

R&Ds in Asia on Large/Single Crystal Niobium after the International Niobium Workshop 2006

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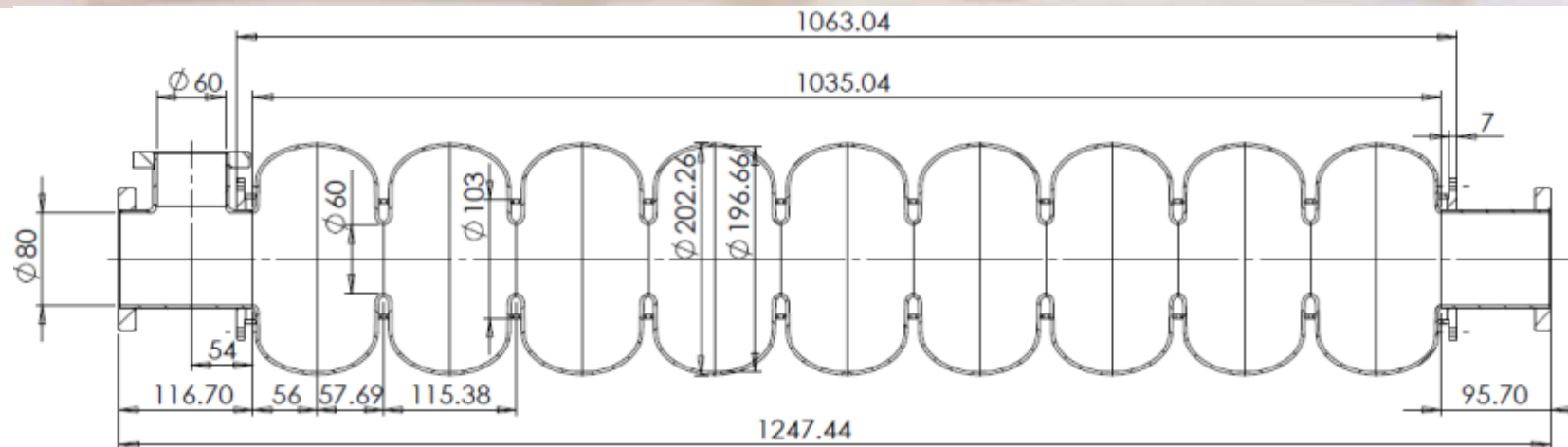
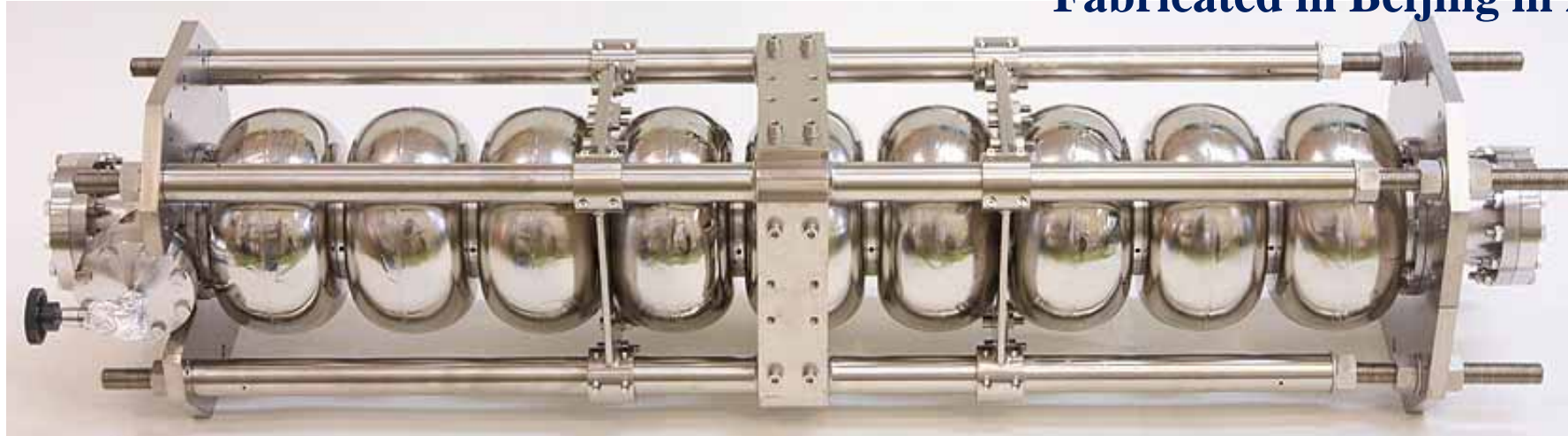
**A:KEK, B: Tokyo Denkai (TD), C:IHEP,
D: Beijing University (PKU), E: Jlab**

