Potential segregation of unwanted phases such as Nb-carbides in Nb_3Sn-based SRF cavities

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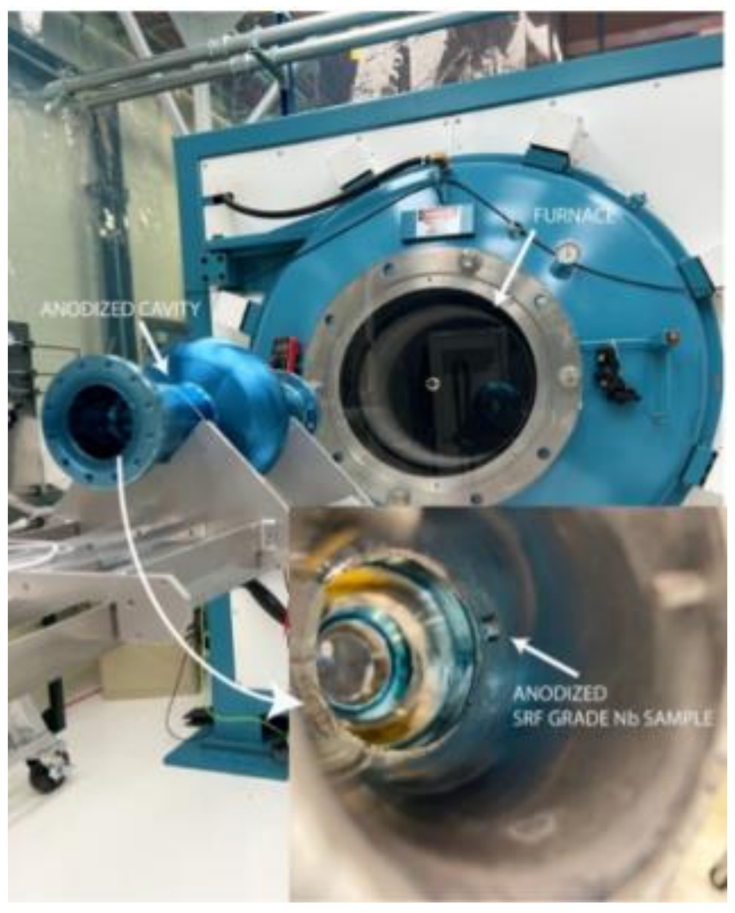
Introduction

Superconducting radio frequency (SRF) cavities are used in particle accelerators in order to have a large acceleration on the particle. They use radio frequencies on the superconducting material to induce an electric field. The surface of the SRF cavity is important in understanding the quality of the material and how strong the electromagnetic gradient can be. Surface oxides, Nb_2O_5 in particular, decrease the quality of the cavity. It is believed that the Nb_2O_5 decreases the quality factor at low fields by microwave losses. When the oxide layers are removed from Nb SRF cavities, the quality factor increases by decreasing the residual surface resistance.

