Nb_3Sn Thick Layers synthesized via Bronze Route

Approach from the Nb/Bronze Composite Wire Process

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- Mr. Yasunari Mizuta
- Dr. Taiji Mizuta

- Mr. Tsubasa Tsubokawa

Diffusion pass for synthesis of Nb_3Sn

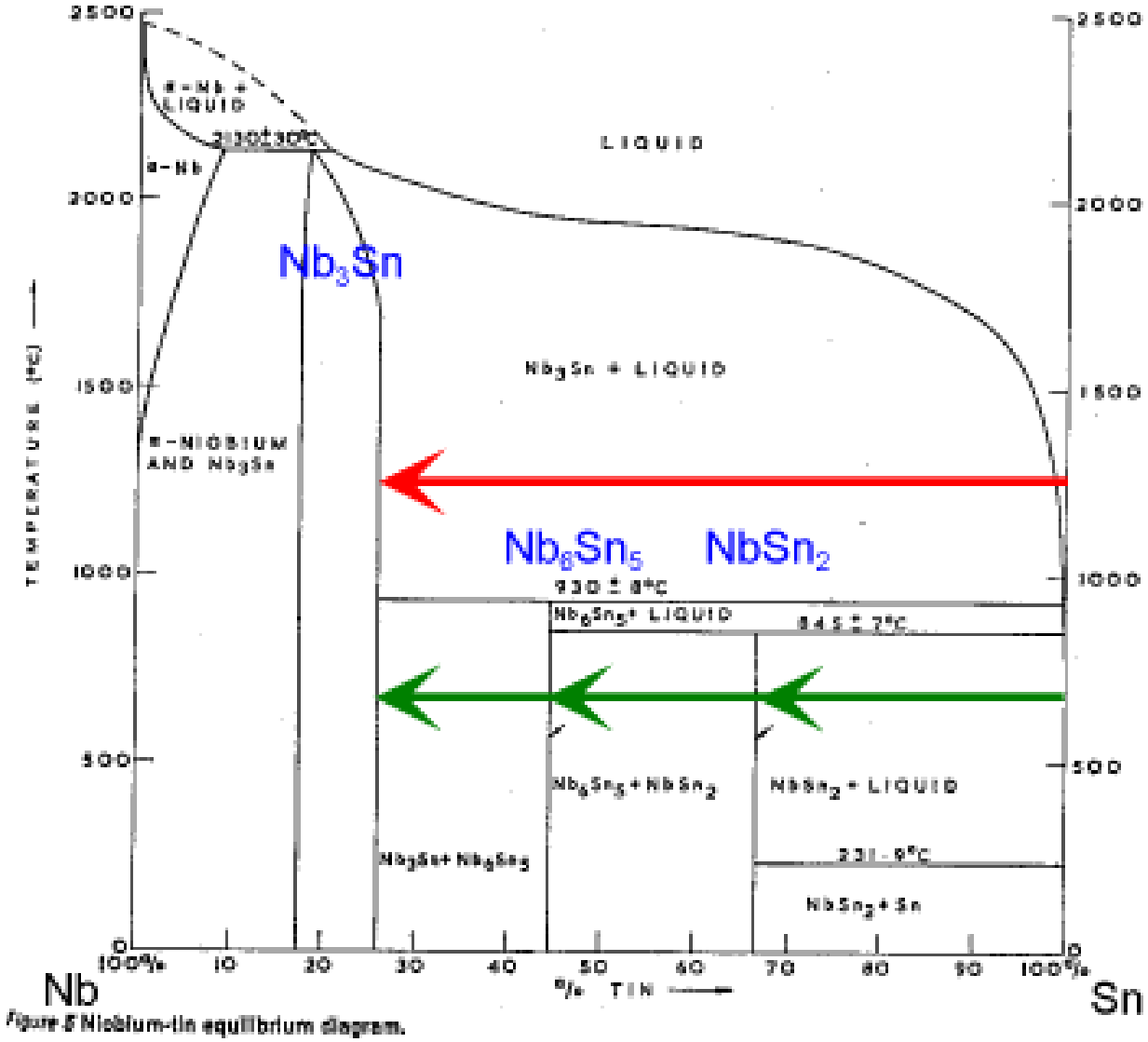


Figure 5 Niobium-tin equilibrium diagram.

High Temperature Reaction

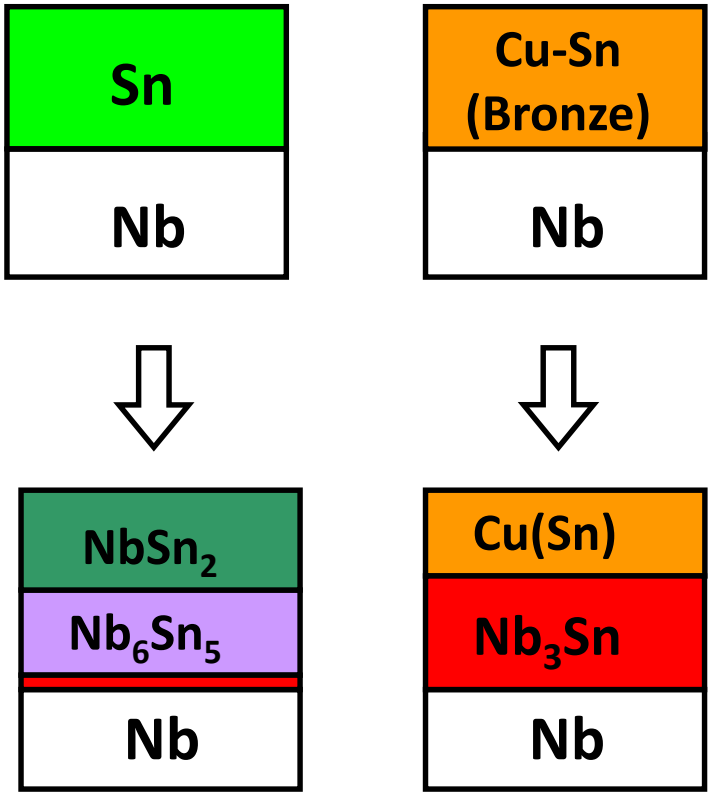
Single Nb3Sn phase can be obtained. But, Nb3Sn grain is very large. Since the grain boundary acts as the flux pinning center, its critical current density, Jc is very low.

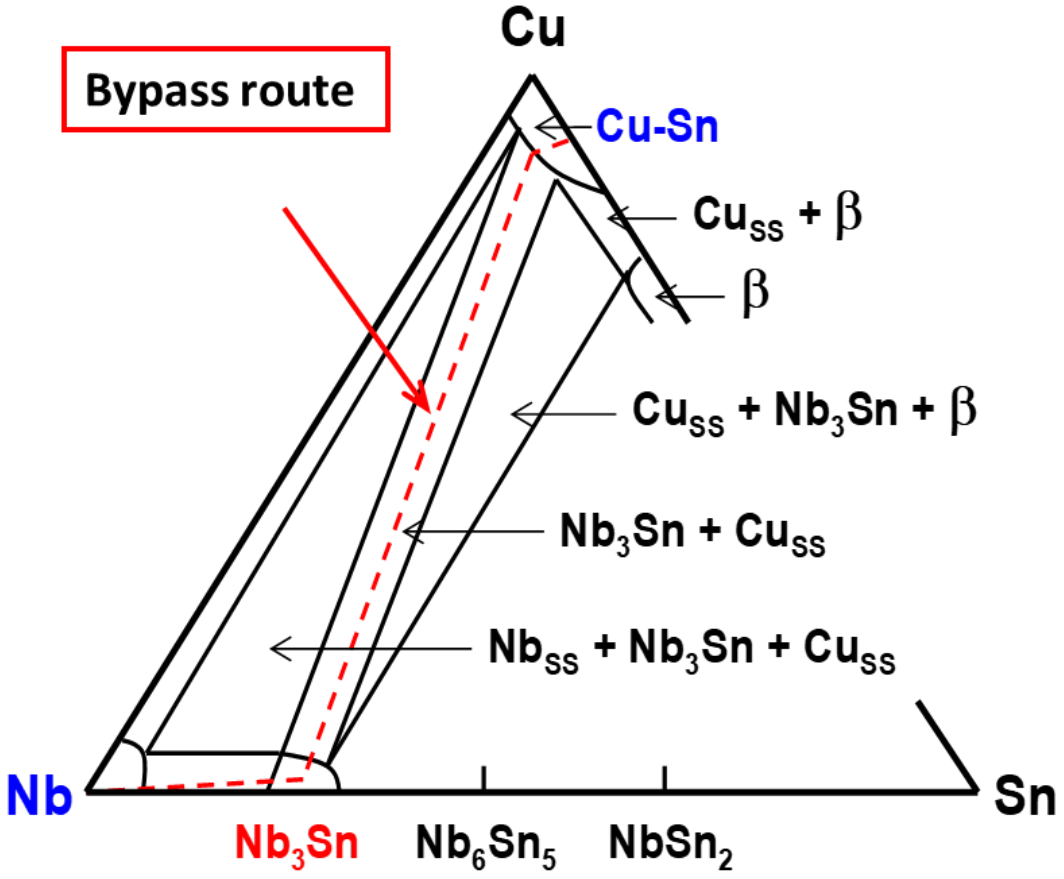
Low Temperature Reaction

Non superconducting NbSn2 and Nb6Sn5 intermediate phases dominantly form with a small amount of Nb3Sn phase. As a result, Jc is still very low.

