NbCu Clad Cavities

Presented by W. Singer

Activities of DESY, KEK, JLab, INFN

advantages

- **fabrication technique**
- **performance**
- **remaining problems**

Fabrication of cavity from bimetallic bonded NbCu tube by seamless technique (spinning or hydroforming).

Combination of the seamless technique with NbCu bonding gives to bimetallic option new opportunity.

Advantages

• cost effective: allows saving a lot of Nb (ca. 4 mm cavity wall has only ca. 1 mm of Nb and 3 mm Cu). Especially significant for large projects like ILC

• bulk Nb microstructure and properties (the competing sputtering technique does not have such advantages)

• the treatment of the bulk Nb BCP, EP, annealing at 800°C, bake out at 150°C, HPR, HPP can be applied (excluding only post purification at 1400°C).

• high thermal conductivity of Cu helps for thermal stabilization

• stiffening against Lorentz - force detuning and microphonics can be easily done by increasing of the thickness of Cu layer.

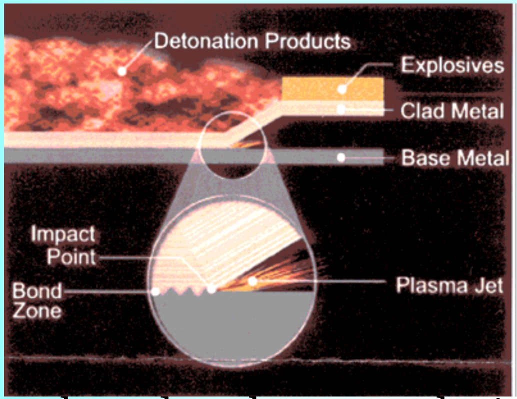
• fabrication by seamless technique allows elimination of the critical for the performance welds especially on equator

Fabrication of bimetallic NbCu tubes. Two options considered.

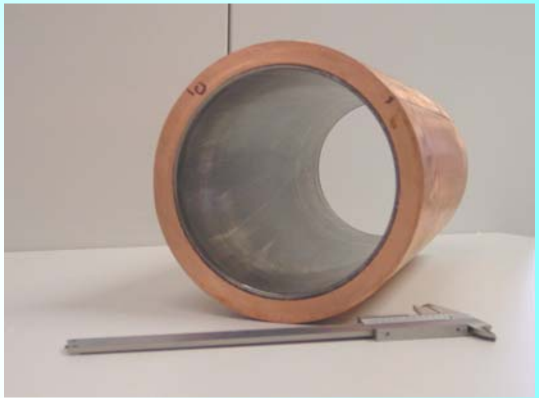
Explosively bonded NbCu tubes:

-Explosive bonding of seamless Nb tube ca. 4 mm wall thickness (RRR=250) with Cu tube of wall thickness 12 mm

- Flow forming into NbCu tube, wall thickness ca. 1mm Nb, 3 mm Cu



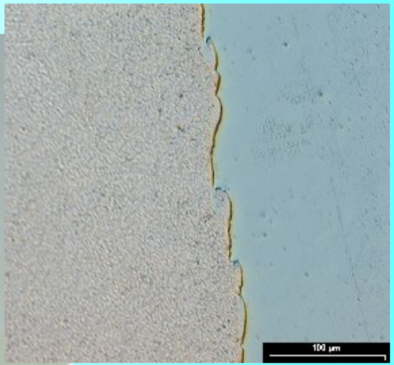
The bonding takes place by an explosively driven, high-velocity angular impact of two metal surfaces.