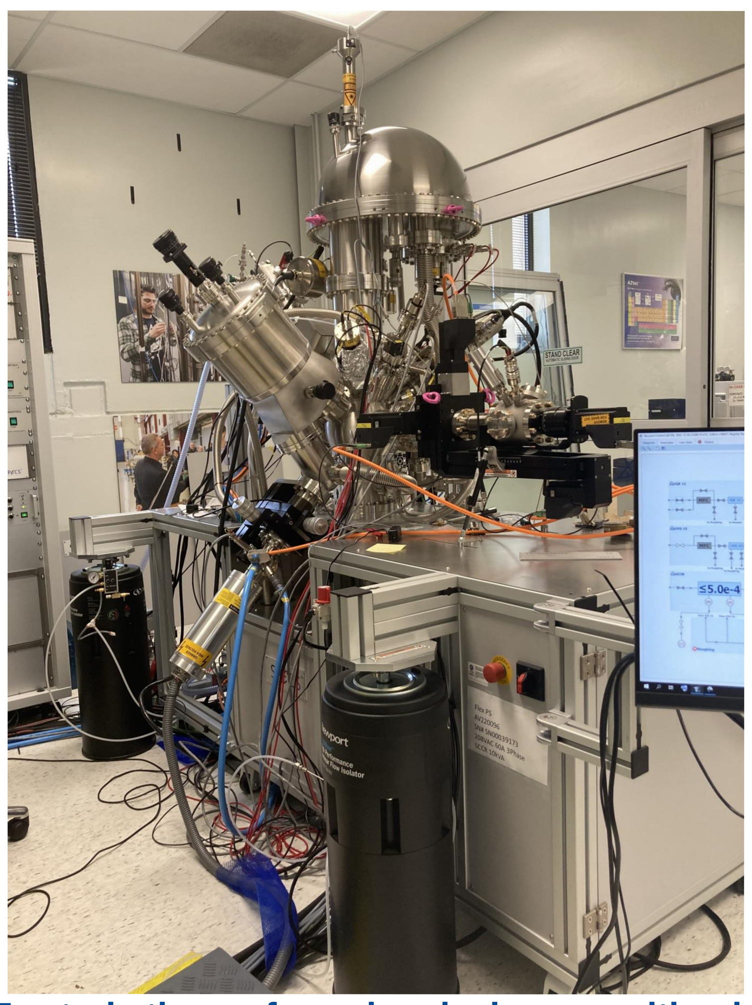


Surface oxides negatively affect the surface quality factor. We will study the effects of carbon and carbides on the surface of Nb3Sn through heat treatment of the sample with a layer of carbon on it. We are studying the potential effects of a heat treatment to remove the oxide layer and evaluate the surface resistance at 4K.

Anodized SRF Nb grade sample mounted inside the TESLA-type 1.3 GHz single cell cavity before the Nb3Sn coating process.

Experimental

We are using two samples of Nb_3Sn, which were coated along with a 1.3 GHz SRF cavity. To increase the C concentration in Nb_3Sn, one sample was covered with "cooking oil", which contains hydrocarbons chains (CH_x), and it was left in air for a period of two days. Meanwhile, the second Nb_3Sn sample will be measured "as received", with the original C concentration absorbed during the coating and air exposure.



To study the surface chemical composition in Nb_3Sn samples, we used X-ray Photoelectron Spectroscopy (XPS) with a probing depth of ~7 nm. Besides, we recorded angle-depended XPS spectra to estimated the surface oxide layer thickness.

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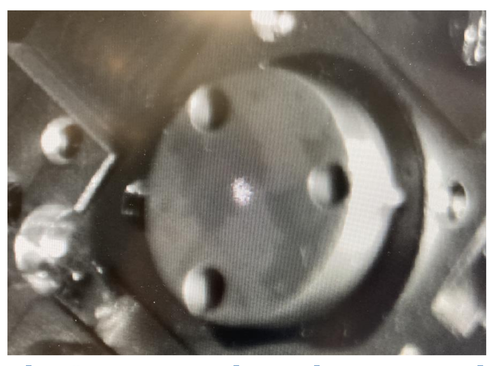
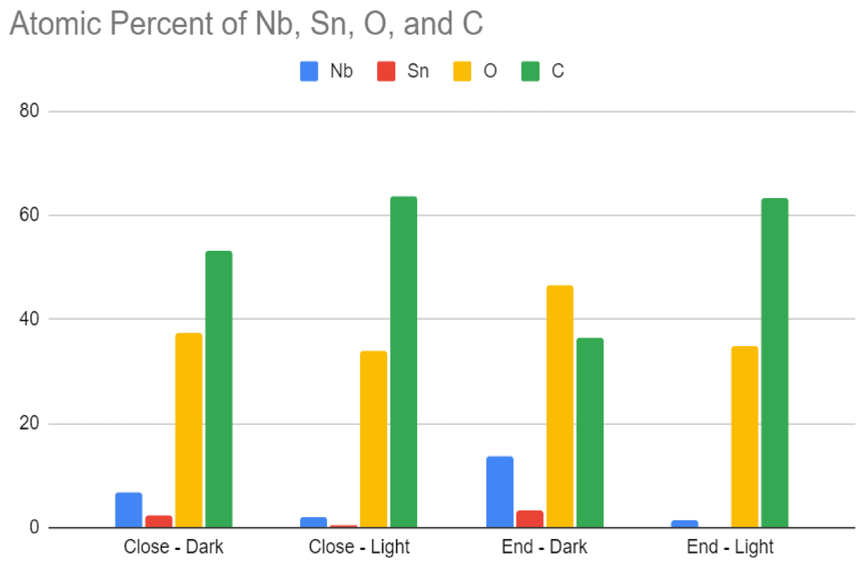
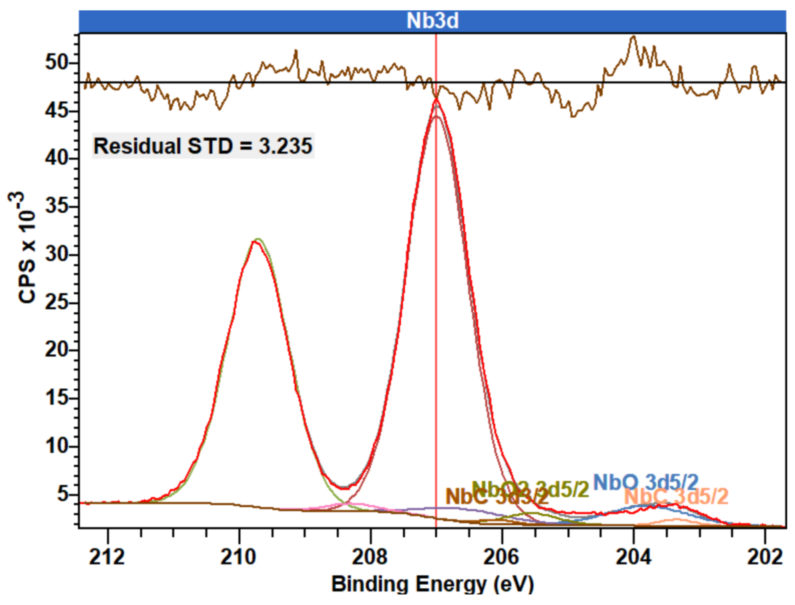
Results