- IHEP/PKU (China) R&D**
- KEK/Tokyo Denkai (Japan) R&D**
- Summary**

IHEP/PKU China Activities

IHEP Large Grain 9-cell Cavity – IHEP01

Fabricated in Beijing in 2009



- **Ningxia large grain niobium**
- **Low loss shape**
- **Dumbbell and cavity frequency and length control method same with DESY**

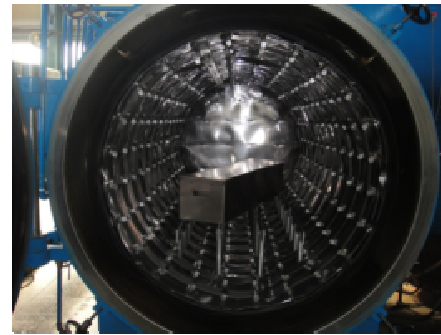
Surface Treatment and Pretuning



CBP



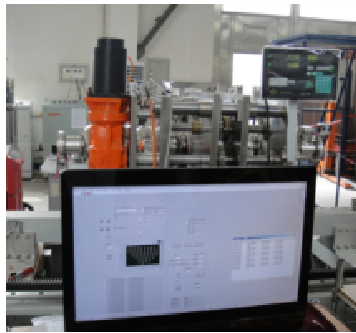
1st BCP



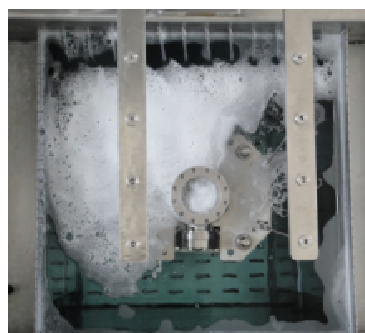
Annealing

Processed and pre-tuned with the SRF facilities developed in IHEP:

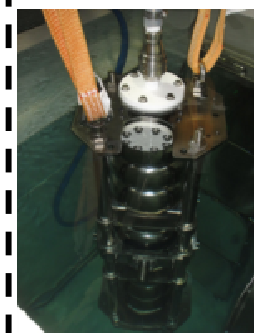
- CBP (tumbling) machine
- Vertical BCP System
- Pre-tuning machine
- Large ultrasonic cleaner



Pre-tuning & 2nd BCP



Ultrasonic Cleaning (at IHEP & KEK)



Field Flatness:

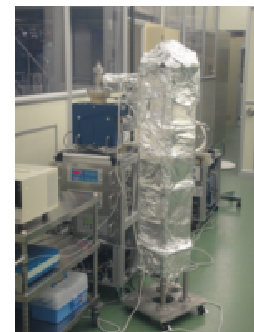
- As delivered: 70 %
- After pre-tuning: 97.6 %
- After jig fitting: 94 %
- After 1st VT: 90 %