Explosively bonded NbCu tube

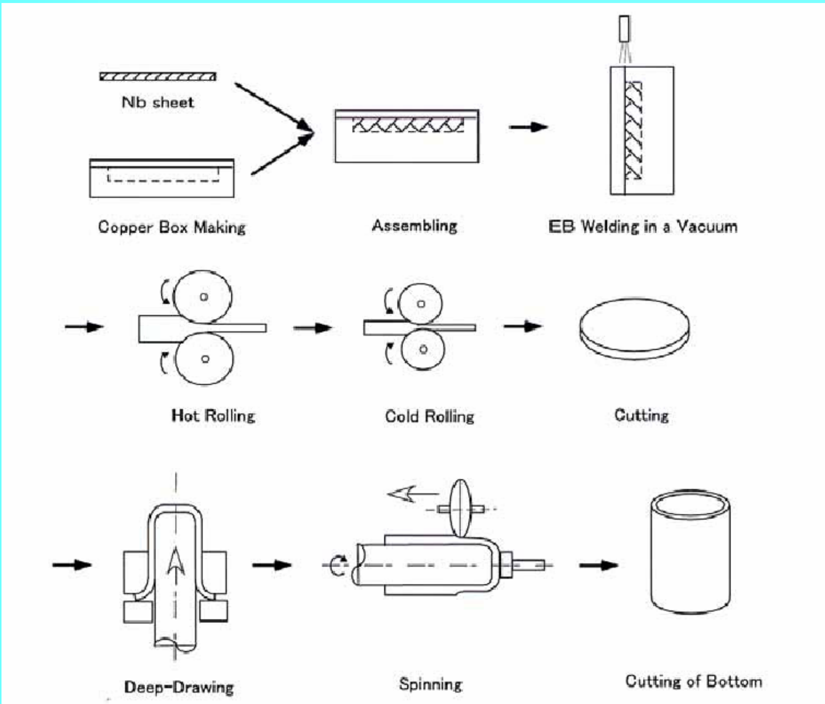
Flow forming of NbCu tube

After flow forming



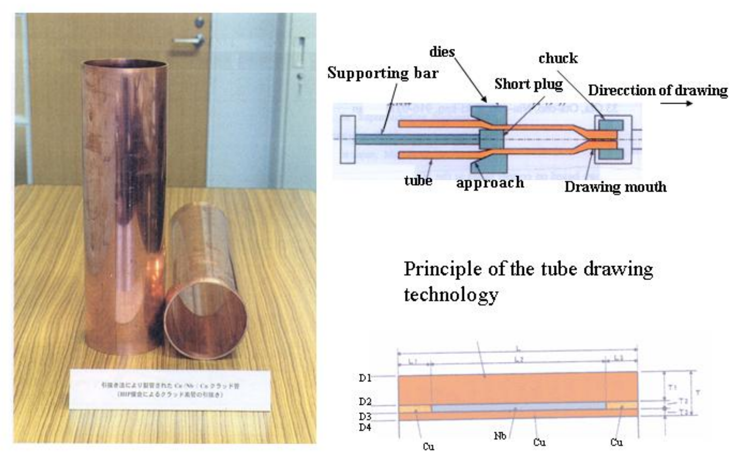
Structure of Nb/Cu interface

• Hot bonded NbCu tubes



Fabrication principle of sandwiched hot rolled Cu-Nb-Cu tube (KEK and Nippon Steel Co.)

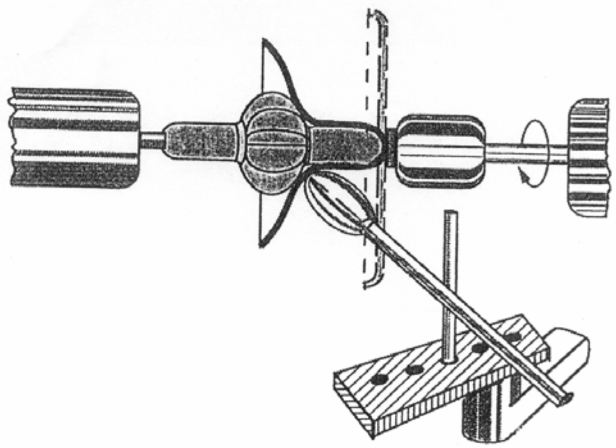
Hot roll bonded Cu-Nb-Cu tube produced at Nippon Steel Co.



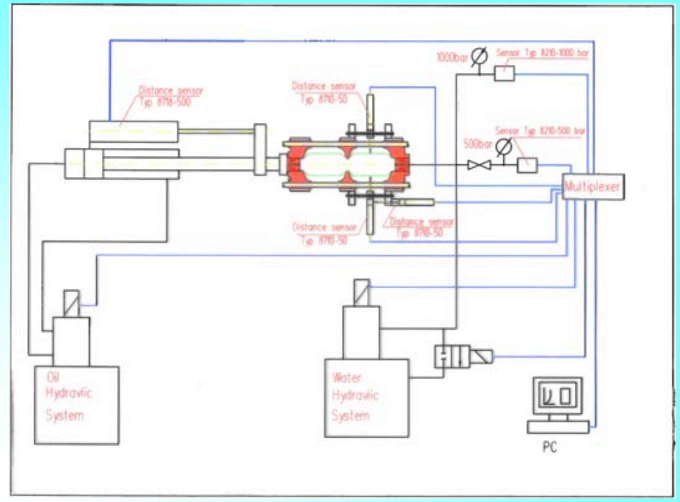
Cu-Nb-Cu Sandwiched Tubes (KEK)

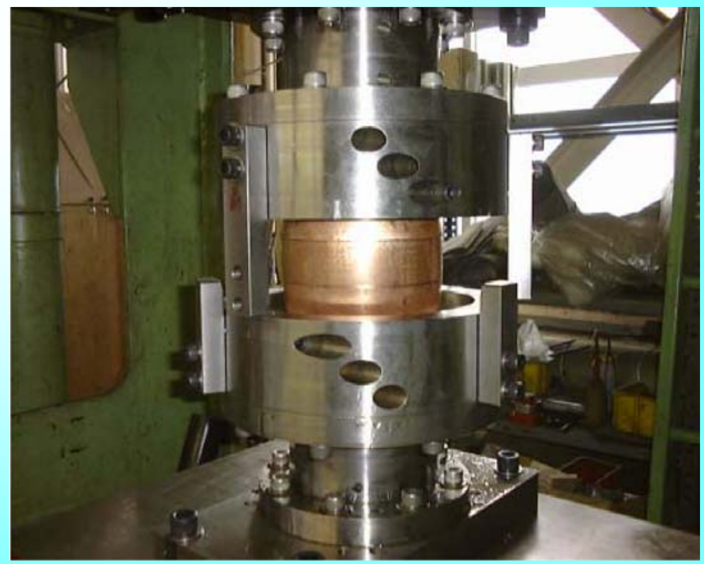
Fabrication principle of sandwiched coextruded Cu-Nb-Cu tube (KEK)

