Study of the Niobium Oxide Structure and Microscopic Effect of Plasma Processing on the Nb Surface

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1. Abstract
A study of the niobium oxide structure is presented here, focusing on the niobium suboxides. Multiple steps of argon sputtering and XPS measurements were carried out until the metal surface was exposed. Subsequently, the sample was exposed to air for different time intervals and the oxide regrowth was studied. In addition, three Nb samples prepared with different surface treatments were studied before and after being subjected to plasma processing. The scope is investigating the microscopic effect that the reactive oxygen contained in the glow discharge may have on the niobium surface. This study suggests that the Nb₂O₅ thickness may increase. Nevertheless, since the Nb₂O₅ is dielectric, its thickening would not negatively affect the cavity performance.

2. Plasma processing to mitigate FE
Reducing FE through CₓHₓ removal from cavity Nb surface Increasing the niobium work function by 10% results in 15% increase in E_{acc} Oₓ + CₓHₓ → CO + CO₂ + H₂O

3. Argon ions sputtering on oxidized Nb sample
- Sample preparation: 800 C x 3 h + 20 µm EP + 5 min HF rinse
- After surface treatment: 1 week to fully oxidize prior to XPS measurement

4. Oxide growth through air exposure
Air exposure steps: 15 min, Additional 15 min, Additional 45 min

5. XPS analysis on plasma processed Nb samples
Sample preparation:
PH 45: 800 °C x 3 h + 20 µm EP
PH 35: 2/6 N doping + 5 µm EP + 5 min HF rinse
PH 40: 2/0 N doping + 7 min cold EP

- Relative intensity of Nb and Nb₂O₅ is modified: ratio of Nb₂O₅ area over Nb area consistently increases after plasma processing
- ΔE between Nb and Nb₂O₅ may be decreased after plasma processing. Further analyses are needed to understand if it is caused by plasma cleaning.

- Similar results obtained on all three samples, independently of the surface treatment
- No particular change was observed in the suboxide spectra

6. Conclusions
- Nb 3d: shift towards lower energy values as the oxidation state decreases
- O 1s: initially three peaks are detected: niobium oxide, C=O, C=O. The niobium oxide peak is due to Nb₂O₅ plus the suboxides

- Sputtering and oxide regrowth: studied niobium oxide structure, identified multiple suboxides (NbO, NbO₂, Nb₂O₅) and extracted parameters for data analysis
- Plasma processed samples:
  - Consistent change in Nb₂O₅/Nb area ratio suggesting oxide thickening
  - Possible reduction in ΔE between Nb₂O₅ and Nb peaks. If caused by plasma processing, it may be due to the introduction of oxygen vacancies in Nb₂O₅ lattice.
  - However, Nb₂O₅ is dielectric; thickness increase would not affect cavity performance

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