" Advanced Topographic Characterization of Variously PreparedNiobium Surfaces and Linkage to RFLosses”

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Abstract

Superconducting radio frequency (SRF) technology is widely adopted in particle accelerators. The shallow penetration (~ 40 nm) of the RF into superconducting niobium lends great importance to SRF cavity interior surface chemistry and topography. These in turn are strongly influenced by the chemical etching “surface clean-up” that follows fabrication.

The principal surface smoothing methods are buffered chemical polish (BCP) and electropolish (EP). The resulting topography is characterized by atomic force microscopy (AFM). The power spectral density (PSD) of AFM data provides a more thorough description of the topography than a single-value roughness measurement. In this work, one dimensional average PSD functions derived from topography of BCP and EP with different controlled starting conditions and durations have been fitted with a combination of power law, K-correlation, and shifted Gaussian models to extract characteristic parameters at different spatial harmonic scales. While the simplest characterizations of these data are not new, the systematic tracking of scale-specific roughness as a function of processing is new and offers feedback for tighter process prescriptions more knowledgably targeted at beneficial niobium topography for SRF applications.

Process development suffers because the cavity interior surface cannot be viewed directly without cutting out pieces, rendering the cavities unavailable for further study. Here we explore replica techniques as an alternative, providing imprints of cavity internal surface that can be readily examined. A second matter is the topography measurement technique used. Atomic force microscopy (AFM) has proven successful, but too time intensive for routine use. We therefore introduce white light interferometry (WLI) approach as an alternative. We examined real surfaces and their replicas, using AFM and WLI. We find that the replica/WLI is promising to provide the large majority of desired information, so that use of the time-intensive AFM approach can be limited to where it is genuinely necessary.

The prevalent idea is that sharp features could lead to magnetic quench or enhance the thermal quench. In this report, a calculation on magnetic field is numerically given on fine structure by finite element and conformal mapping methods. Corresponding RF Ohmic loss will be simulated. A certain thermal tolerant will be calculated. A Q~E curve will be predicted from this model.

A perturbation model is utilized to calculate rough surface additional RF loss based on PSD statistical analysis. This model will not consider that superconductor will become normal at field higher than transition field. Therefore, it is only expected to explain mid-field Q performance. One can calculate the RF power dissipation ratio between rough surface and ideal smooth surface within this field range. Additionally, the resistivity of Nb is temperature and magnetic field dependent from classic thermal feedback model theory. Combining with topographic PSD analysis and Rs temperature and field dependency, a middle field Q slope model could be modeled and the contribution from topography can be simulated.