Spinning (V.Palmieri,INFN Legnaro)

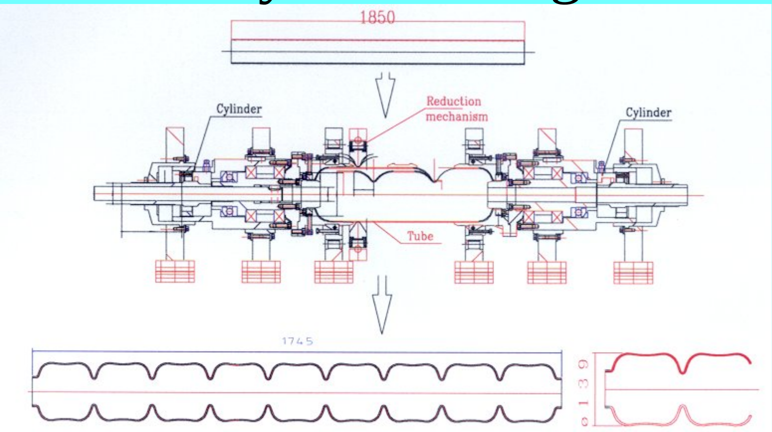


Hydroforming, DESY, KEK

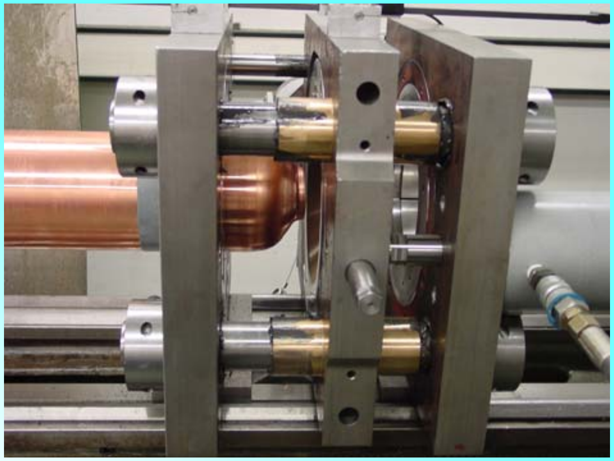




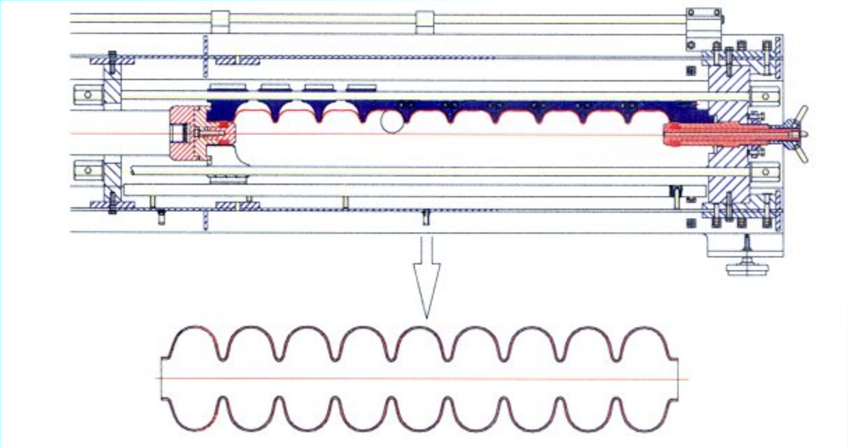
Hydroforming technique



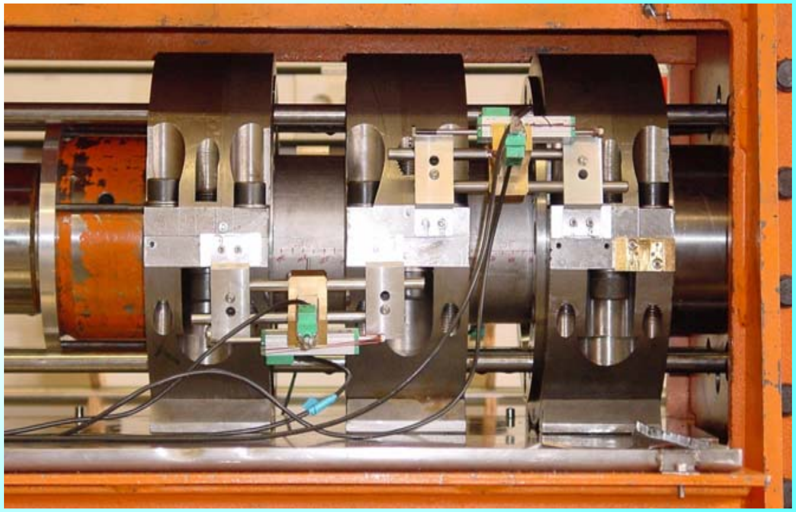
Principle of tube diameter reduction in the iris area



Reduction mechanism.