Discovered Effect of Cu in 1967

Bypass Route for Direct Forming of Nb_3Sn Phase at low temperature diffusion reaction. (*Tachikawa Method*)





Nb_3Sn Multifilamentary Wires (1972)

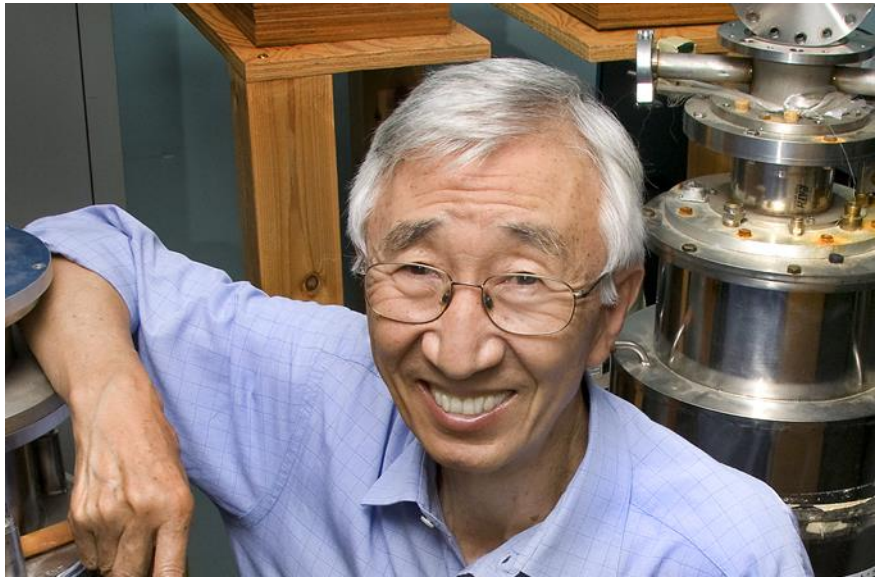
Superconducting Properties of Multifilamentary Nb_3Sn Made by a New Process*

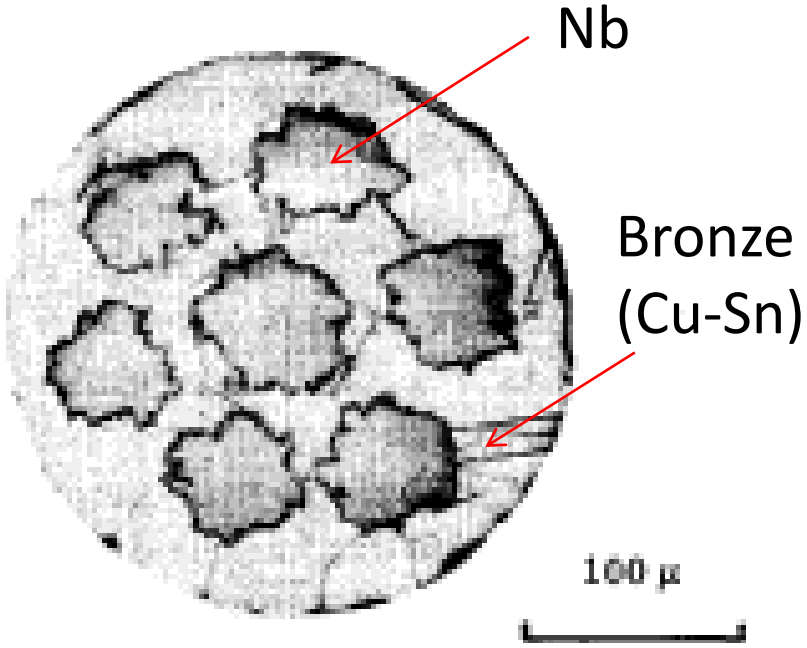
M. Suenaga and W. B. Sampson†

Metallurgy and Materials Science Division, Brookhaven National Laboratory, Upton, New York 11973

(Received 6 January 1972; in final form 13 March 1972)

A new processing method for producing multifilamentary A-15 superconducting composite wires in a ductile matrix is described. Nb_3Sn made in this way was found to have a critical temperature of 17.5 K and a critical current density of 7.5×10^5 A/cm^2 at 40 kG when suitably heat treated. The composite conductor could be bent with a radius of 2 cm or greater without appreciable degradation of its current-carrying capacity.





Production Scheme of Nb_3Sn wires

Billet Assembly
(with EB welding)

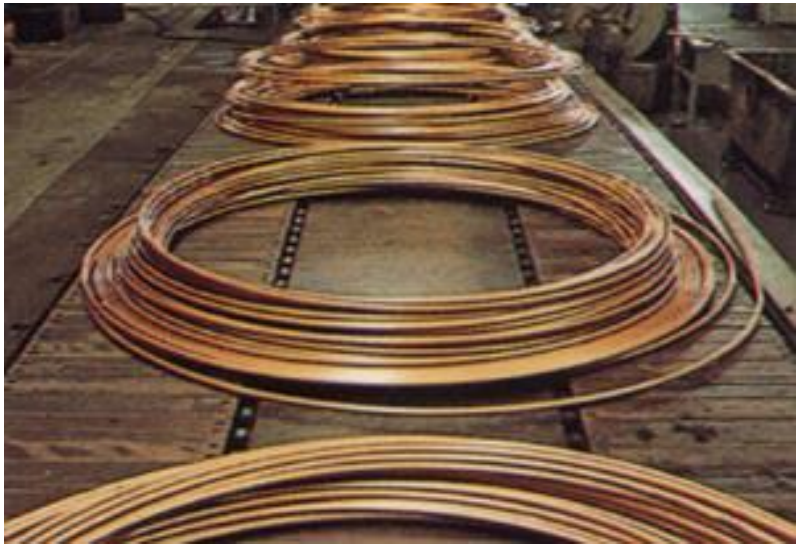
Hot Extrusion

Very important step to obtain strong mechanical bonding between Nb and bronze.

Production Scheme of Nb_3Sn wires

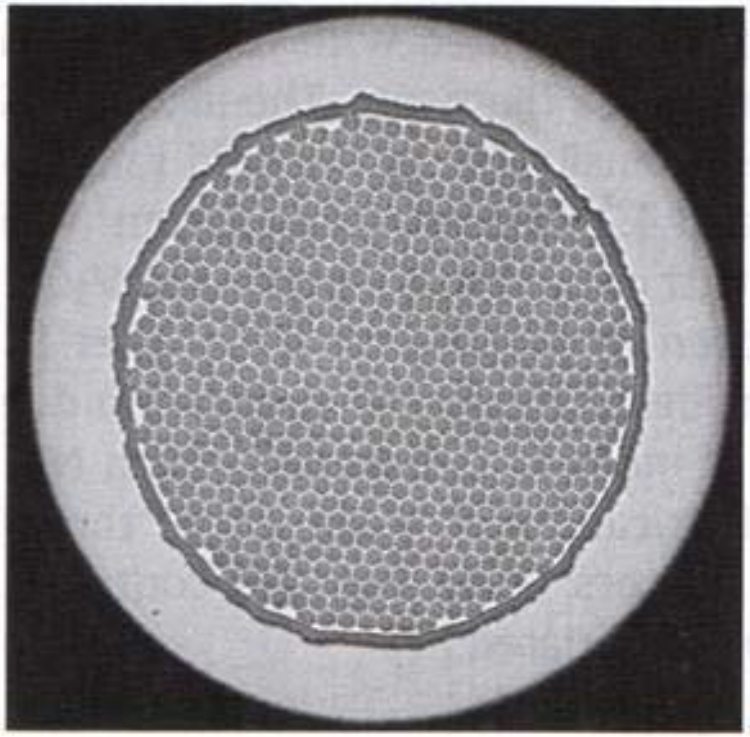
Cold-Die-Drawing

Intermediate annealing

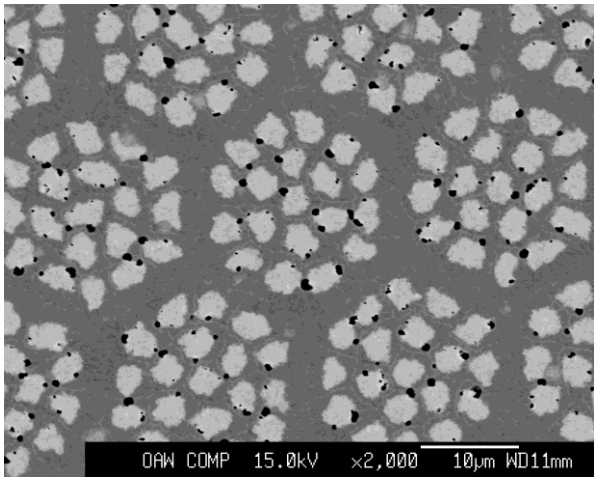


Bronze shows significantly work hardening. In order to keep well-balanced hardness between Nb and bronze, frequent intermediate annealing is needed in cold die drawing.

