TTC Mtg – July 6, 2016

Nb_3Sn Developments at JLab

C. Reece
for
Grigory Eremeev, Uttar Pudasaini (W&M),
Jay Tuggle(VT) and Michael Kelley (W&M, VT, JLab)

JLab Nb_3Sn Program

- In our present furnace-based configuration, niobium cavities, tin shots and tin chloride powder are maintained at the same temperature during the coating process.
  - "Siemens" configuration
  - Can add implement a vapor guide with a separate tin crucible temperature control system if it appears helpful.
  - However, can achieve performance comparable to Wuppertal without independently controlled Sn source.
- Cavity process development (Grigiory) runs in parallel with sample prep and analysis (Uttar).

JLab Nb_3Sn Program

- Aim is two pronged:
  A. Press the technology forward toward useful 4 K, L-band 5-cell cavity system. Deploy in JLab's new Injector Test Stand.
  B. Understand the film growth dynamics to guide process optimization.

JLab Nb_3Sn Program

A. Cavity work

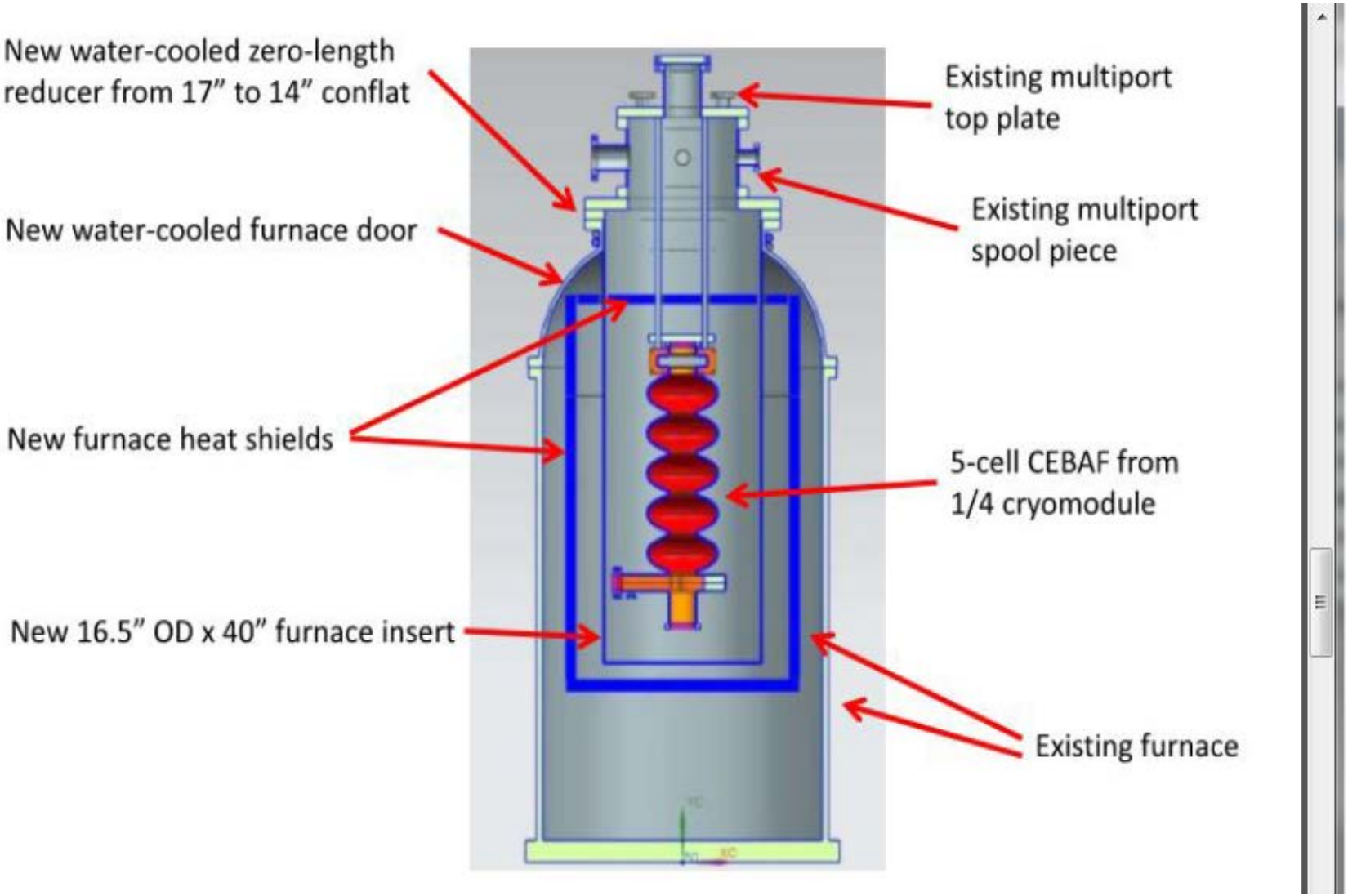
1. Challenge and characterize uniformity on extended surfaces
2. Variation of RF properties with material and process parameters – multiple single cell, 2- cell, and 5-cell cavities.
3. Enlarging furnace to accommodate CEBAF 5-cell with WG couplers.

JLab Nb_3Sn Program

B. Understand the film growth dynamics to guide process optimization.

1. Nucleation process
    1. Vary Sn and $SnCl_2$ load, interrupt process, vary temperature, examine samples.
    2. What determines lateral grain size?
2. Substrate dependence
    1. Morphology, not much
    2. Nb quality (interstitial load), yes
    3. Suspect “patches” with thin Nb_3Sn layer – why?
3. Roll of Ti – potential contaminant?
4. Influences on resultant surface morphology – roughness influence on field-dependent losses
5. Systematic material characterization W&M and VT.

