POINT CONTACT TUNNELING SPECTROSCOPY FOR SRF CAVITIES

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INTRODUCTION

For over three decades, the SCRF cavities performances have been continuously improved to reach now reproducible quality factor of 10^10 and max accelerating field E of 30 MV/m. However, unresolved mysteries among which High field Q-slope and its mitigation by a mild baking treatment remain and prevent cavities from reaching the intrinsic Niobium limit believed to be around 50-55 MV/m. The interactions between Nb surface superconductivity and the native oxides are complex and not fully understood [1]; a fundamental investigation of the microscopic mechanisms by which oxygen and the complex set of niobium oxides influence cavity performance seems now to be unavoidable. We will present first, a tunneling spectroscopy study of the mild baking effect on cavity-grade electropolished Nb samples. We were able to correlate the surface superconductivity properties and the cavities performance and to identify a heretofore unrecognized contributor to the dissipation mechanism at the surface of Nb: In a second part we will present the Atomic Layer Deposition technique and the first attempts to improve the Nb surface superconductivity by getting ride of the oxides: In conclusion, we will present the first results obtained on coated cavities and the future projects associated with ALD.

EXPERIMENTAL

The surface superconductivity of cavity-grade niobium coupons was probed by Point contact tunneling spectroscopy (PCT) [2], and the niobium oxides surface composition by X-ray photoemission spectroscopy (XPS). Both techniques are used to correlate various surface treatments found to improve cavity performances and the interaction superconductivity-oxides at the surface. All the experiments were done on cavity grade niobium samples, single or polycrystals, electropolished in the same way cavities are and one sample was given the same mild baking (120 C-24h) found to improve cavity performance.
Once understood the state of the art of Nb SRF cavities and their limitations, we developed a method based on Atomic layer deposition (ALD) [3] to improve the superconducting properties by getting ride of the oxides: a cavity grade niobium coupons was coated with 2-3 nm of Alumina and subsequently baked in UHV for 20 h up to 450 C.
In order to test the results we obtained on niobium coupons to real scale Nb cavities, we coated 1.3 Ghz cavities and performed RF performance test at Jefferson laboratory.

RESULTS

We identified magnetic impurities [4] present in the Niobium oxides as a heretofore unrecognized contributor to RF dissipation mechanism and proposed a simple model based on the local reorganization of the niobium oxides at the surface to explain the mild baking effect. We showed that the conductance value at the Fermi level and the superconducting gap value, both measured by PCT, correlate very well with cavity performance and point out PCT as a relevant tool to predict RF test.
An annealing above 450 C of the Al_2O_3 coated Nb samples by ALD was found to improve greatly the superconducting properties at the surface of niobium [5]. This method has the potentiality to optimize niobium cavities performances. RF test are being performed at Jefferson lab on coated and baked Nb cavities.
Finally, a Nb cavity has been coated with a 10 nm thick Alumina protective layer on the inner walls. The preliminary RF test of as coated cavity reveal for the first time in the thin film technology history applied to RF cavities, An improvement of the cavity performance and a potentiality to cure the field emission problem.

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