Principle of the tube expansion in the equator region



Heart of hydroforming machine

Forming of cells in two steps without intermediate annealing

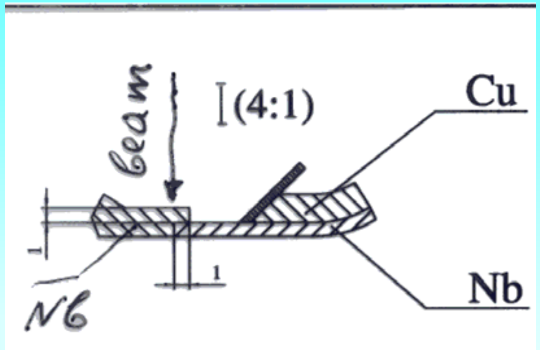
a) reduction of diameters at ends of tubes and iris areas

b) tube expansion at the equator

Single cell NbCu cavities produced at DESY by hydroforming from KEK sandwiched tube.

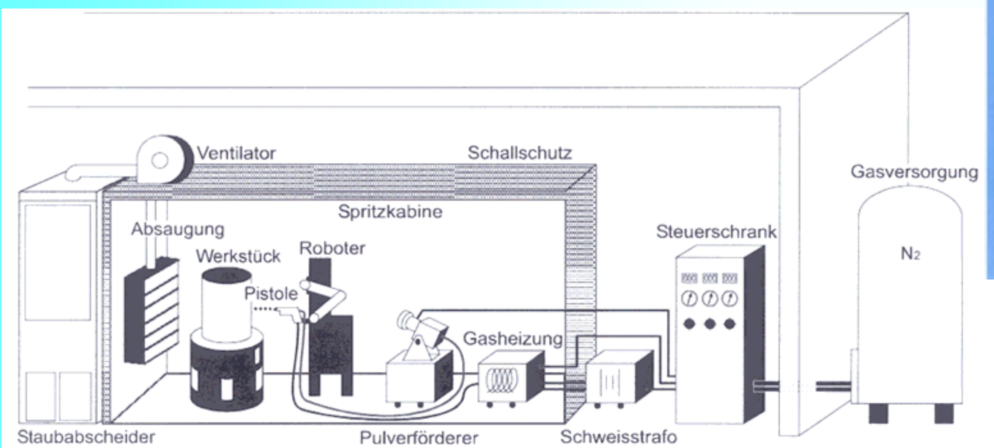
NbCu cavities hydroformed from explosively bonded tubes at DESY.

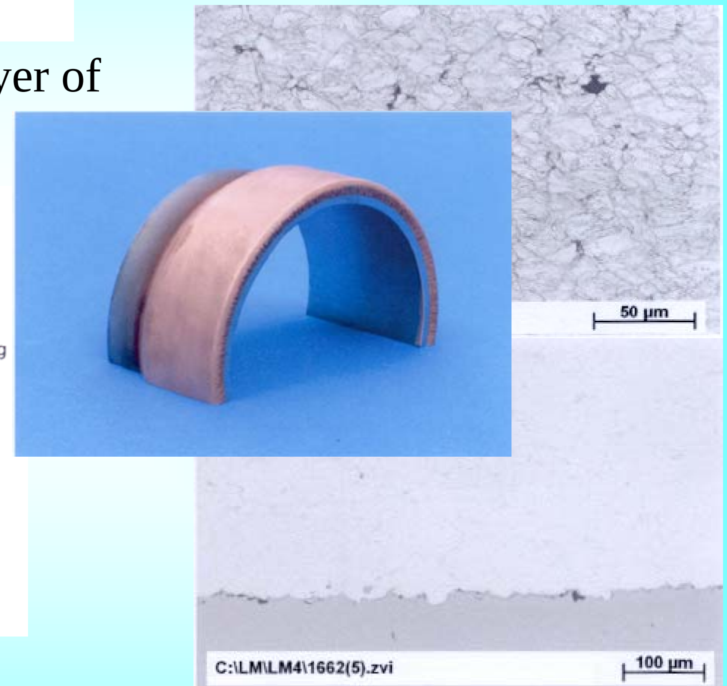
Connection of end tubes to NbCu cells



Cu layer on Nb tube. Small purity degradation of Nb during spraying: from RRR=300 to RRR=250

Principle of the welding of 0,7-1 mm thick Nb layer of the cavity with 2 mm thick wall of Nb end tube.