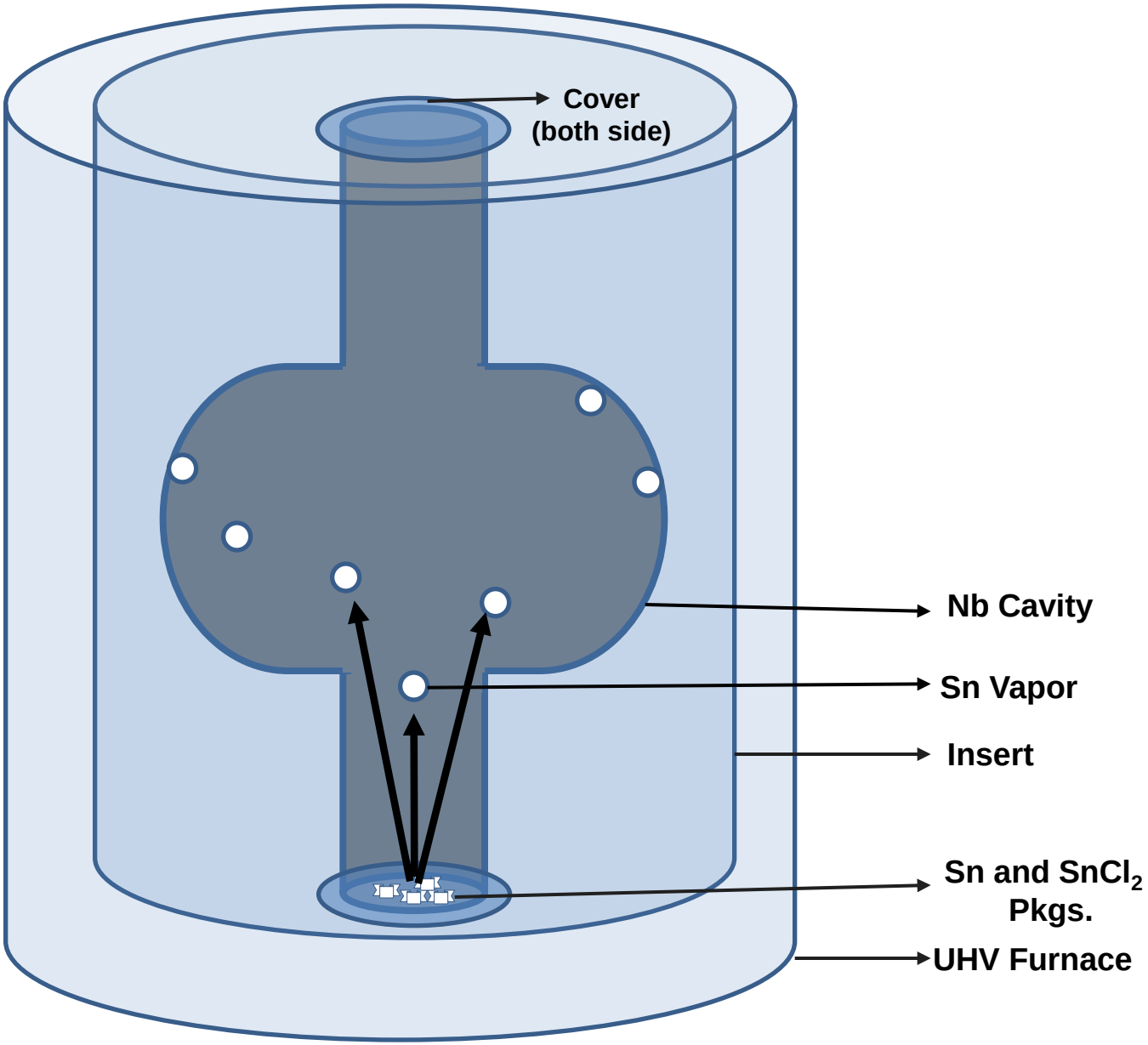
Many open questions, but we are on the hunt.


New water-cooled zero-length reducer from 17" to 14" conflat
New water-cooled furnace door
New furnace heat shields
New 16.5" OD x 40" furnace insert
Existing multiport top plate
Existing multiport spool piece
5-cell CEBAF from 1/4 cryomodule
Existing furnace