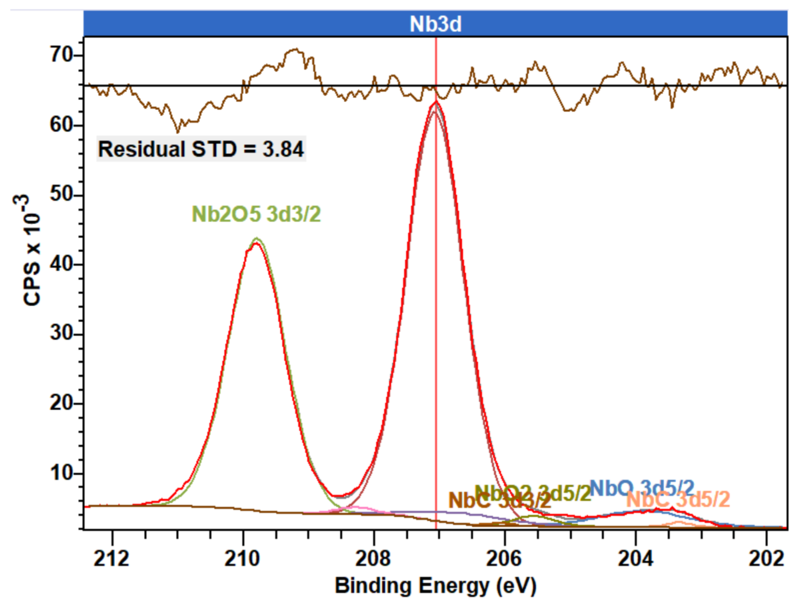


Nb_3Sn sample. The sample was located close to the heater during the coating process.

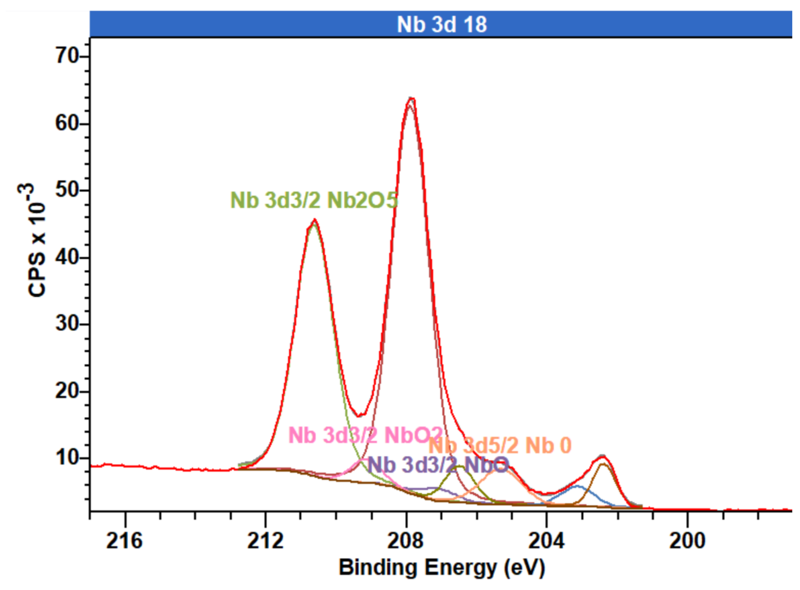


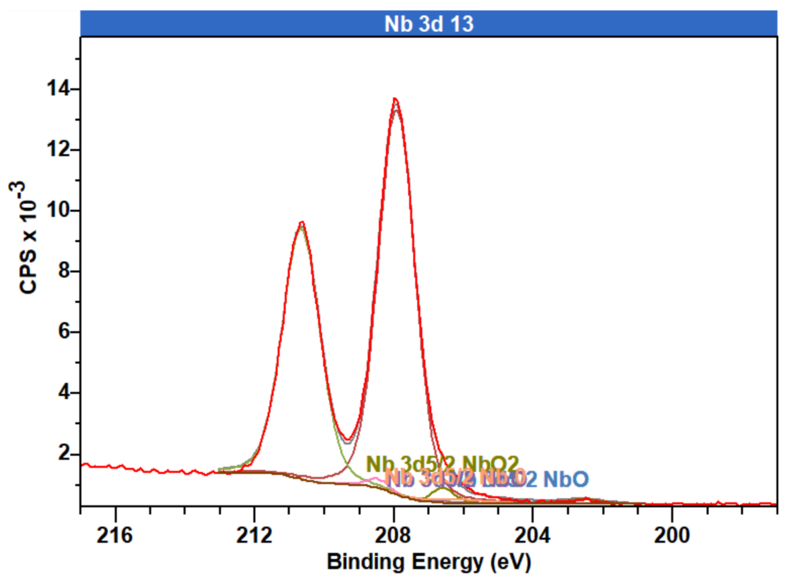
Atomic percentage of Nb_3Sn at the surface normal angle for both the light and dark regions of the surface.