Typical Nb_3Sn Multifilamentary Wires



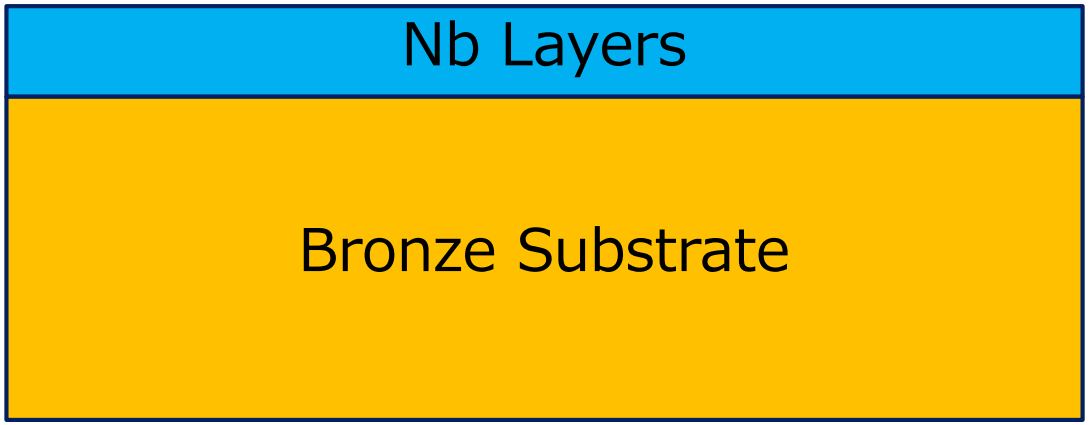
Wire diam. (with Cr plating)	0.826 mm
Twist pitch	15.0 mm
Bronze composition (wt%)	Cu-15.5 Sn-0.3Ti
Filament composition (wt%)	Nb-1.0 Ta
Filament diameter	3.0 μm
No. Filament	19×583=11,077
Cu/non Cu ratio	1.0
Barrier material	Nb
non Cu J_c @ 12 T, 4.2 K	820 A/mm^2
n-value @ 12 T, 4.2 K	30.0
Hysteresis loss @ ± 3 T, 4.2	620kJ/m^3



From the achievements on the fabrication of multifilamentary wires, we can say that is possible control the Nb thickness on the bronze substrate through the plastic deformation of Nb/Bronze composite.

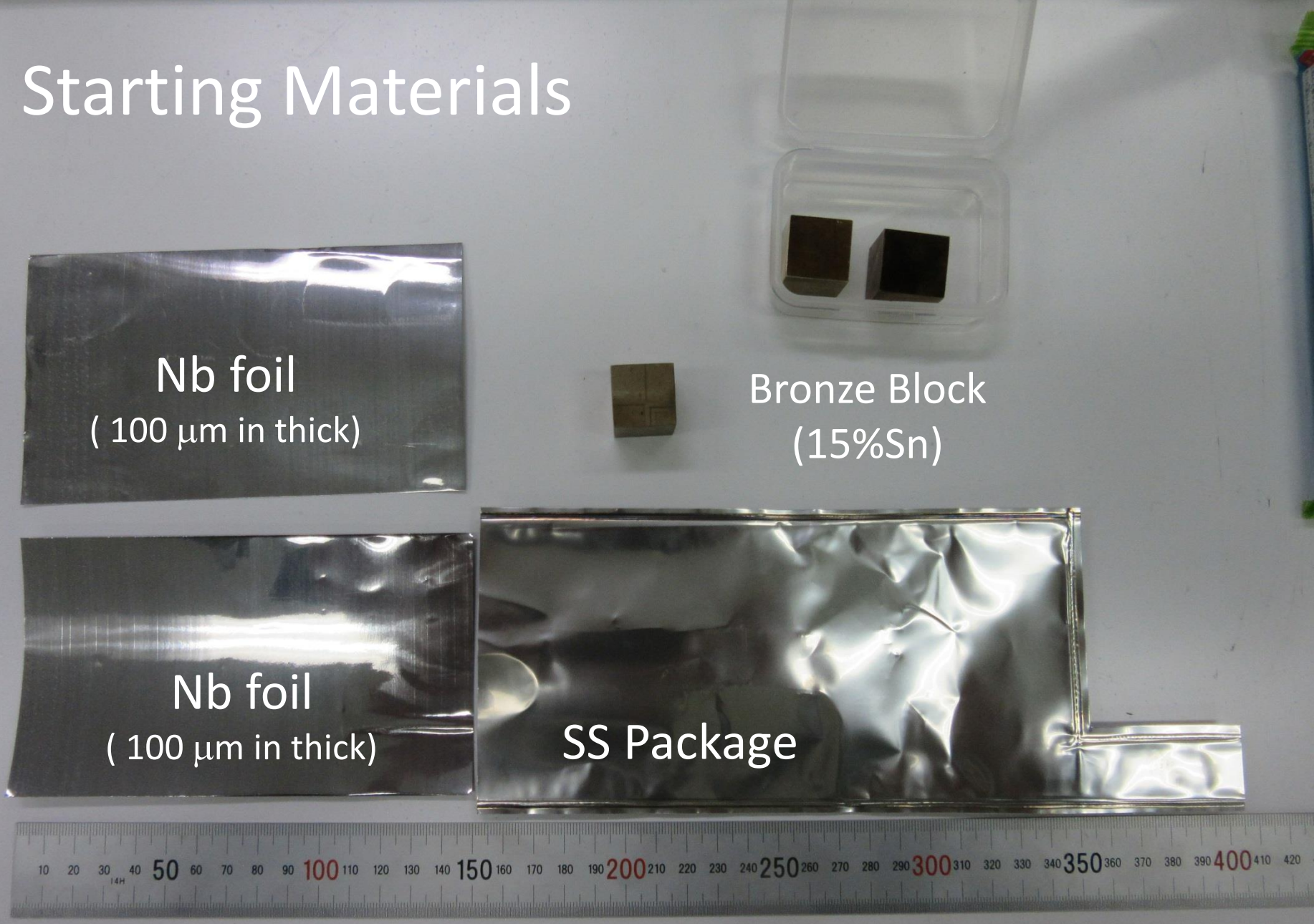
1. Combination of Hot Pressing and Cold Flat Rolling