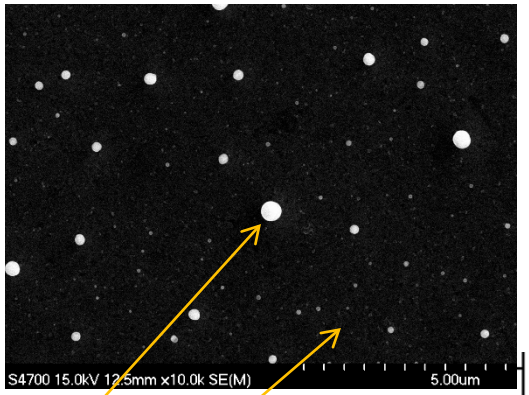
Coating Technique

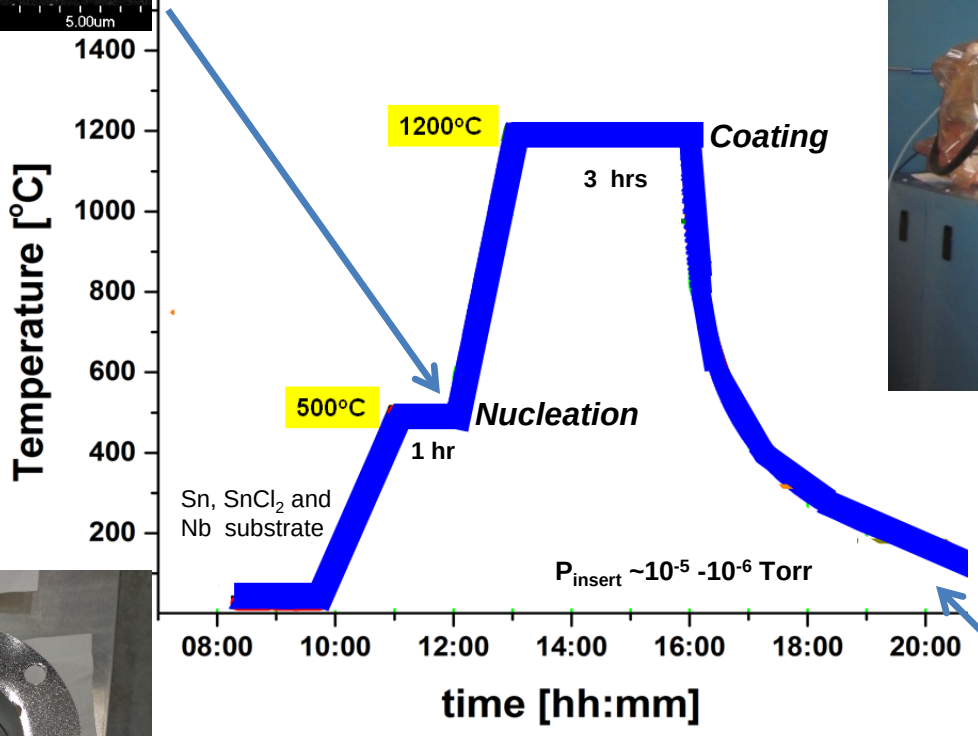
Diffusion coating

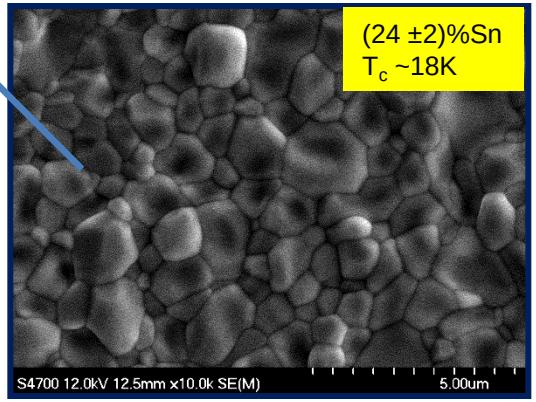
- Diffusion followed by reaction
- Transportation to the substrate
- Creation of active atoms



