SRF Materials:
Fundamental studies of interfacial oxidation chemistry of niobium

Lance Cooley – FNAL

Mike Pellin, Jim Norem – ANL

Steve Sibener – UC

John Zasadzinski, Thomas Prolier – IIT

May 2007 SRF Materials Workshop @ FNAL energized 2 collaborations being reported here

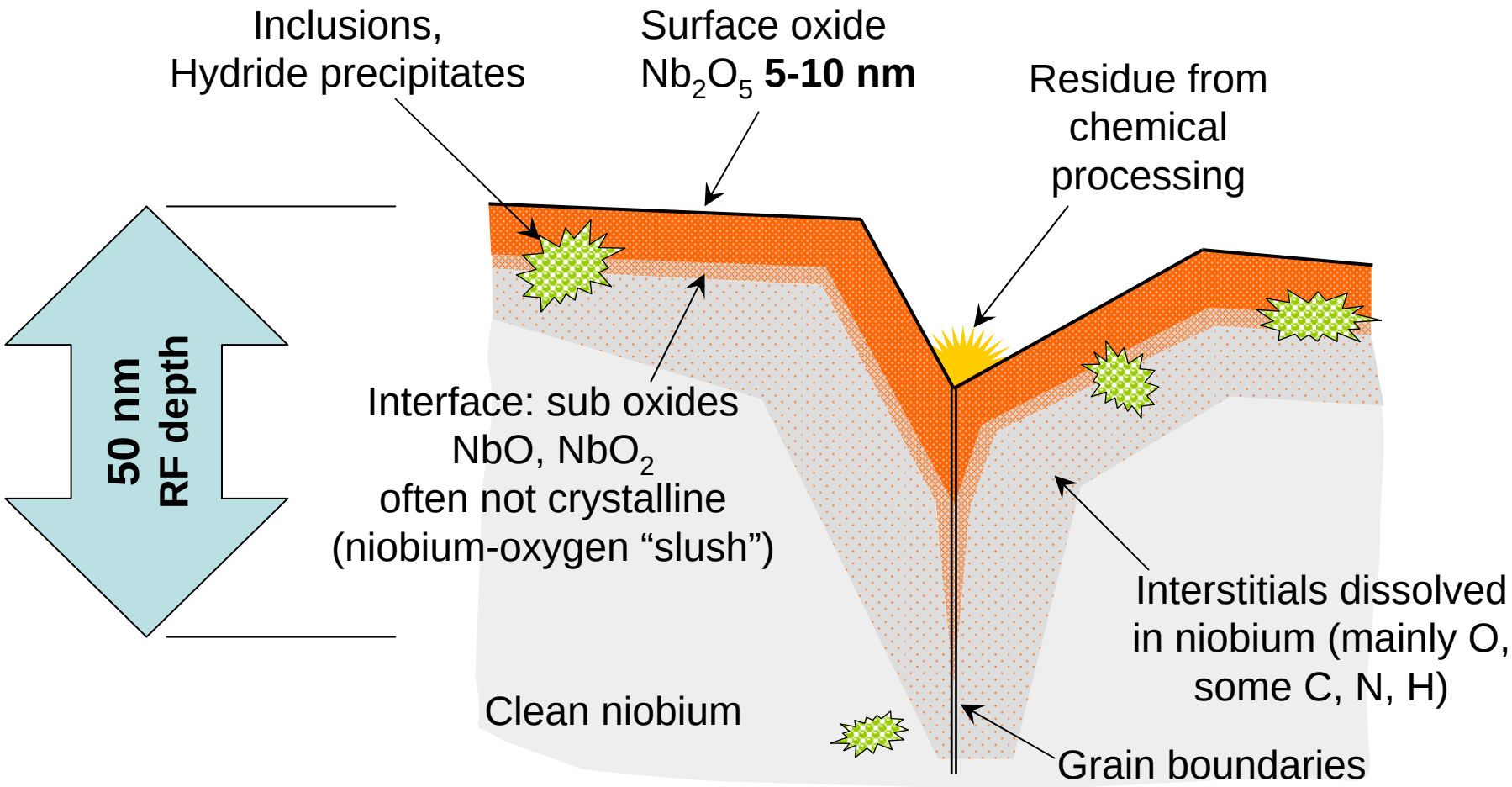
- *Atomic layer deposition of conformal coatings onto cavities* (Pellin, Zasadzinski, Prolier, Norem, Antoine/Wu/Cooley)
  - Directly probe surface superconductivity (SC) via 1.5 K STM + XPS surface composition
  - Nb oxidation layer proximity effects!
  - ALD Al_2O_3 coated cavity first, for oxidation control; multilayer-coated cavity later - A new philosophy: build up, not etch down
  - First annealing results reveal oxidation vs SC effects