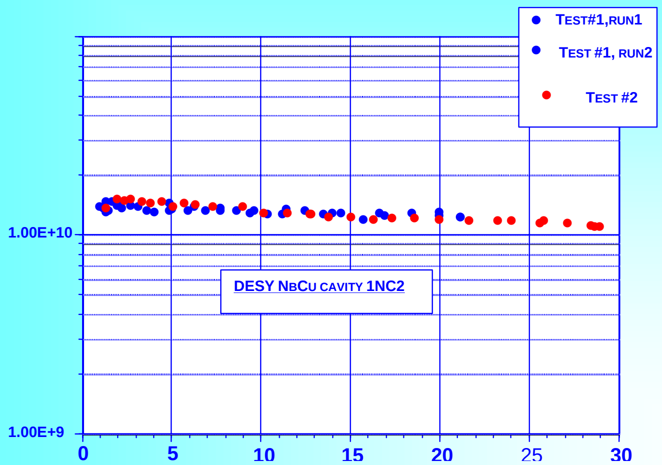


New Cold Gas Dynamic Spray System. Warms up the particles by only ca. 300°C and accelerate to velocities of 600-1500m/s (H.Kreye, University of the Federal Armed Forces in Hamburg)

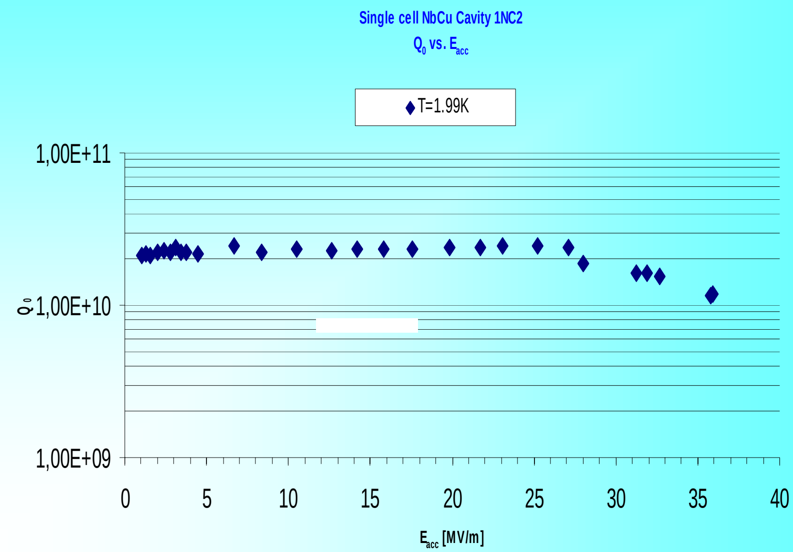
Microstructure of CGDS Cu coating on Nb, small porosity ca. 1%, small oxidation. electr. conduct. ca.80% of bulk Cu (top: spraying by Nitrogen, bottom- by Helium)

Performance:

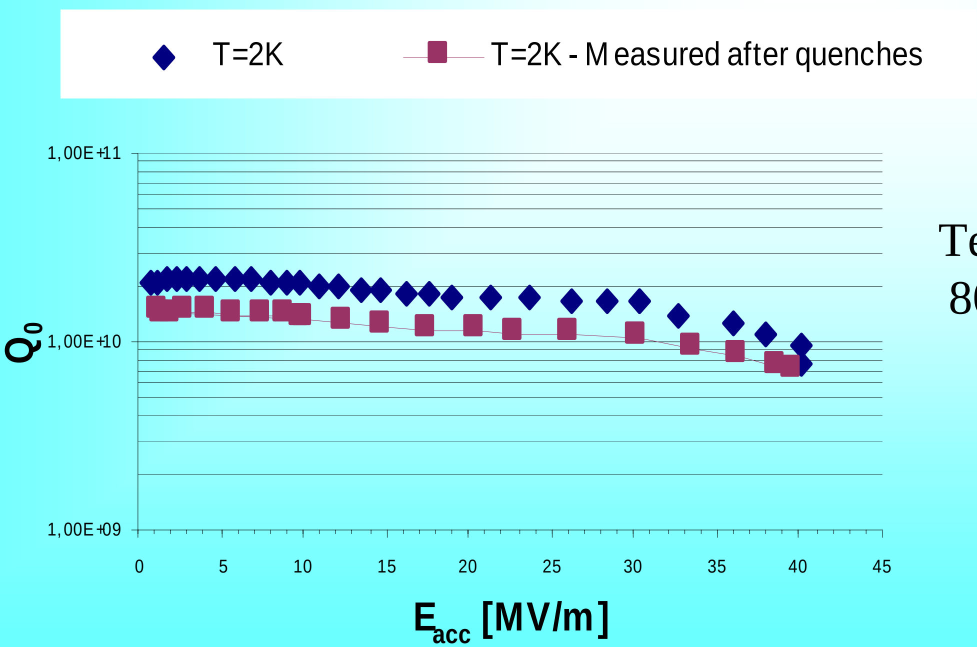
NbCu single cell cavity 1NC2 produced at DESY by hydroforming. Preparation and HF test P.Kneisel (JLab)



Test 1- after 90µm BCP, test 2- add. 80µm BCP.