Coating Recipe

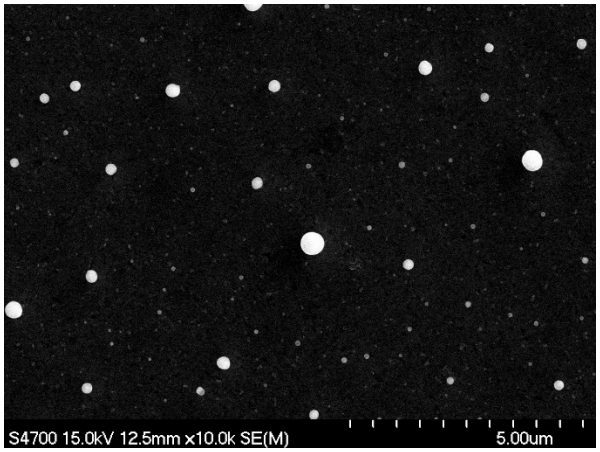


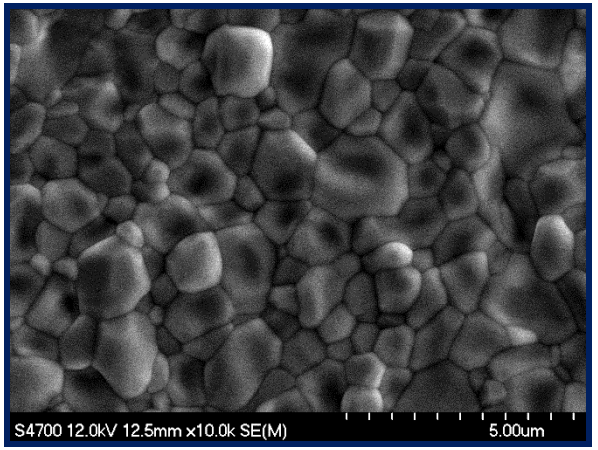




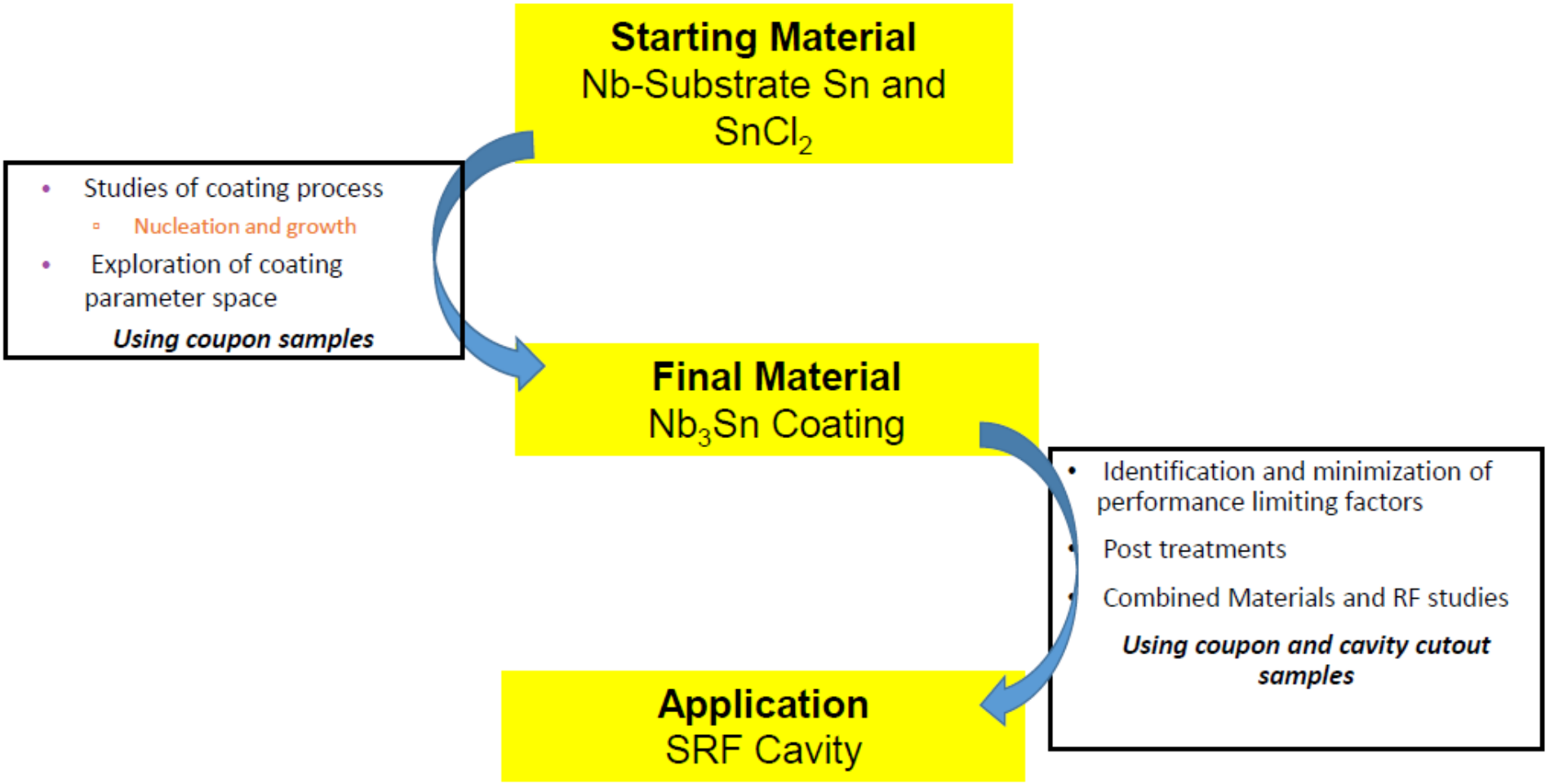
(Assumed) Coating Growth Mechanism

- Niobium surface covered with native oxide and some hydroxyl
- $SnCl_2$ transported reacts with surface to deposit Sn
  - Surface covered with Sn ions ?
  - Nucleation controls grains?
- Vaporized Sn arrives to the surface and join existing tin
- Phase formation and grain growth
  - What would be effect of changing amount of Sn?
  - What annealing will do?





