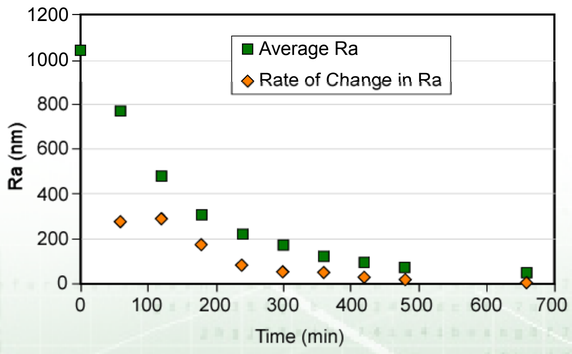




Surface Finish



Time Study



Summary

- **The FARADAYIC HF-free electropolishing process has shown feasibility to uniformly electropolish Nb to a microscale finish in an HF-free electrolyte.**
- **The process is anticipated to be cost effective compared to conventional polishing methods due to the robust control mechanisms and minimal associated waste.**

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