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Plasma Electrolytic Polishing for SRF

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"The performance of superconducting radio frequency (SRF) cavities is critically influenced by surface preparation. Traditionally, electropolishing (EP) has been employed to achieve a clean, low-roughness surface on both niobium (Nb) and copper (Cu) substrates, despite requiring harsh and corrosive acids. Since 2019, our research at LNL has focused on an alternative approach: Plasma Electrolytic Polishing (PEP). This method uses only diluted salt solutions, presenting several advantages over EP, including a superior removal rate (2-8 μm/min for Nb and 3-30 μm/min for Cu) and achieving a surface roughness (Ra) lower than tens of nm. Additionally, we have significantly optimised the process by using external cathodes instead of internally placed ones inside the elliptical cavity.

In 2022, we established the initial recipes for PEP, and four of them were subsequently patented in 2023. Our first successful applications included a Cu 6 GHz elliptical cavity. Since then, the workflow for cavity preparation at LNL has incorporated PEP, effectively substituting EP. Our achievements allowed us to extend PEP to QPR samples, underscoring its versatility and effectiveness. PEP has demonstrated its potential not only for SRF cavities but also for other accelerator components, such as couplers. We have achieved remarkable results on 3D-printed substrates, suggesting that PEP is nearing readiness for production and optimisation phases.

Scaling up such a process is extremely difficult, as the working and peak current densities are close to 0.2-0.6 A/cm², meaning that a 1.3 GHz cavity might require a few hundred amperes of current. In this work, we present our results on successfully applying PEP to dummy bulk Cu 1.3 GHz samples, followed by PEP testing on a 1.3 GHz cavity scheduled for this month. This abstract outlines our journey and the promising future of scaling up PEP for Cu substrates."

Presenter: CHYHYRYNETS, Eduard

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