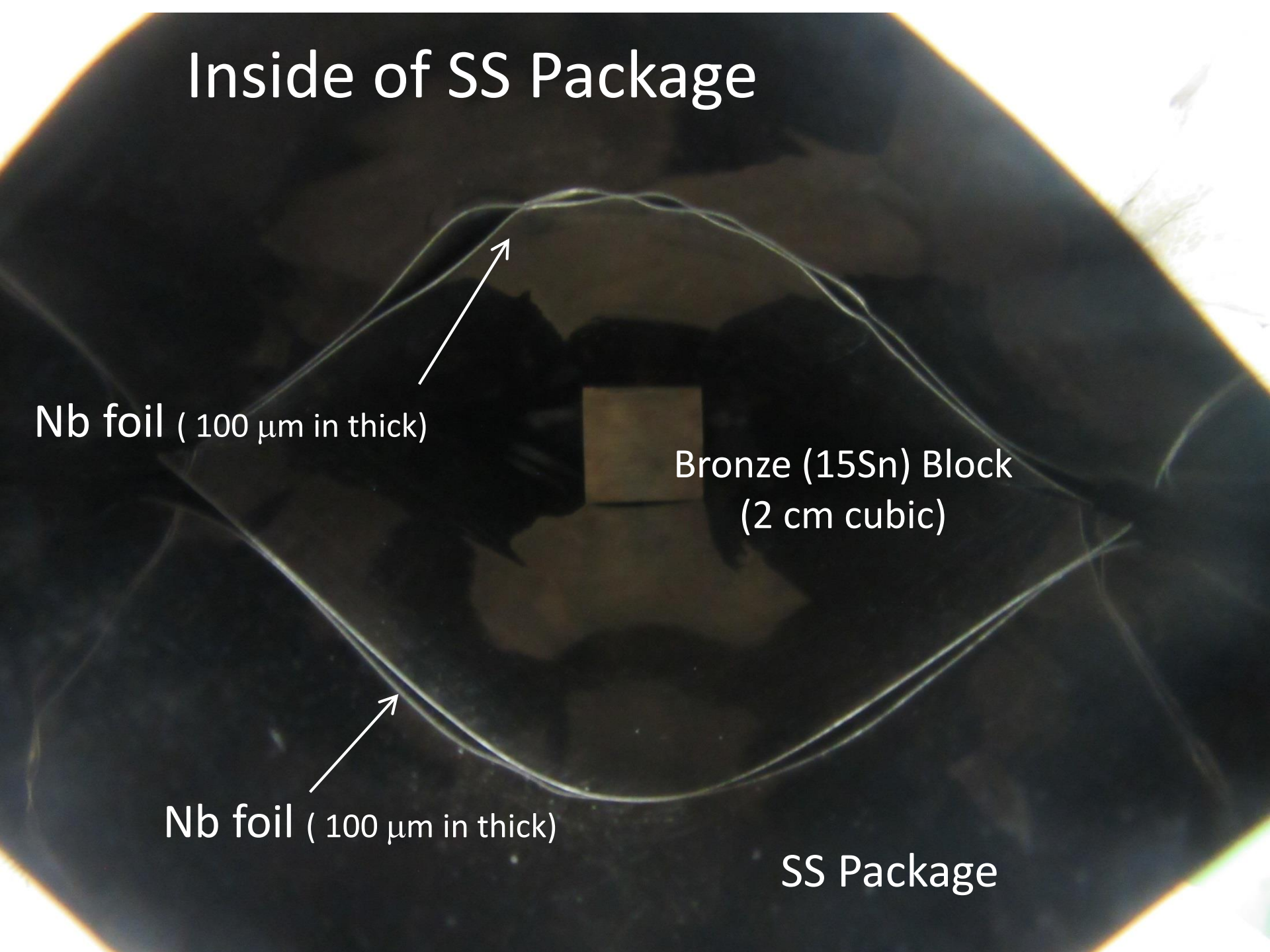
(Fabrication of Nb/Bronze Composite Plate)



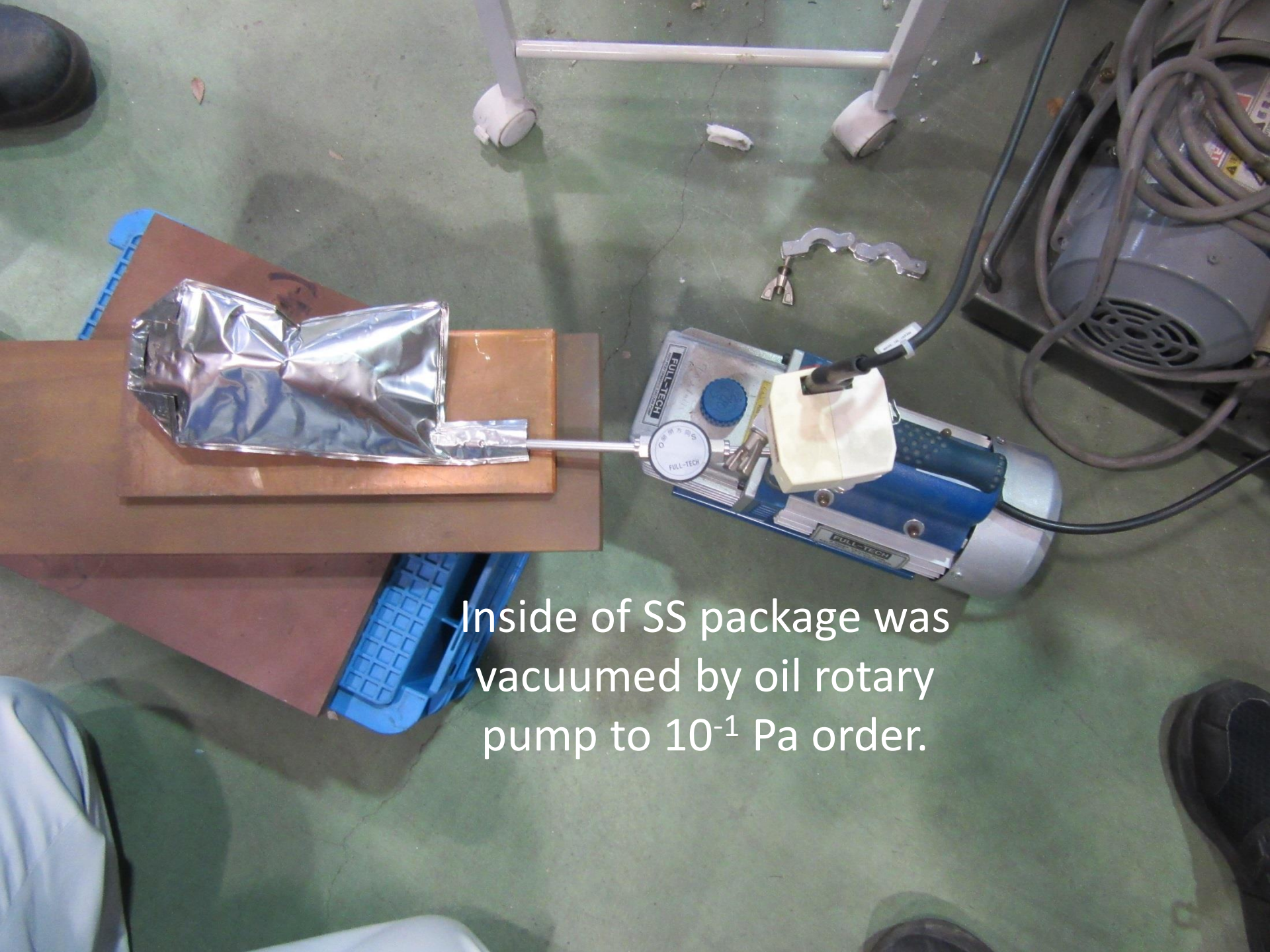
10 μm

Starting Materials




Inside of SS Package
Nb foil (100 μm in thick)
Bronze (15Sn) Block
(2 cm cubic)
Nb foil (100 μm in thick)
SS Package


The wide end of SS
package was sealed
by a spot welding .



Inside of SS package was vacuumed by oil rotary pump to 10^{-1} Pa order.

300 ton Press at NIMS

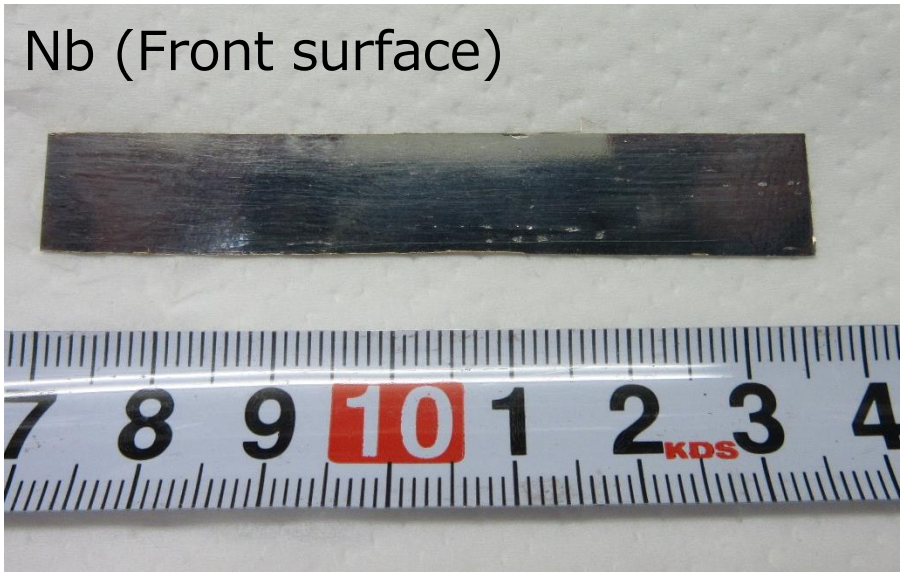
The Package was heated up to 720 ^{o}C before pressing