Sample Studies

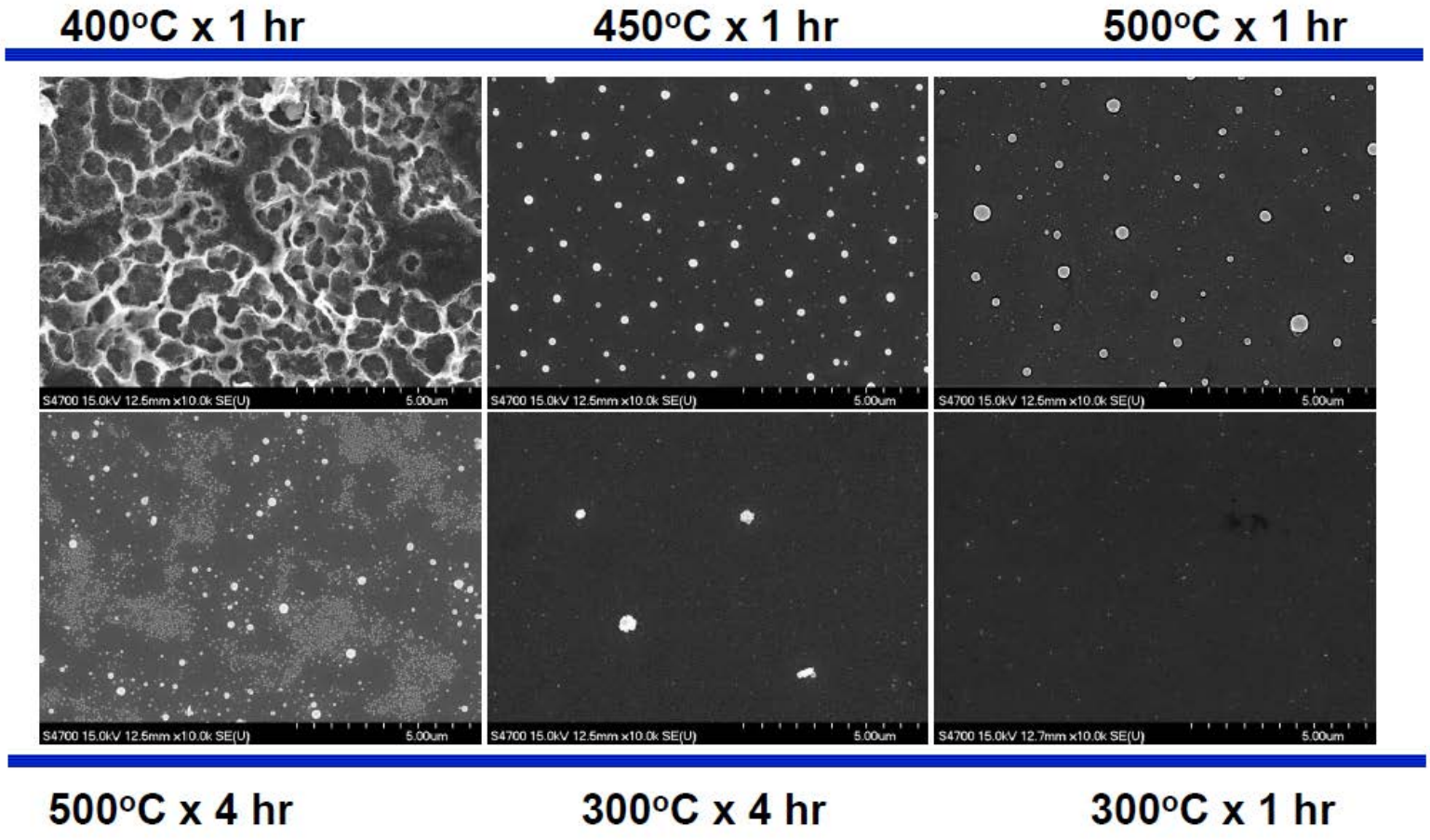


Nucleation

- Action of $SnCl_2$
- Generates tin enriched locations early
- Effect on uniformity and coverage
- Controls the final structure of coating ?
- Variables and Experiments

Nucleation Experiment

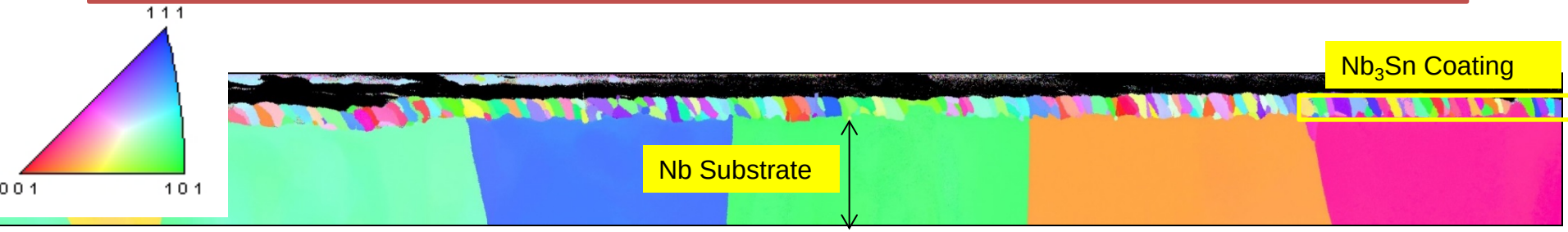
- 1g Sn, 1g $SnCl_2$ and Nb Samples
- 6°C/min to reach nucleation temperature

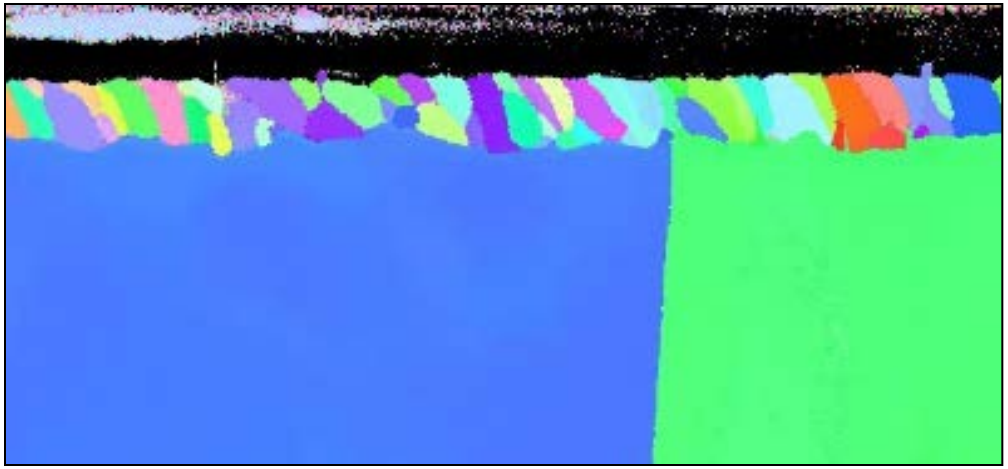


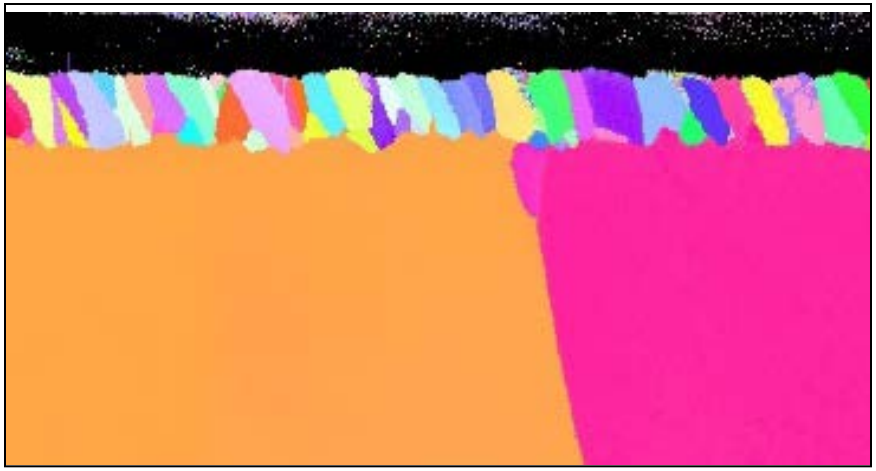
Next : Can we make a difference in final coating?