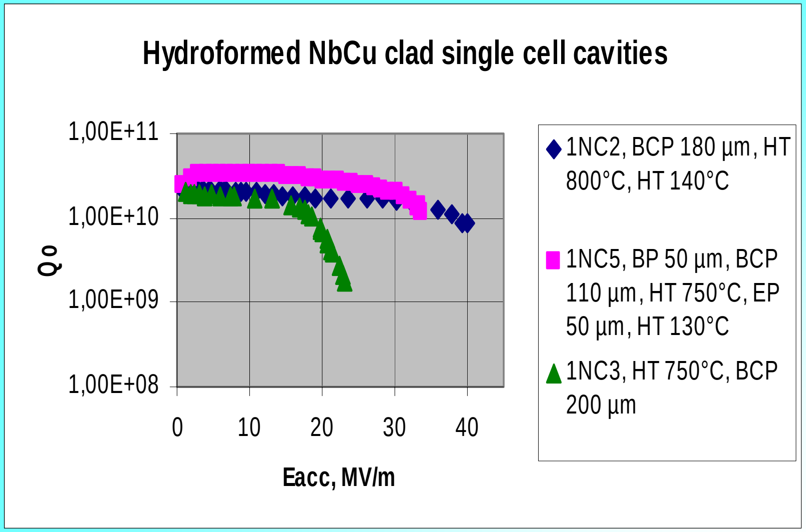


Tests 4 and 5 after 180 µm BCP, annealing at 800°C



Test 6 after 180 µm BCP, annealing at 800°C, baking at 140°C for 30 hours, HPR.

40 MV/m without EP

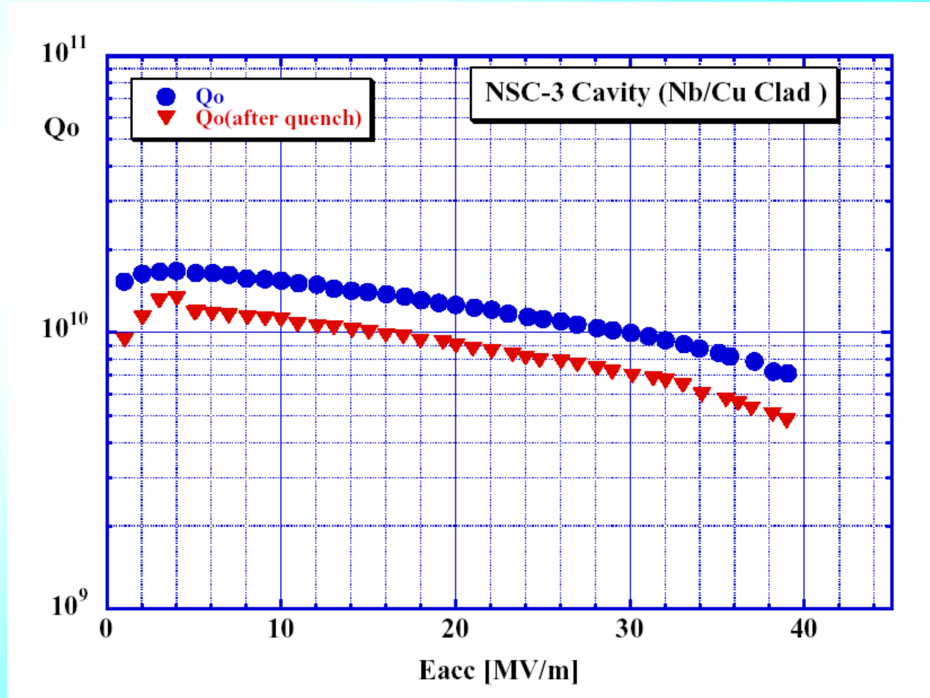


Summary of HF tests on 1NC2-1NC5 explosively bonded single cell cavities. Preparation and RF tests at JLab, KEK, DESY. 1NC4 destroyed during EP

Not enough statistic for comparison of explosive bonding and hot bonding. Quality of hot bonding is more reliable; better statistic is to expect

Up to now only one NbCu sandwiched cavity was tested NSC-3.

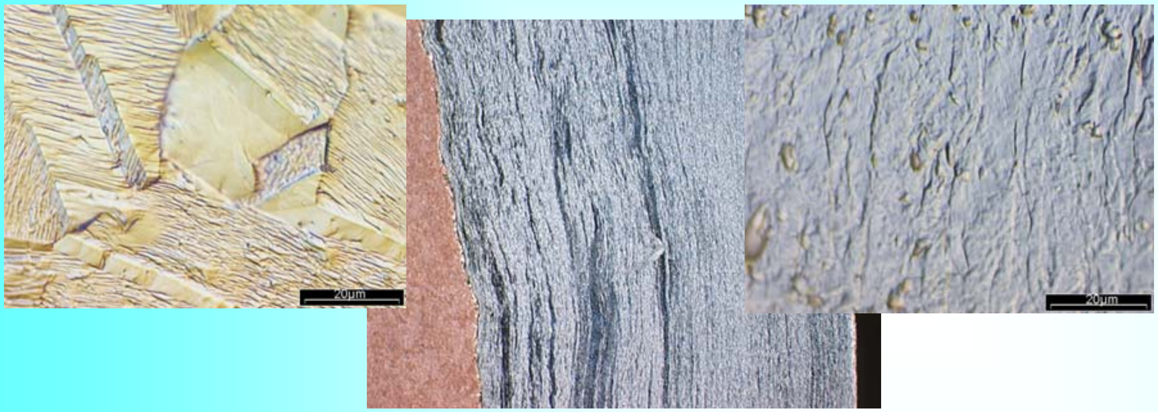
Hot roll bonded tube fabrication at Nippon Steel Co., hydroforming at DESY, Preparation and RF tests at KEK