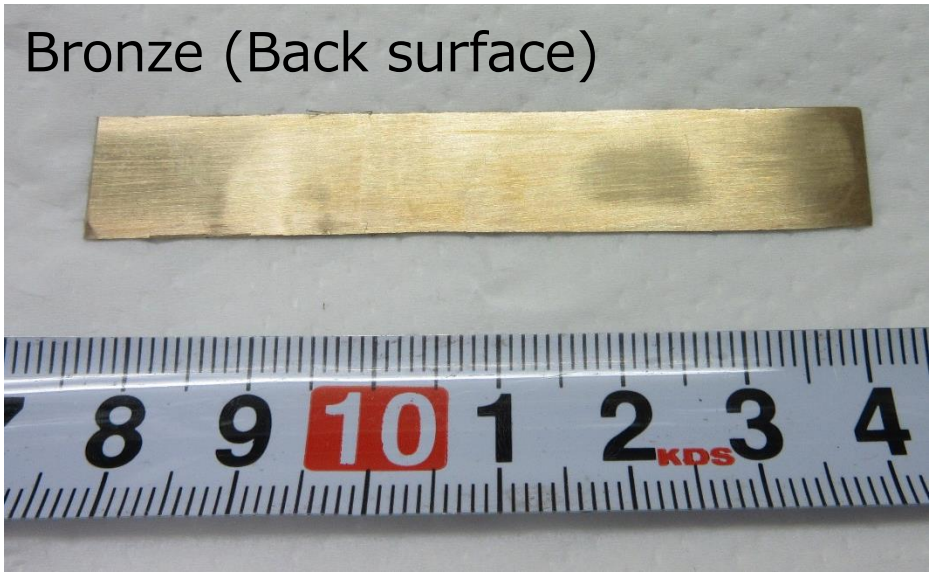
Cold Flat Rolling to Tape Shape

Cut to appropriate size

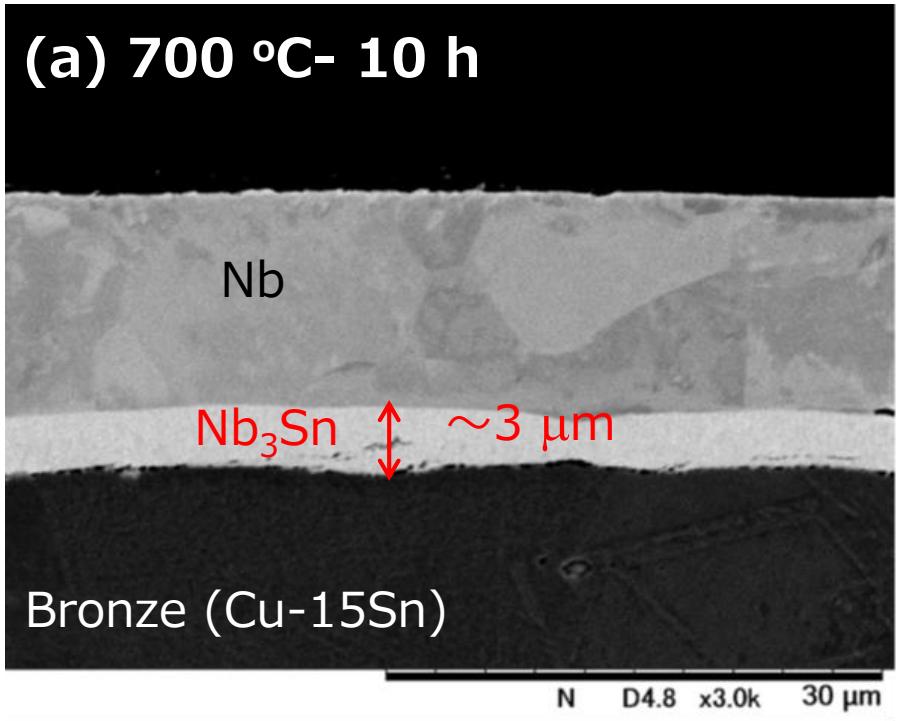
Flat rolling at room temperature

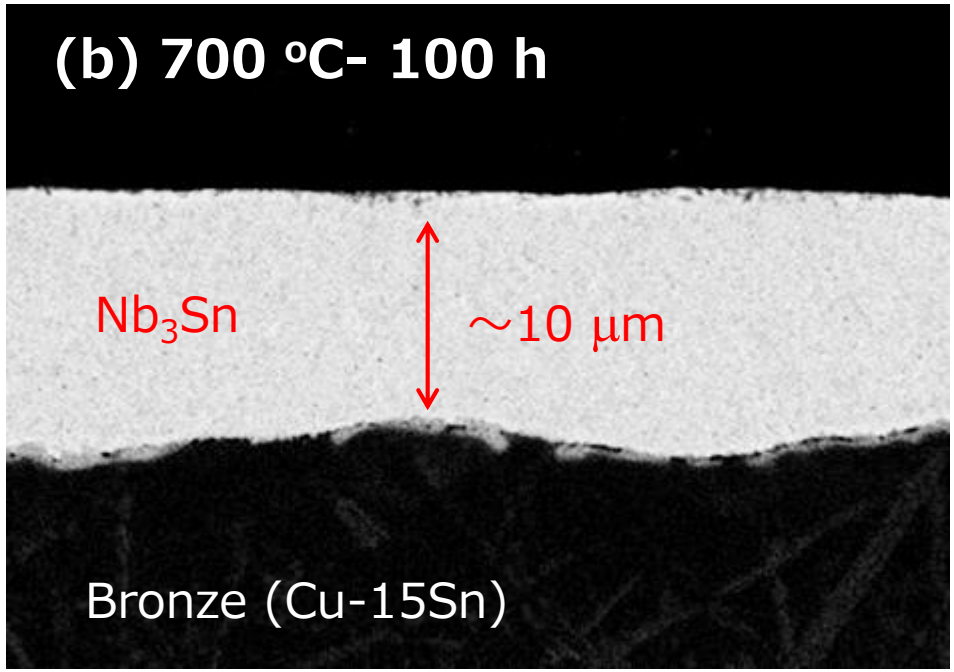
0.4 mm thick Nb/Bronze (Cu-15Sn) Clad Tape
- Appearance -