Growth of Coating

- Columnar Growth
- Grain orientation independent of substrate
- No effect of Nb substrate grain boundary

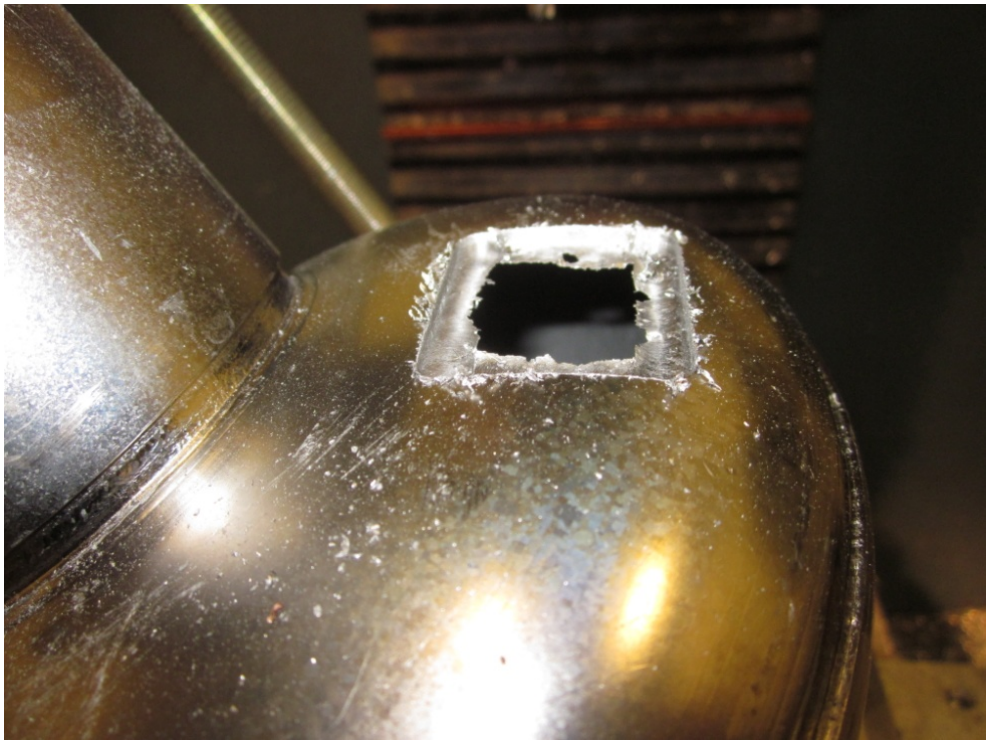






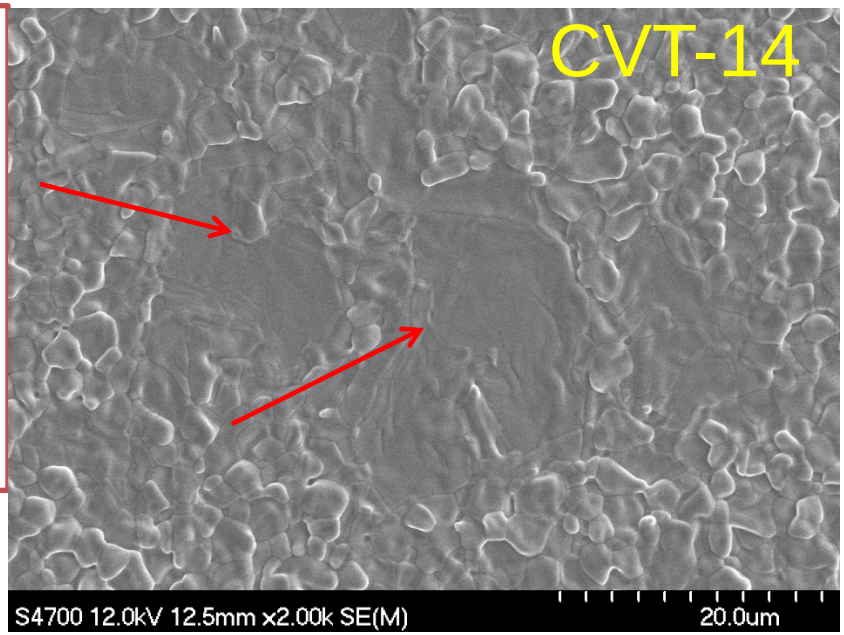
Sample U3

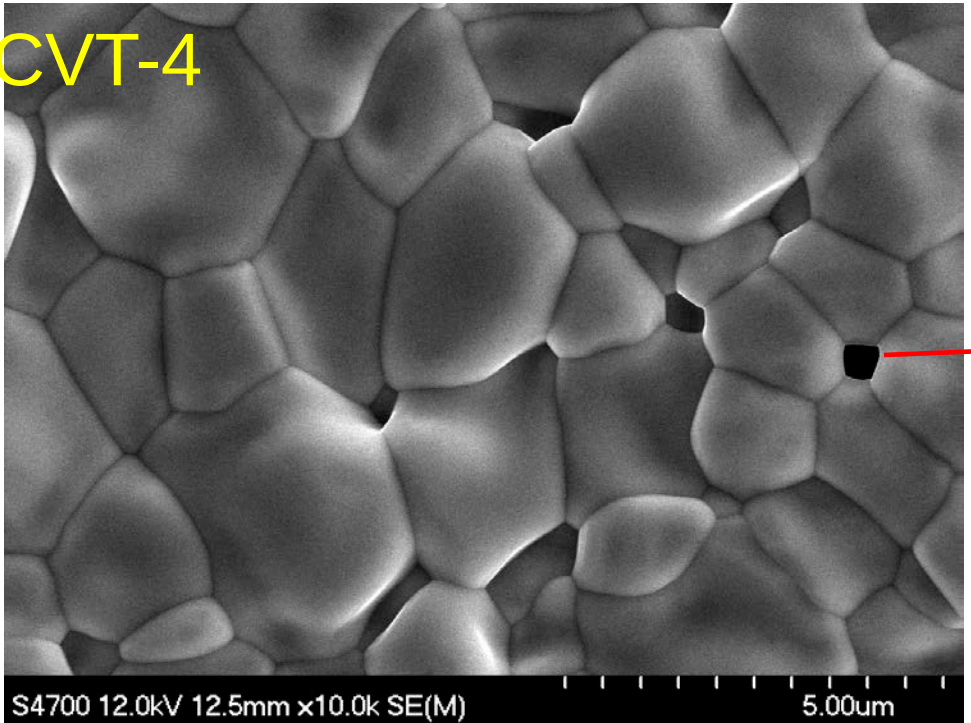