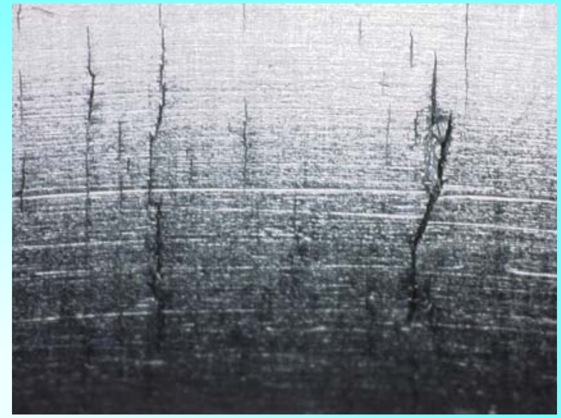
NSC-3: Barrel polishing, CP(10microns), Annealing 750^{o}C x 3h, EP(70microns) by K.Saito

Remaining problems in NbCu technology

1. Fabrication difficulties: **Dangerous of cracks creating in iris area during fabrication (because of big difference in recrystallization temperature of Nb and Cu)**



Microstructure of Cu and Nb after annealing at 560°C for 2 hours. Nb is not recrystallysed (hard).



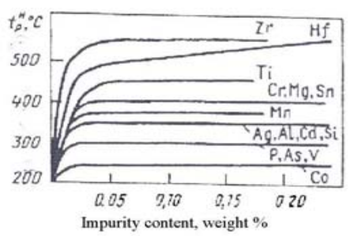
Example of cracks at iris area after hydroforming

Possible solutions:

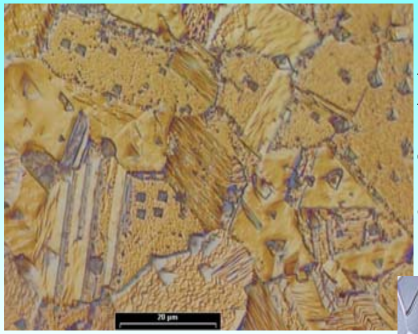
a) Forming of the sandwiched tube (Nb is between two Cu layers. Cu layer on both sides prevent creating of cracks in Nb); removing of inside Cu layer on the cavity after forming (K.Saito). The option was checked, it works

Possible solutions

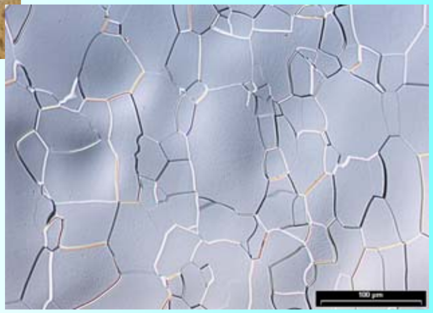
b) using special Cu with high recrystallization temperature



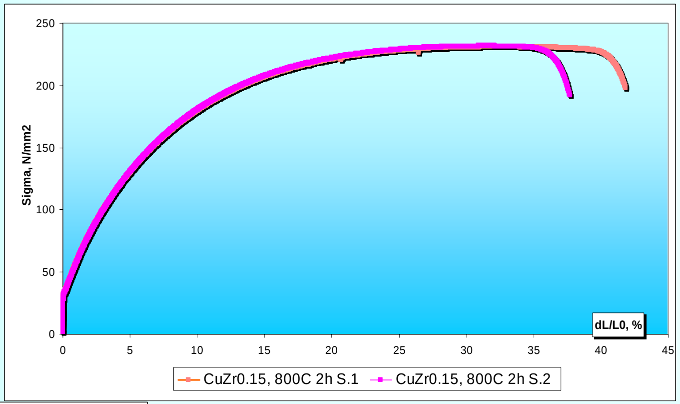
Small additions of some metals (Zr, Hf, Ti, Cr, Mg, Sn, Mn, Al) allow to increase the recrystallization temperature of Cu.



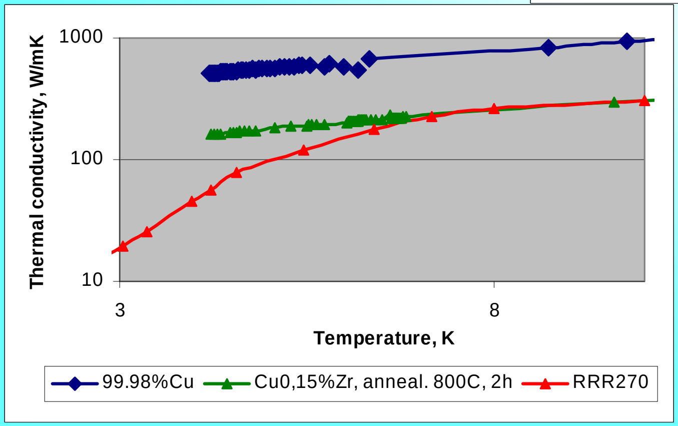
Microstructure of Cu0.15%Zr and Nb after annealing at 800°C for 2 hours.



Stress –strain behavior and thermal conductivity of Cu0,15%Zr after annealing at 800°C for 2 hours compared with Cu and Nb.