Heat Treatment for Nb_3Sn Formation

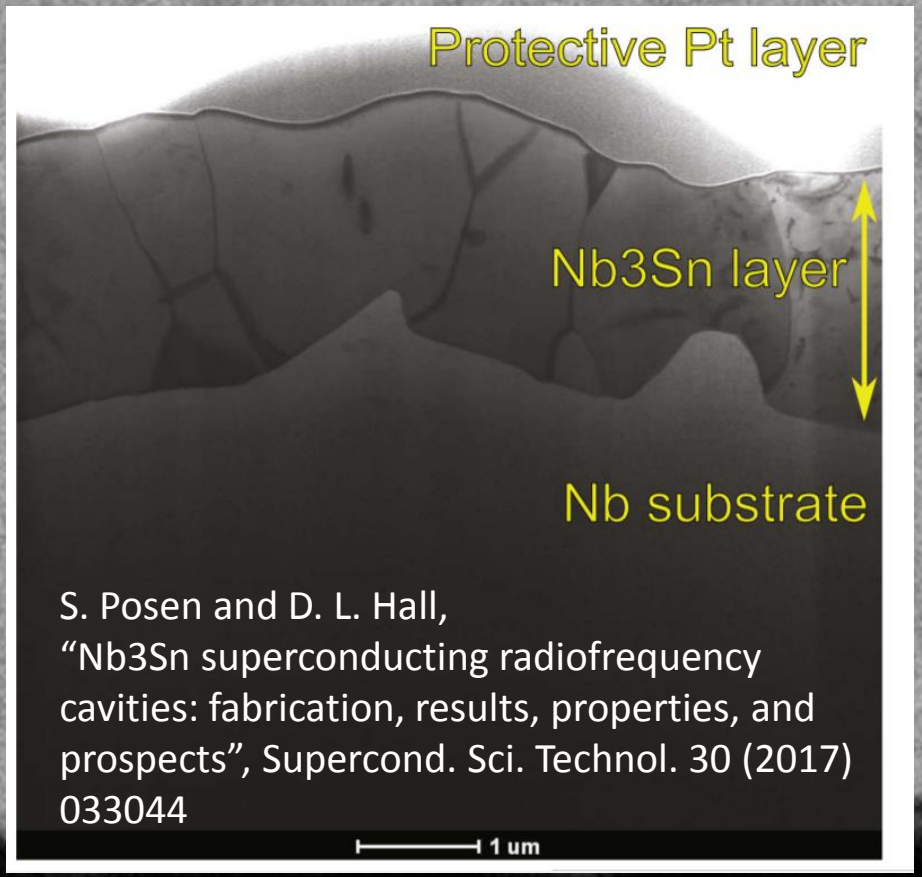




Small Grain Size and Uniform Microstructure

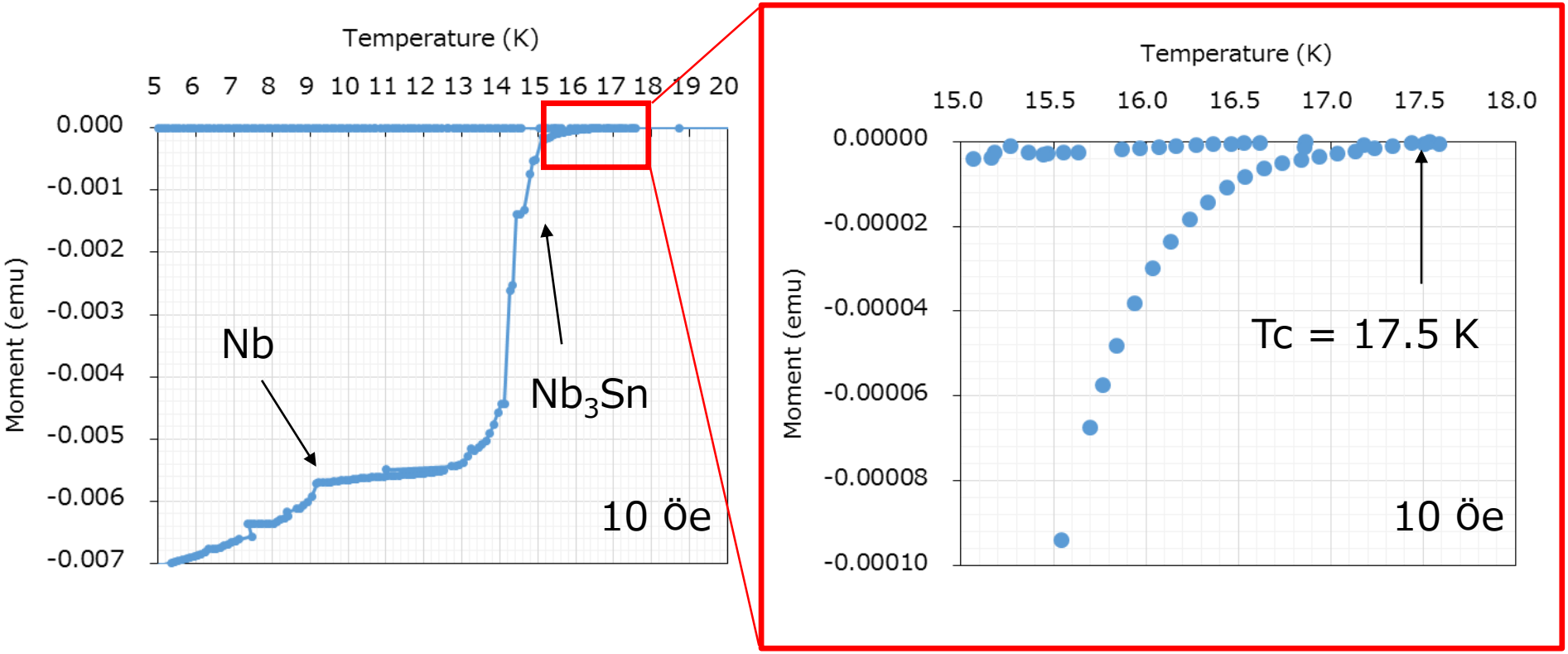
700 °C- 100 h

1 μm

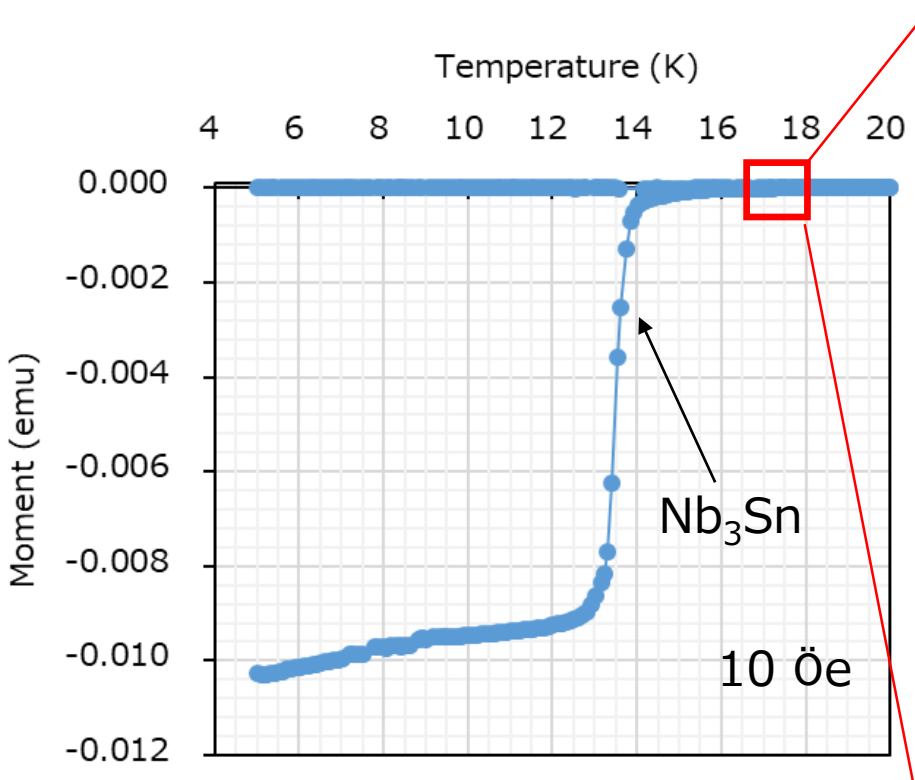


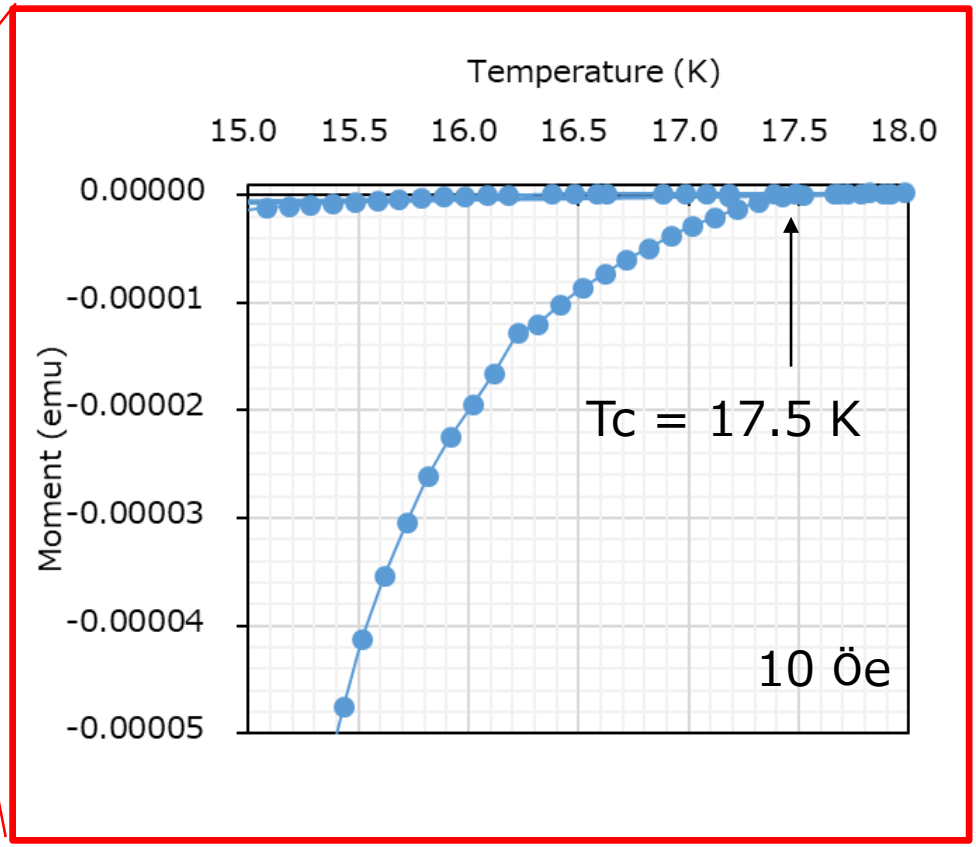
S. Posen and D. L. Hall,
"Nb3Sn superconducting radiofrequency cavities: fabrication, results, properties, and prospects", Supercond. Sci. Technol. 30 (2017) 033044