Cavity Cutouts

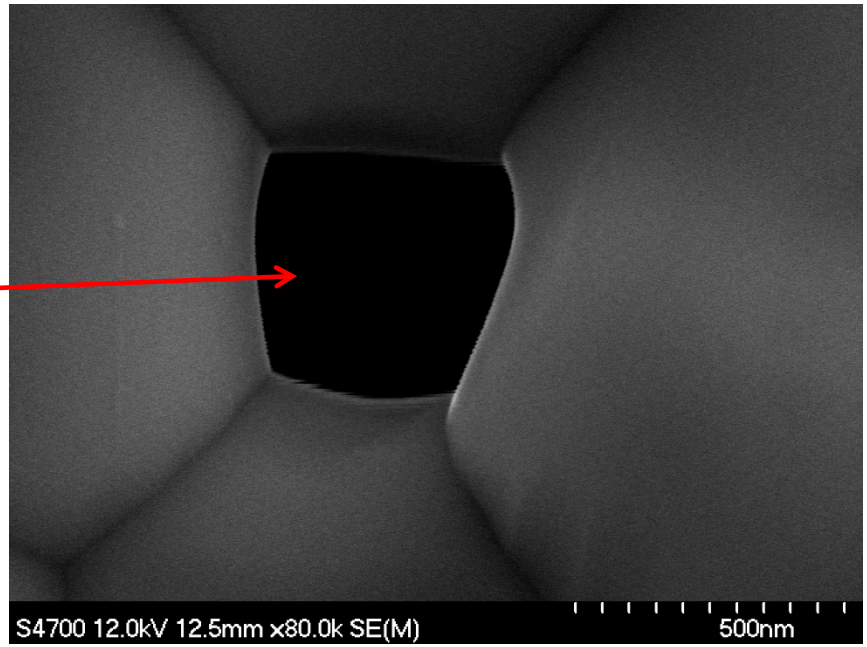


SEM/EDS on Cavity Cutouts

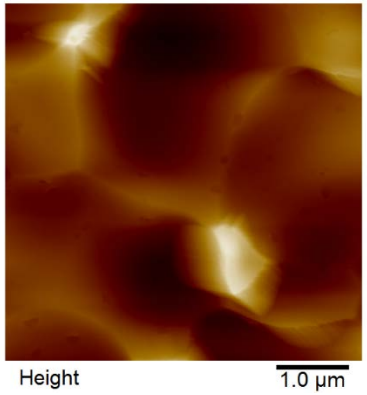
- Pits and cracks
- Different than coupons
- Composition similar to coupon
- “Patches” with different composition