Nb_3Sn sample on left at 30° RT, 0° RT on right. The sample was heated and exposed to the air leaving no metallic Nb or Sn. Substrate used was NbO.



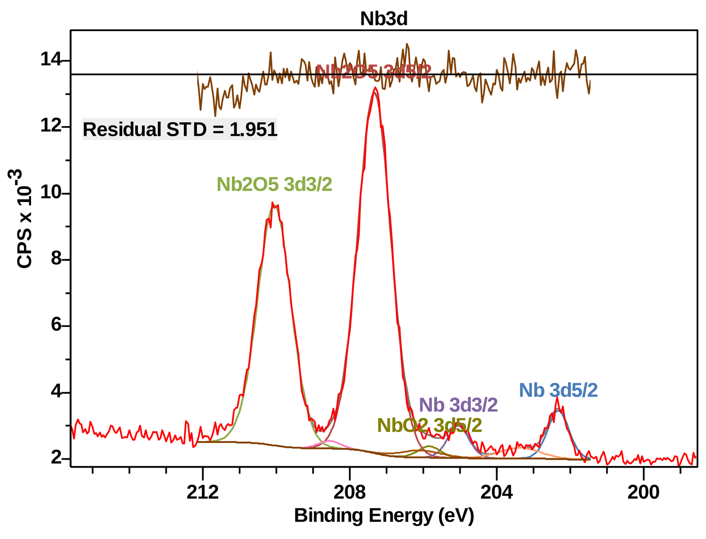


Niobium Sample: 10° RT

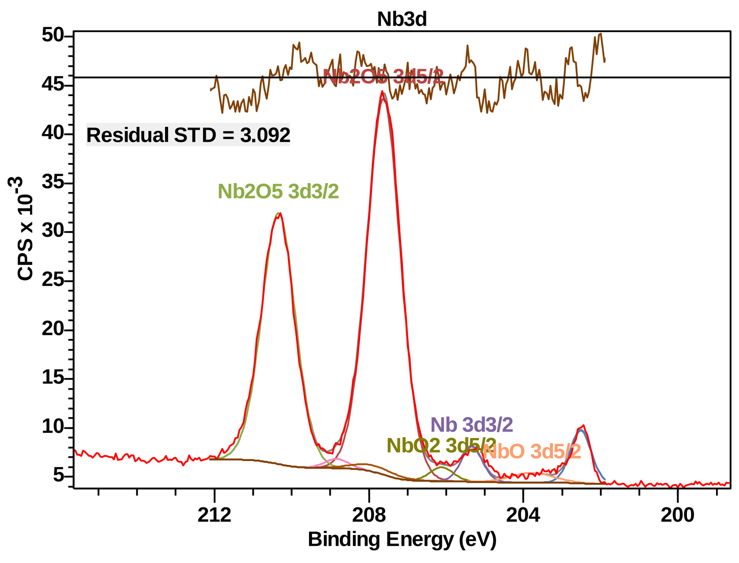
75° RT

Method

To calculate the oxide thickness, I used the equation: $\ln[1+R/R_\infty] = d/(\lambda_A \cos\theta)$. I graphed the left side of the equation against $1/\cos\theta$, and the gradient is equal to the thickness/ inelastic mean free path of the oxide. The Nb2O5 thickness for the Nb_3Sn baked sample was .57nm, SnO_2 was 1.87nm, with suboxides exceeding 2.85nm using the information depth sampled: 3imfp for 0°. The Nb sample has a Nb2O5 thickness of 4.77009, and a suboxide thickness of 2.35nm.



Nb 3d dark area 0° RT – close to heater



Surface chemical composition of aged Nb_3Sn samples, before cleaning.

Nb 3d dark area 0° RT – at end

Conclusions and Next Step

The thickness of the Nb3Sn samples used in this experiment will be recorded. The formation of niobium carbide and the presence of Nb oxides will be recorded at each temperature to monitor the effects of niobium carbide on the oxide layer and surface resistance. We will try to observe the segregation of Nb carbides, and the unwanted phases' effects on overall cavity performance using a VTS test.