THE NB OXIDE SYSTEM – IMPLICATIONS FOR SRF CAVITIES

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Abstract

Corrosion, i.e. oxidation in air, of metals is well known and cost billlions of dollars per year, despite modern corrosion protection. What happens to Nb, where corrosion protection has not been applied to SRF cavities, yet? Based on elaborate surface studies at Karlsruhe the following scenario has to be dealt with: The strong, directional Nb-O bonding via d-electrons together with the open lattice of Nb-metal causes a sequence of reactions:

– Nb sucks up O, which precipitates to metallic NbO_x ($x \leq 1$), especially, to the NbO_x surface layer.
– A dielectric Nb_2O_{5-y} coating forms by Cabrera-Mott oxidation where nanocrystalline Nb_2O_{5-y} grows consisting of crystalline blocks (CB) of size 1 nm and barrier height $\Phi_B \approx 1$ eV separated by crystallographic shear planes (CS) with $\Phi_S \approx 0.1$ eV housing localized states $n_L(z) \approx 10^{19}/cm^3$ easing the charge transfer across Nb_2O_{5-y}.
– In oxidation the factor three volume increase by CB strains the Nb surface being released by nucleated injection of NbO_x into Nb up to depth between 0.1-50 µm. Nb_2O_{5-y} does not dissolve in most acids.
– Nb_2O_{5-y} hydroxilize and chemisorbes water and hydrocarbons.

Consequences of the O dissolution and of the crack corrosion on Nb RF cavity performance reach from the reduced energy gap $\delta\Delta \approx 10x\Delta$ by O_x in the BCS surface resistance $R_{BCS}(T,f)$, to RF residual losses $R_{res}(T \leq T_c/2, \omega) \propto \omega^2$, to the $R_{BCS}(T,\leq 15mT)$ minimum, to hysteresis losses $R_{hys} \propto \omega B$, to heating $\delta R(T,B) \propto (B/B_c)^2$, and to dielectric interface losses $R_E \propto \exp(-c/E)$, which do depend not only on Nb quality but also on the oxidation process, e.g., speed or chemical environment, as will be elucidated. Further improvements by corrosion protection will be mentioned.

NO SUBMISSION RECIEVED