Partial Reacted at 700 °C for 10 h



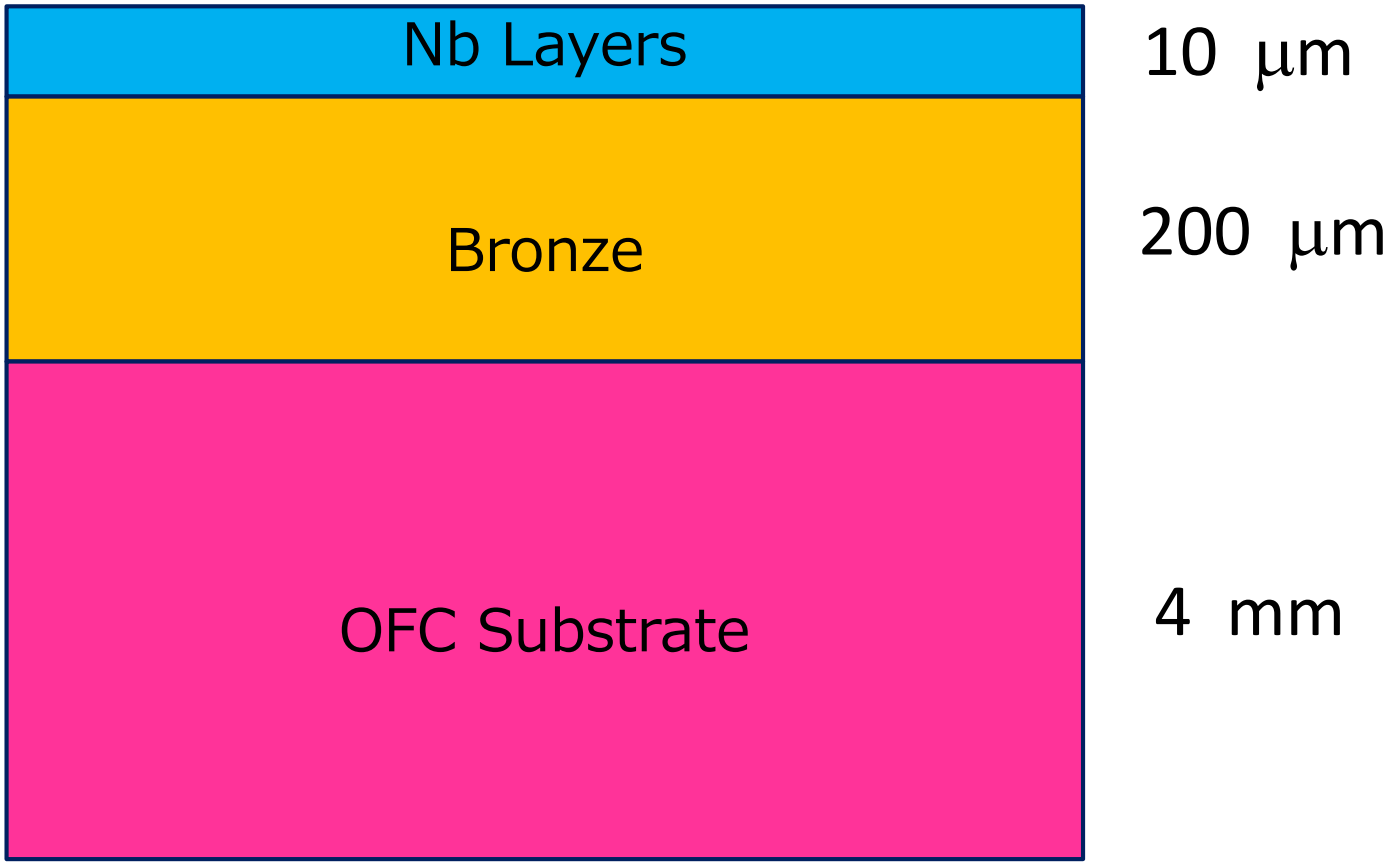
Full Reacted at 700 °C for 100 h



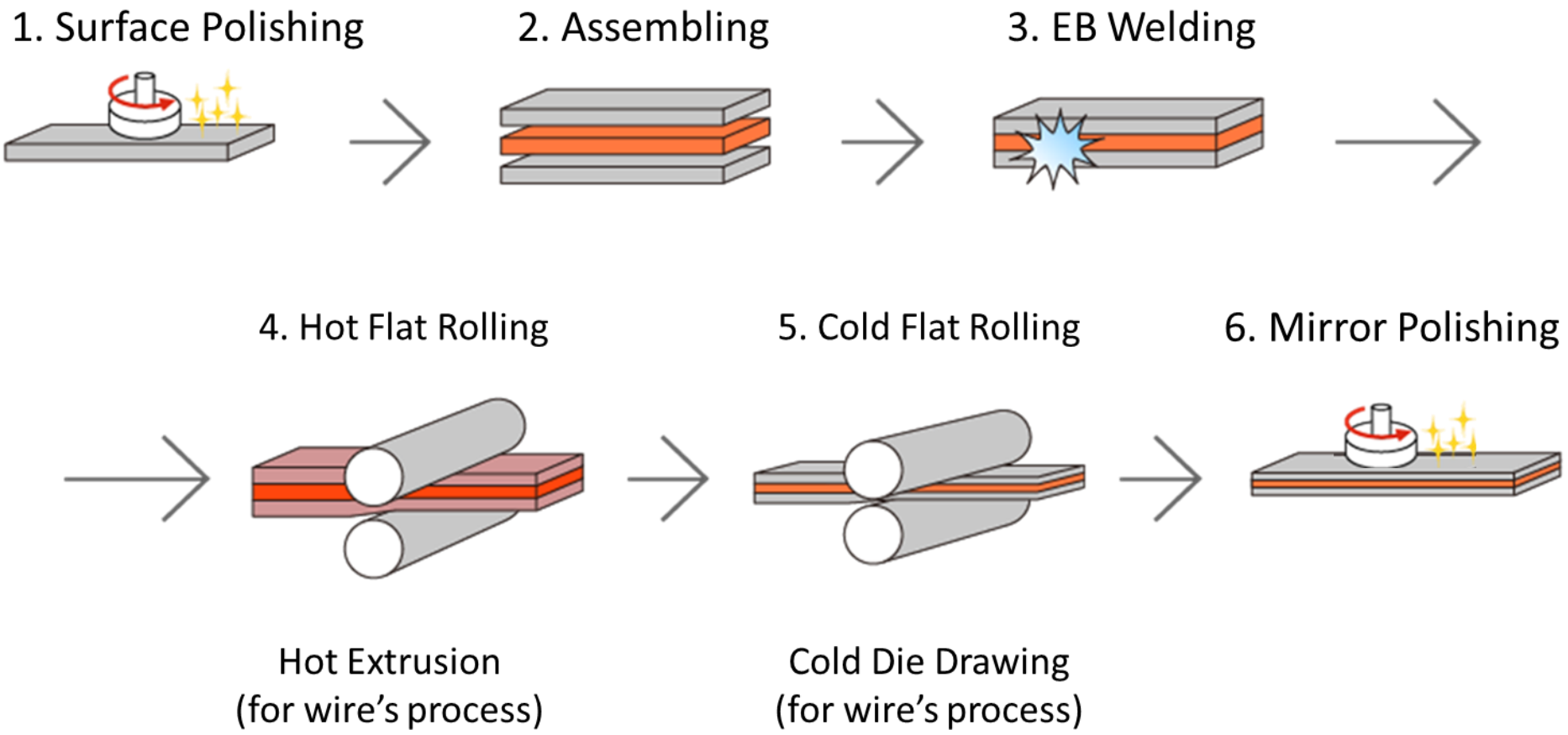


2. Combination of Hot Flat Rolling and Cold Flat Rolling

(Fabrication of Nb/Bronze/OFC Composite Plate)