HPR



Assembly and Pumping



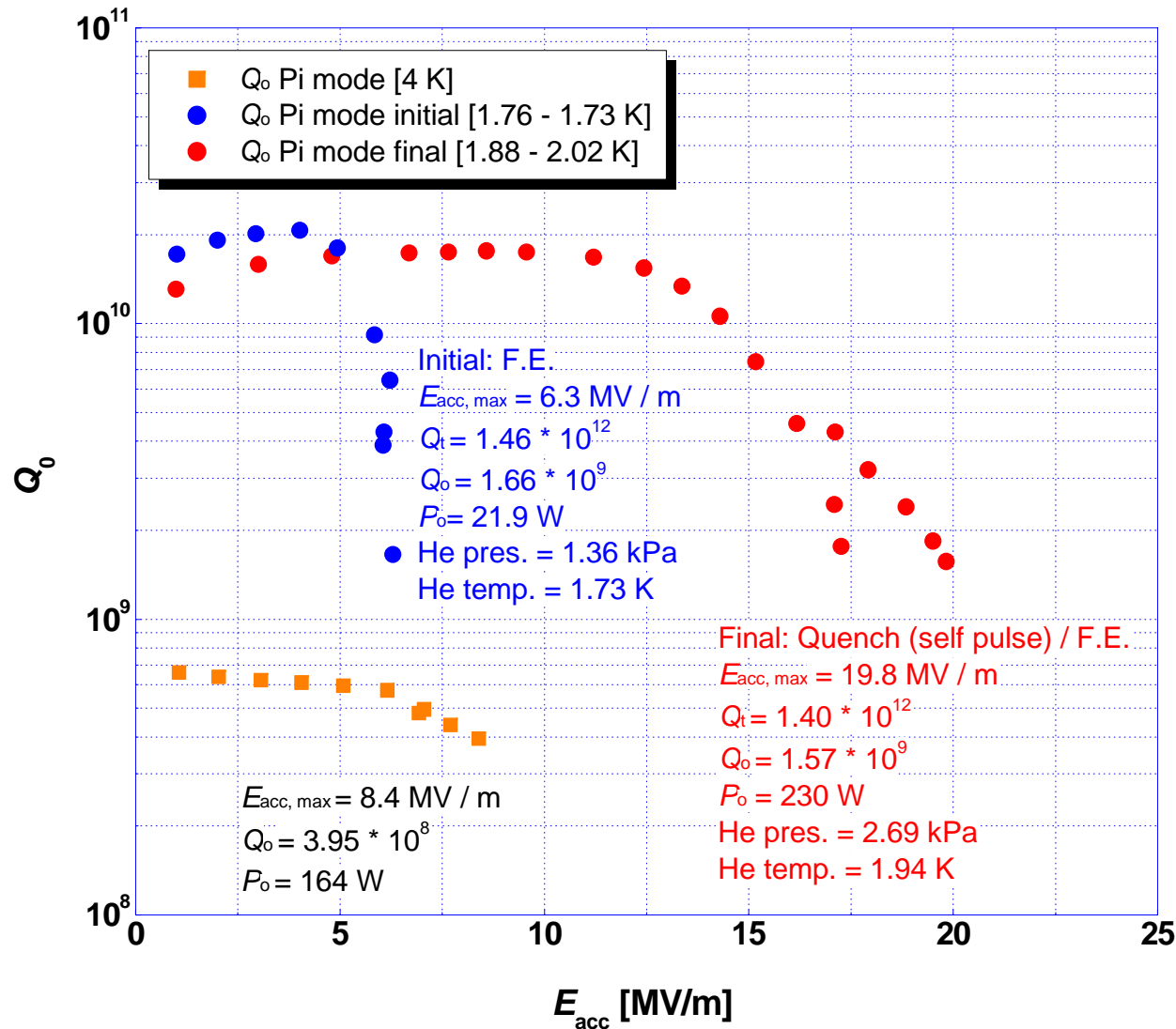
Baking

First Vertical Test Result

IHEP-01 Large Grain Low Loss 9-cell Cavity (without HOM couplers)

1st Vertical Test, July 1, 2010

CBP (190 μm), BCP (110 μm), Annealing (750°C, 3 h), Pretuning (94 %), Ultrasonic (Micro-90 2%, 50°C, 3 h), BCP (20 μm), Ultrasonic (UPW), Low Pressure Rinsing @ IHEP
Ultrasonic (Liquinox 2%, 43°C, 3 h), HPR (8.5 h), Baking (105°C, 48 h), VT @ KEK



Tested at KEK STF

- pumping during VT
- Bad vacuum**
- 2~5E-7 Pa
- one order of magnitude worse than normal case