ANL-LDRD

- *Niobium oxidation kinetics & oxide surface structures* (Sibener, Cooley)
  - Just underway as of October
  - Study structure and chemistry *in-situ* as oxides are forming

FNAL-UC seed

Pollution at niobium surfaces



Slide courtesy of C. Antoine

Separately, the collaborations attack fundamental questions associated with the niobium surface

- Atomic layer deposition
  - Is it possible to passivate niobium permanently to eliminate the problematic variations of niobium oxides?
  - It is possible to exceed the intrinsic SRF limits of niobium?
  - Is it possible to smooth out rough spots?
- Oxidation kinetics
  - Can we understand / predict effects of exposure to air, humidity, and vacuum vs. temperature and time ?
  - Do different niobium crystallographic directions affect the kinetics?
- STM / STS + XPS
  - Are there clear changes of the niobium superconducting gap with respect to location and pollutant?

Coordinated effort has produced a compelling discovery and a potential pathway for breakout

- It is natural for the collaborations to cross-fertilize
- Discovery: the superconducting gap profile can only be explained if *some oxide is magnetic*!
  - Magnetic niobium oxides were known, e.g. early days of HTS
  - Magnetic transitions occur at ~2.5 K for one of the oxides
- Baking (a common post-process fix-up) changes the magnetic oxide content
  - STM of ALD coatings, possibly also in baked spoke cavity (Kelly)
- Implication: since magnetism is antagonistic to superconductivity, magnetic niobium oxide would easily break Cooper pairs and initiate hot spots

The structure of “niobium oxide” is more subtle than previously acknowledged, and its properties, therefore, are more complex than presently appreciated!

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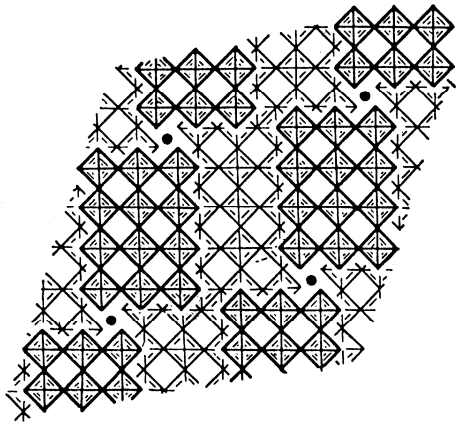
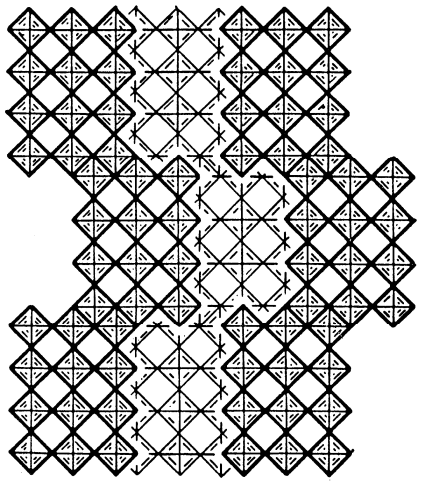
Electrical and magnetic properties of $Nb_2O_{5-\delta}$ crystallographic shear structures

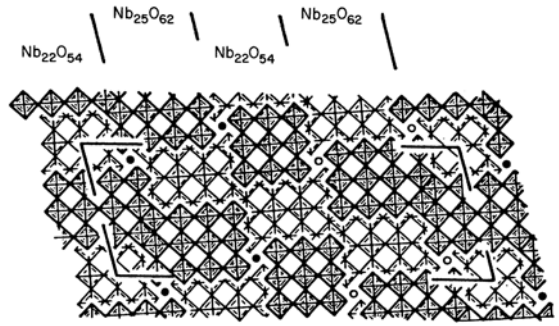
R. J. Cava, B. Batlogg, J. J. Krajewski, H. F. Poulsen, P. Gammel, W. F. Peck, Jr., and L. W. Rupp, Jr.



Nb_2O_5
(= $Nb_{12}O_{30}$)



$Nb_{12}O_{29}$
T_{Neel} = 2.5 K



Shear structure of
22/54 + 25/62