The Cu0.15%Zr shows a high elongation after annealing at 800°C, small and rather uniform grain and can be a good candidate for replacing of pure Cu in NbCu clad tubes

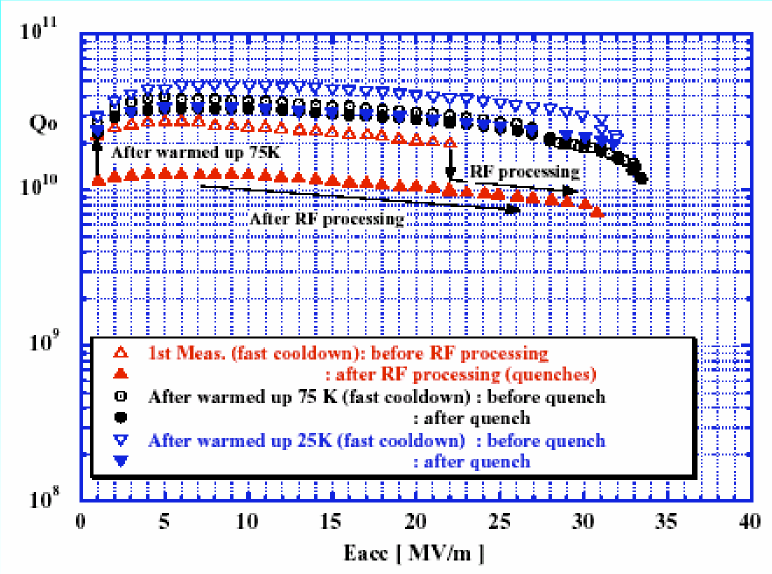


Thermal conductivity can be recovered by aging at ca. 400°C/one hour. Zr lived the solid solution and creates precipitates Cu_5Zr finely distributed in Cu matrix

2. Q degradation during fast cool down, RF processing or quench (trapping of magnetic flax caused by thermo - coupling effect).

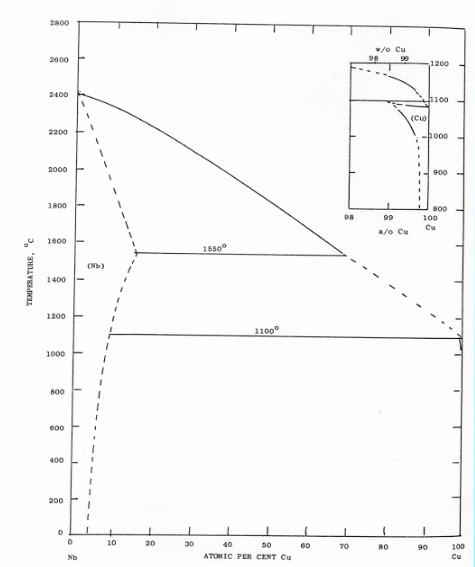
• Is not completely understood, more work is necessary. Similar effect was observed on Nb_3Sn cavities (M.Peiniger). Similar effect is to expect in sputtered NbCu cavities.

• The Q degradation is relatively moderate especially for rather thick Nb layers of ca. 1 mm thickness (less than one order of magnitude). Can be cured by warm up over Tc and slow cool down.

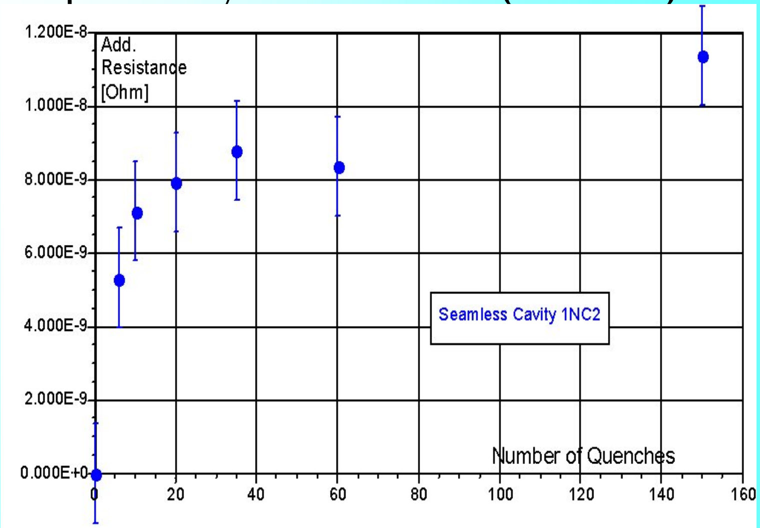


Q degradation in a seam less single cell cavity from NbCu explosively bonded tube (K.Saito)

• It seems that annealing and hot bonding (due to diffusion) should contribute to reduction of the thermal coupling effect



NbCu phase diagram



Additional surface resistance after quenches at ca 40 MV/m (P.Kneisel)

Conclusive remarks

- Performance of bonded NbCu cavities is similar to bulk Nb cavities.
- Best cavities have the same limit as bulk Nb (Eacc up to 40 MV/m) what is much better compare to NbCu sputtered cavities.
- Big variety of cavity shapes can be produced by the technique (for example cavities of reentrant shape)
- More work should be done to defeat the thermo-coupling effect