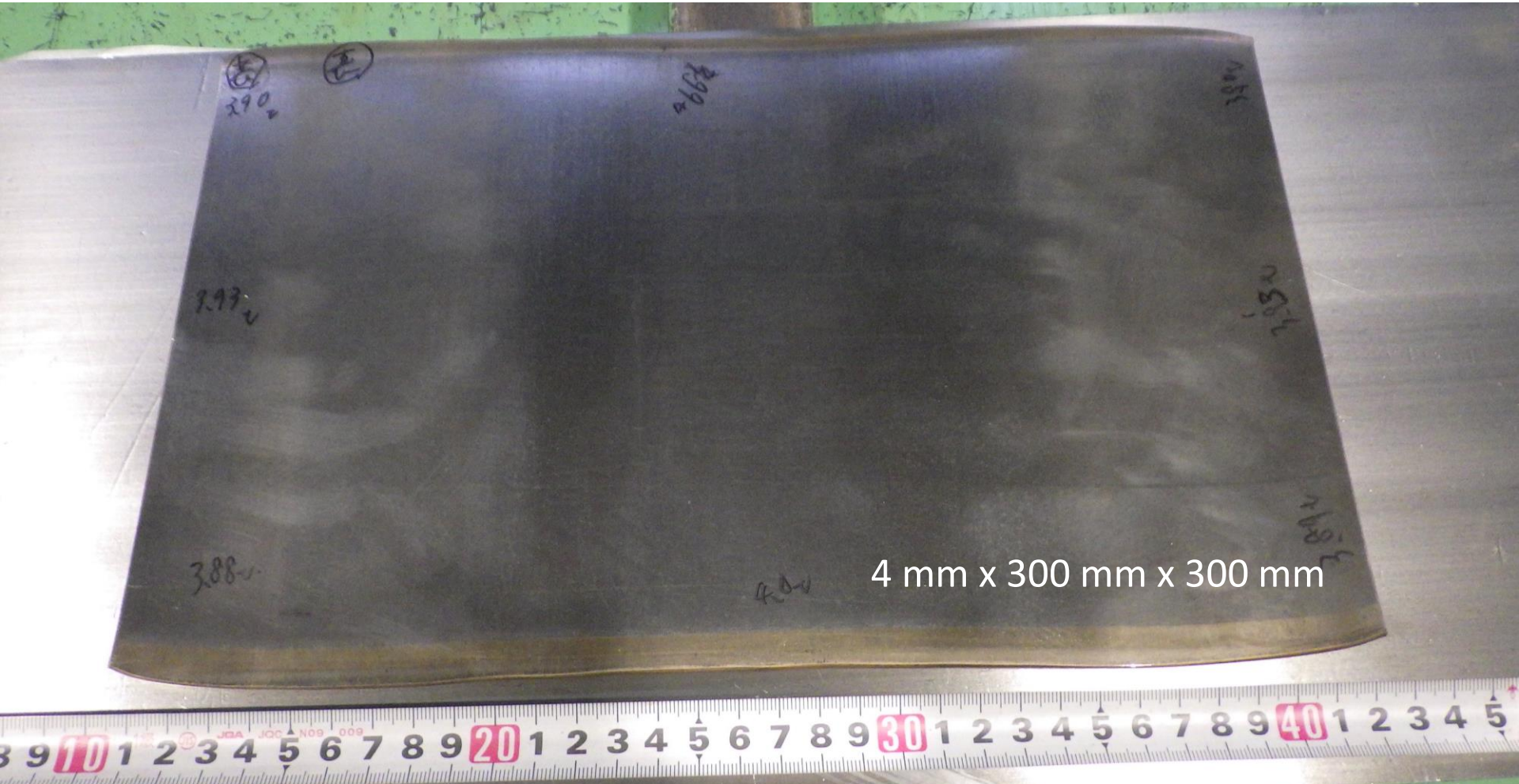


Production Scheme of Nb/Bronze/OFC Clad Plate

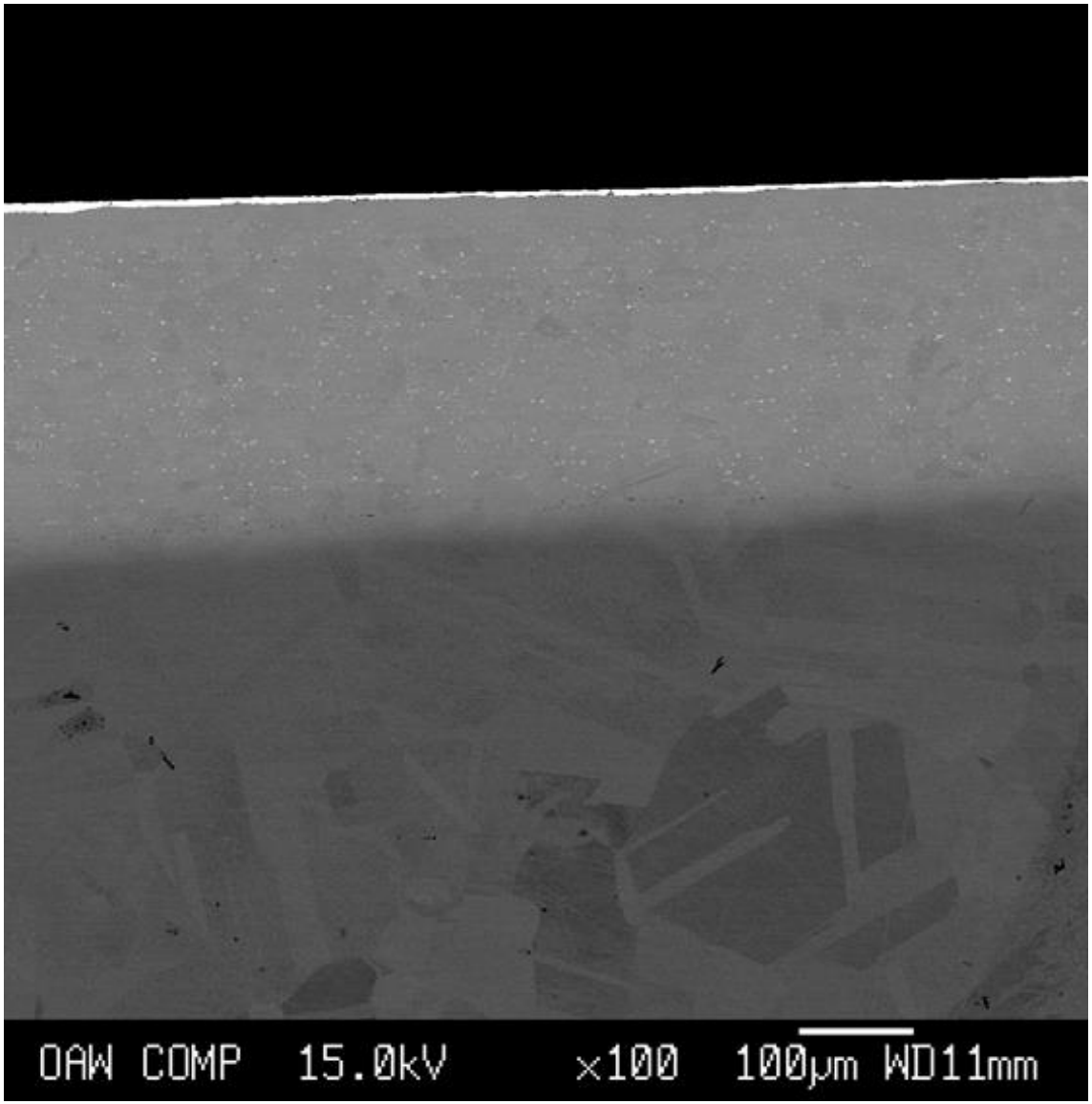


Hot Flat Rolling for Mechanical Cladding

4mm thick Nb/Bronze/OFC Clad Plate (Before Mirror Polishing)



Nb/Bronze/OFC Clad Plate



Nb (10 µm)

Bronze 14Sn (300 µm)

OFC (4 mm)

One estimation for Production of Cavity

Nb/Bronze/OFC
Clad Tube

Hydro-Forming for Cavity

Summary

- Nb/Bronze and Nb/Bronze/OFC composite plates could be fabricated by plastic deformation process, such as pressing and rolling.
- 10 microns thick and homogeneous Nb_3Sn layers were easily synthesized through a bronze route with a low temperature diffusion reaction at 650 – 750 ^{o}C.
- Nb_3Sn grain size (a few nm) is much smaller than that (a few microns) formed on the Sn vapor processed samples.
- Rs and other interesting measurements would be expected to perform by new collaborators in the near future.