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# First $Nb_3Sn$ Coating and Cavity Performance Result at KEK

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## Abstract

At KEK, $Nb_3Sn$ vapor diffusion R&D for High-Q has just started. We have performed Nb3Sn coating on niobium samples and characterized these samples to optimize the cavity coating parameter. After optimizing the parameter, we have performed Nb3Sn coating on TESLA-like single cell Nb cavity and measured cavity performance.
The result of the cavity coating and performance results is reported in this poster.

## Coating System at KEK

- KEK coating system : vertical type.
  - Furnace, tin heater, Nb coating chamber, pumps
  - **In the coating as describe, clean booth was not yet built**

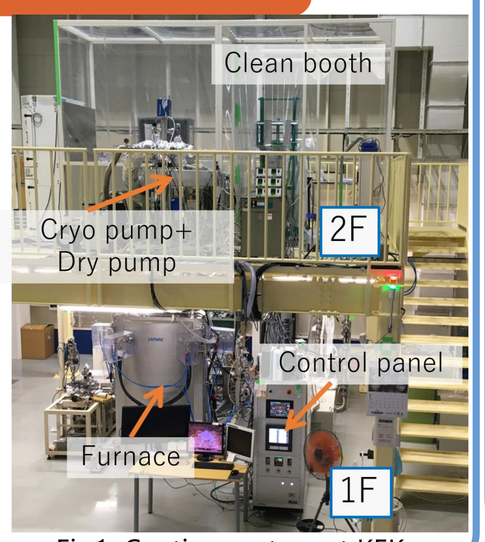


Fig1. Coating system at KEK

## Sample Coating

- Two type of samples were coated $Nb_3Sn$
  - Nb plate (RRR : cavity grade, 7 mm × 7 mm)
  - Nb foil (RRR : around 30, 4 mm × 50mm)
- Coating temp. 1200℃ (4th) : Tc was lower than others.
- Annealing time 1.5 hours (9th) : **Voids on the surface** Tc was around 18 K
- Annealing time 0 hours (11th , 23rd) : **Few voids on the surface** Tc was around 18 K
- All sample surface have patchy region
- Coating parameter for cavity is same as sample 23rd
  - Nucleation : 4.5 hours, 500 ℃
  - Coating : 3.0 hours, 1100 ℃(Furnace) 3.0 hours, 1400 ℃(Tin heater)
  - Annealing : 0 hours

Cavity coating parameter

| Number of coating | 2nd | 4th | 9th | 11th | 23rd |
|---|---|---|---|---|---|
| Coating Time [h] | 6.5 | 1.5 | 1.5 | 1.5 | 3.0 |
| Coating Temp.(Furnace) [°C] | 1100 | 1200 | 1100 | 1100 | 1100 |
| Coating Temp.(Tin heater) [°C] | 1300 | 1400 | 1400 | 1400 | 1400 |
| Annealing Time[h] | 1 | 1.5 | 1.5 | 0 | 0 |
| $T_c$[K] | 16.1±0.1 | 11.1±0.1 | 18.0±0.2 | 17.9±0.4 | 18.1±0.1 |
| Thickness[$\mu$m] | 1.7± 0.4 | - | 1.7±0.2 | 1.3±0.3 | 1.5±0.3 |
| Sn at% | 22.8 | 18.2 | 24.1 | 23.5 | 24.0 |
| Voids | ☑ | ☑ | ☑ | none | none |

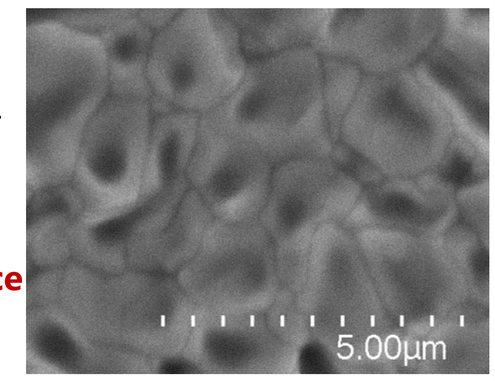


Fig. 2 Sample surface with voids

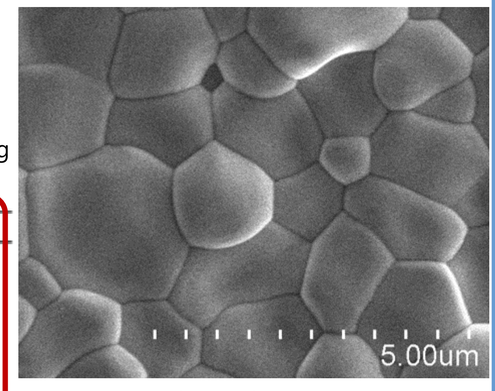


Fig. 3 Sample surface without voids

## Cavity Coating

- Cavity coating parameter
  - Nucleation : 4.5 hours, 500 ℃
  - Coating : 3.0 hours, 1100 ℃(Furnace) 3.0 hours, 1400 ℃(Tin heater)
  - Annealing : 0 hours
- Witness samples was coated with the cavity.
- Before coating : metallic luster
- After coating : matte