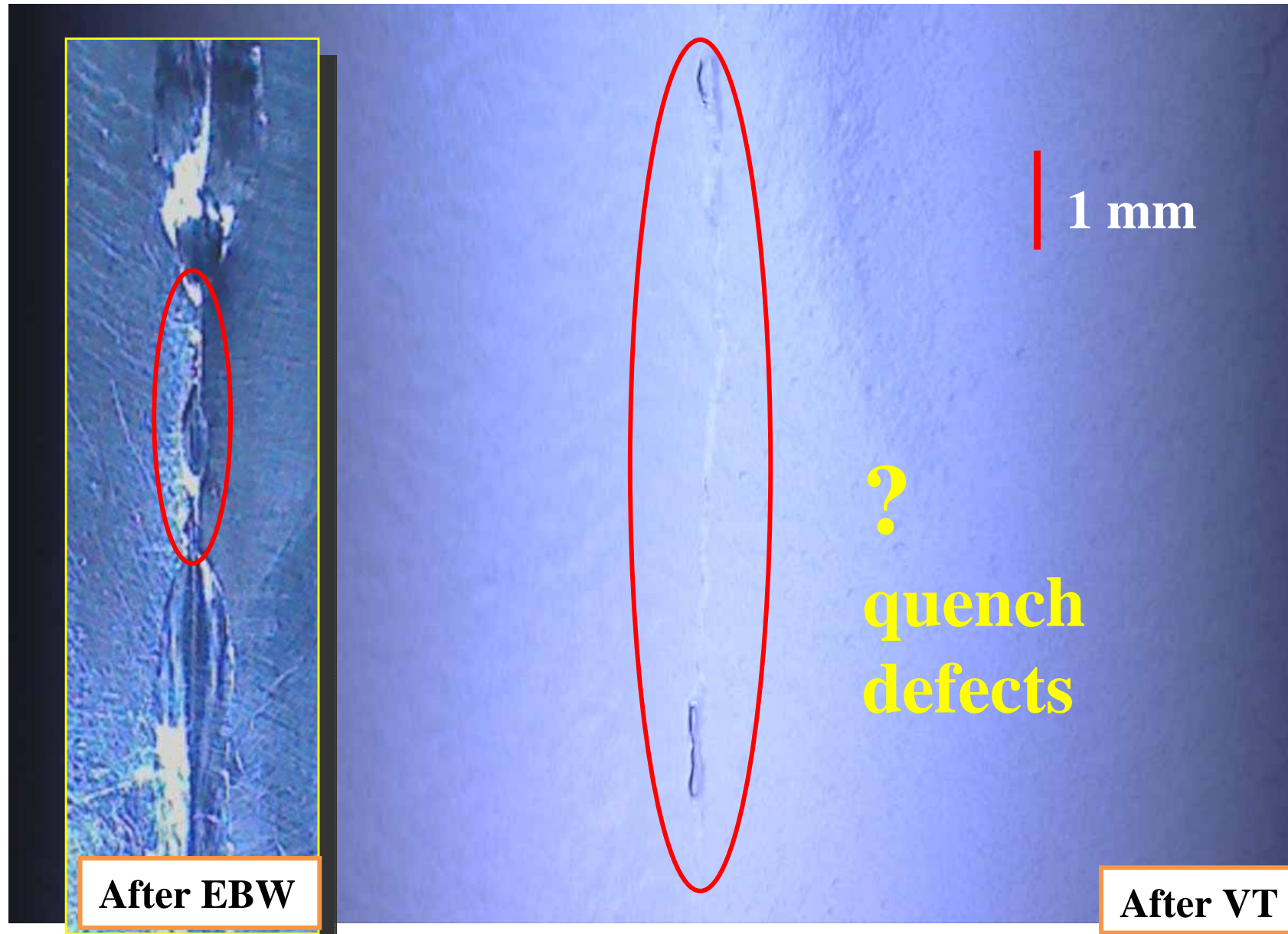
Strong Field Emission:

- processed from the initial 6 MV/m to final 20 MV/m

Hard Quench:

- cell # 9, 270-300° equator at 20 MV/m
- T-mapping and optical inspection diagnostics

