SRF2025 TOKYO

22ND INTERNATIONAL CONFERENCE ON RF SUPERCONDUCTIVITY

September 21-26, 2025

Contribution ID: **126** Contribution code: **THP35** Type: **Poster Presentation**

Electrochemical impedance spectroscopy analysis of Nb electropolishing in HF solutions

Thursday 25 September 2025 14:30 (3 hours)

Electropolishing (EP) is a critical process for achieving high quality factors (Q) and high accelerating gradients in superconducting radiofrequency (SRF) cavities. Despite its importance, the chemical mechanisms of EP remain unclear. Two primary models have been proposed: the viscous boundary layer theory, which attributes polishing to the formation of a viscous, HF-depleted boundary layer, and the compact film theory, which suggests polishing results from the formation of a solid, passivating film on the niobium's (Nb) surface. In this study, we investigate the EP mechanism using Electrochemical Impedance Spectroscopy (EIS) to probe the electrical properties of the Nb electrode during EP. By analyzing the distribution of relaxation times, we gain insights into the interfacial chemical processes occurring at the electrode's surface. Our EIS data supports the compact film model and indicates a two-step oxidation mechanism: initially, Nb is oxidized to NbO_2, followed by further oxidation to Nb_2O_5 as the applied voltage increases. The formation of Nb_2O_5 is correlated with a reduction in surface roughness, suggesting that effective EP occurs when a stable oxide layer develops on the surface. These findings provide new insights into the role of surface oxide formation in the EP of Nb for SRF applications.

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Footnotes

Funding Agency

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Session Classification: Thursday Poster Session

Track Classification: MC3: Cavities