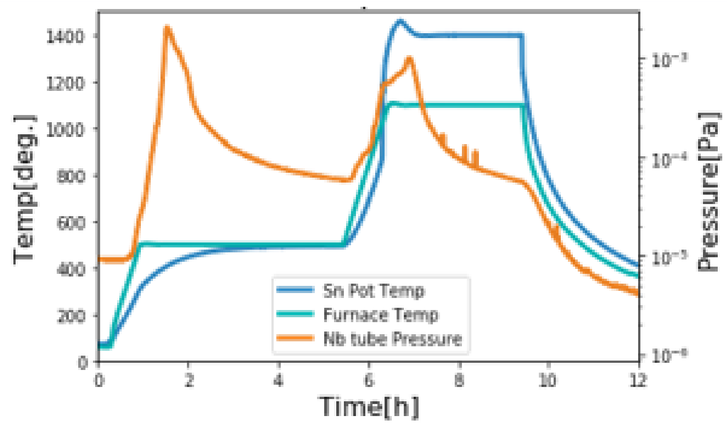


Fig. 4 Cavity coating profile

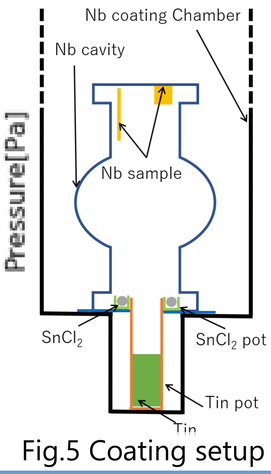


Fig.5 Coating setup

Fig. 6a Before coating

Fig. 6b After coating

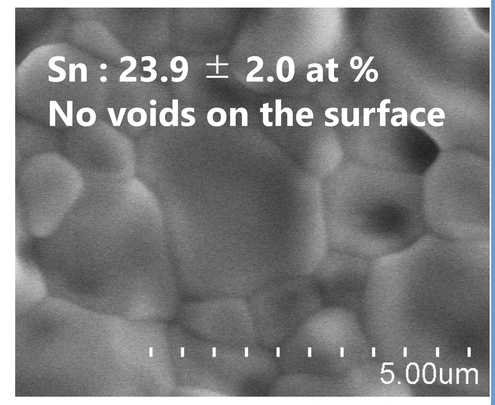


Fig. 7 Witness sample surface

## Cavity Performance Result ・Discussion

### Cavity Performance Result

- Cavity performance test : 4.2 K & below 4 K
- $Q_0$ : 3.9 × $10^9$ (1MV/m) , $E_{acc,\ Max}$ = 11 MV/m
  - ΔT = 0.01 K, 4.2 K
- Q0 was lower than 1 × $10^{10}$
  - Contaminated carbon impurities
  - Low Tc Nb-Sn compounds were formed ?
  - Tin residue was on the surface?
    - Annealing process was omitted.
  - Patchy region was on the surface?
- Rs was decomposed to $R_{BCS}$ and $R_{res}$.
  - $R_{BCS}$ : almost constant
  - $R_{res}$ : **increased depending on ΔT**
    - **Flux from thrmo-current was trapped**.

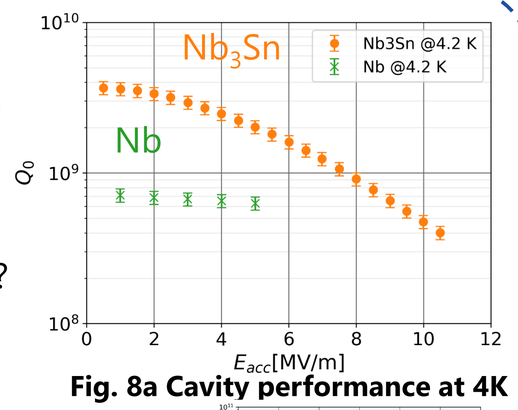


**Fig. 8a Cavity performance at 4K**

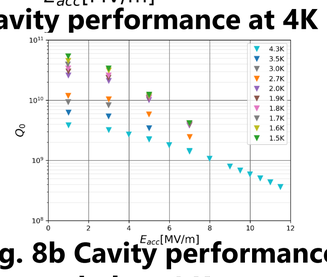


**Fig. 8b Cavity performance below 4 K**

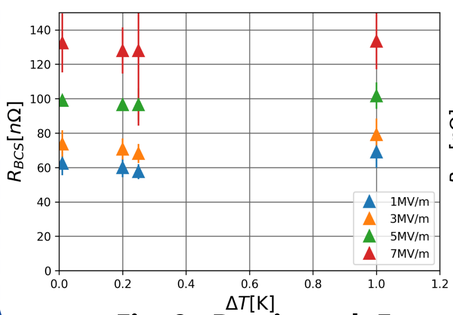


**Fig. 9a $R_{BCS}$ in each $E_{acc}$**

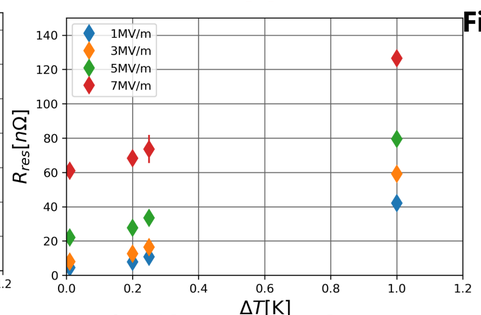


**Fig. 9b $R_{res}$ in each $E_{acc}$**

### Magnetic Field Change Measurement

- Mag. field change between normal and superconducting state was measured.
- ΔT : 0 K
  - Mag. field change was almost zero in each external field.
- ΔT : 1 K
  - Mag. field change was a dozen mG in each external field.
  - Mag. field change was dominant on ΔT.
  - **Dominant by thermo-electric effect.**




Fig. 10a Z axis




Fig. 10b θ axis




Fig. 10c R axis




## Summary

- At KEK, $Nb_3Sn$ coating was applying for the single-cell cavity.
- $Q_0$ : 3.9 × $10^9$ (ΔT = 0.01 K, $E_{acc}$ = 1 MV/m, 4.2 K)
- Maximum $E_{acc}$ : 11 MV/m
- Rres : increased depending on ΔT.
  - Trapping magnetic flux from thermo current.
- Magnetic field change when cavity become SC state were dominated from thermo-electoric effect.

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