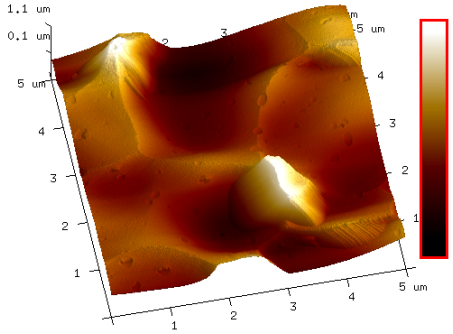


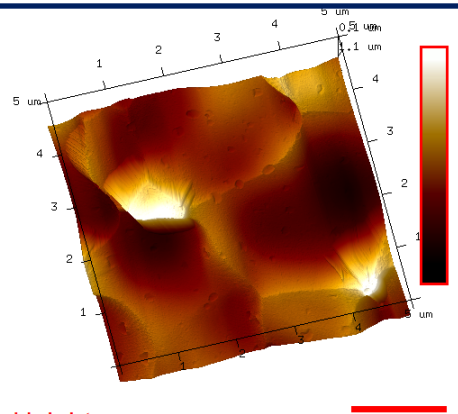




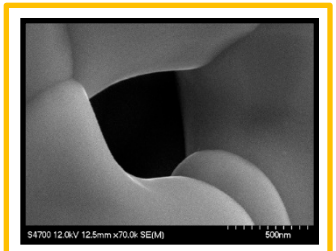
Replication of Cavity Cutout surface

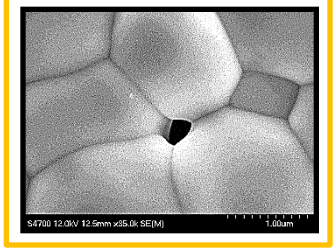


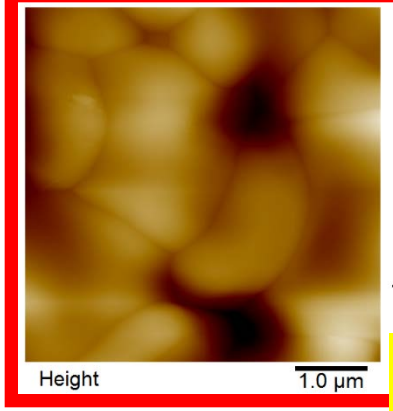




CVT12 Replica 01

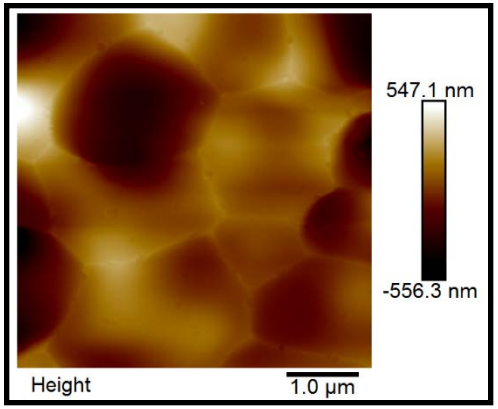






CVT2

Pits in original surface



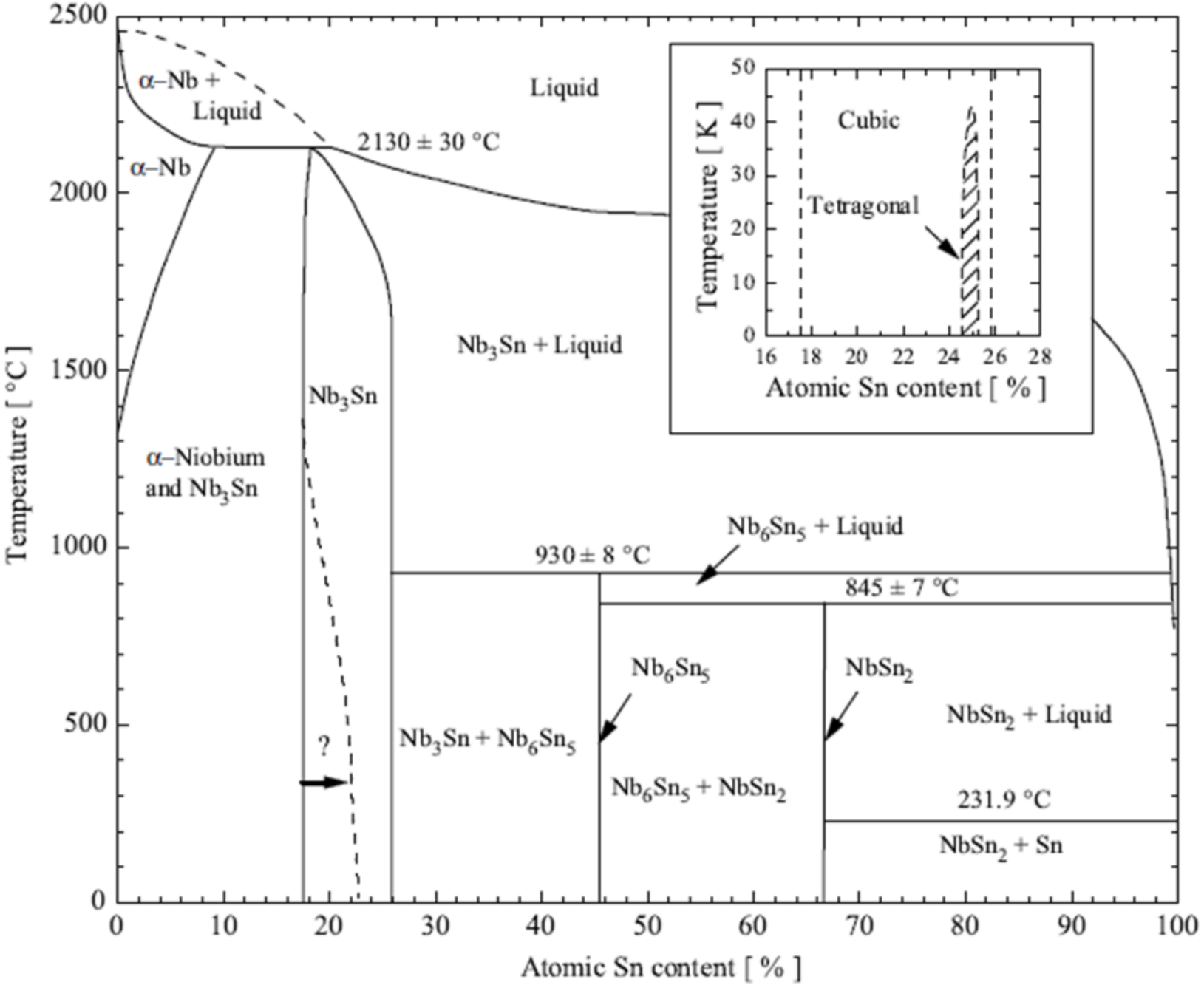
CVT12 Replica 02

- **Cellulose acetate Replication tape**
- **Tried on CVT4 and CVT12**
- **Successful replicas shows clear GB**
- **Looks like replicas can resolve pits formed in GB junction (preliminary)**

Current Status

- Studies of cavity cutouts
- Nucleation studies
- Oxy-polishing
- Other
- Short 5-cell cavity initial coating runs have begun

Stay tuned


α–Nb +
Liquid
Liquid
2130 ± 30 °C
α–Nb
Nb3Sn + Liquid
Nb3Sn
α–Niobium
and Nb3Sn
Nb6Sn5 + Liquid
930 ± 8 °C
845 ± 7 °C
Nb6Sn5
NbSn2
NbSn2 + Liquid
Nb3Sn + Nb6Sn5
Nb6Sn5 + NbSn2
231.9 °C
NbSn2 + Sn
?
Temperature [°C]
Atomic Sn content [%]
Cubic
Tetragonal
Temperature [K]
Atomic Sn content [%]