Optical Inspection of Cell #9 Equator 290°



After EBW

After VT

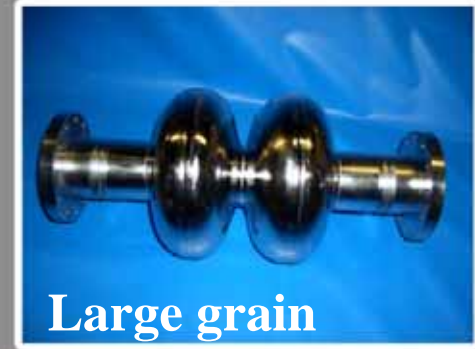
EBW seam ending problem

SRF Cavity activities in Peking University since 2006

单晶腔



Single crystal



Large grain

大晶腔系列

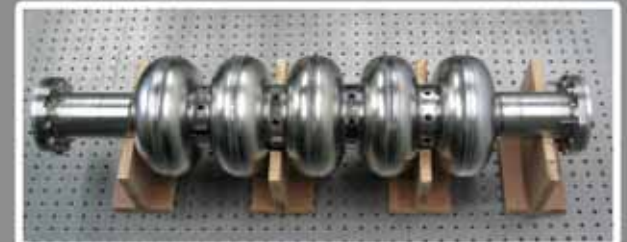


9cell铜腔



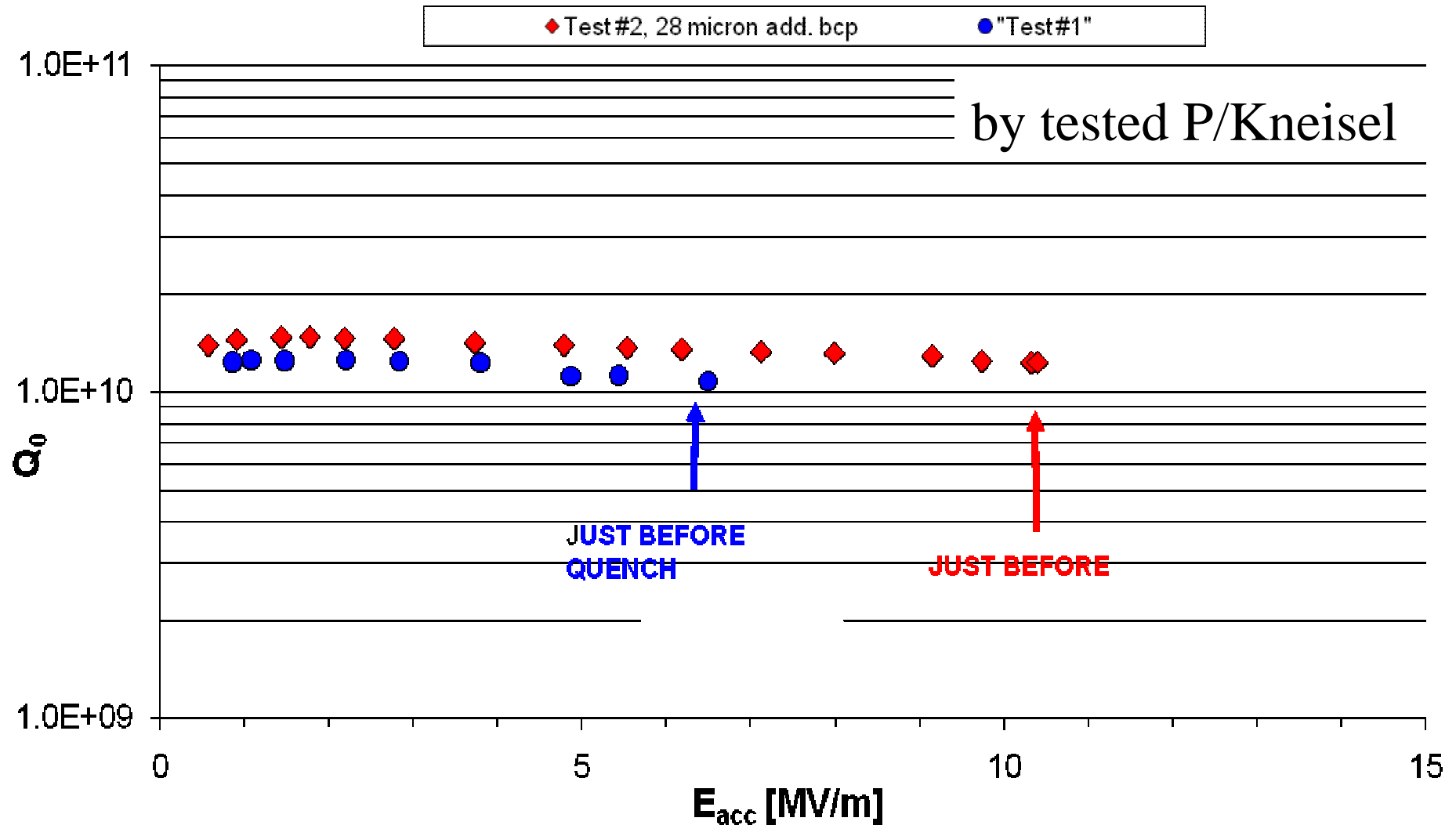
Fine grain

细晶腔系列



Single Crystal 1-cell Cavity with Ningxia

Single Crystal PKU Cavity, Ningxia Niobium

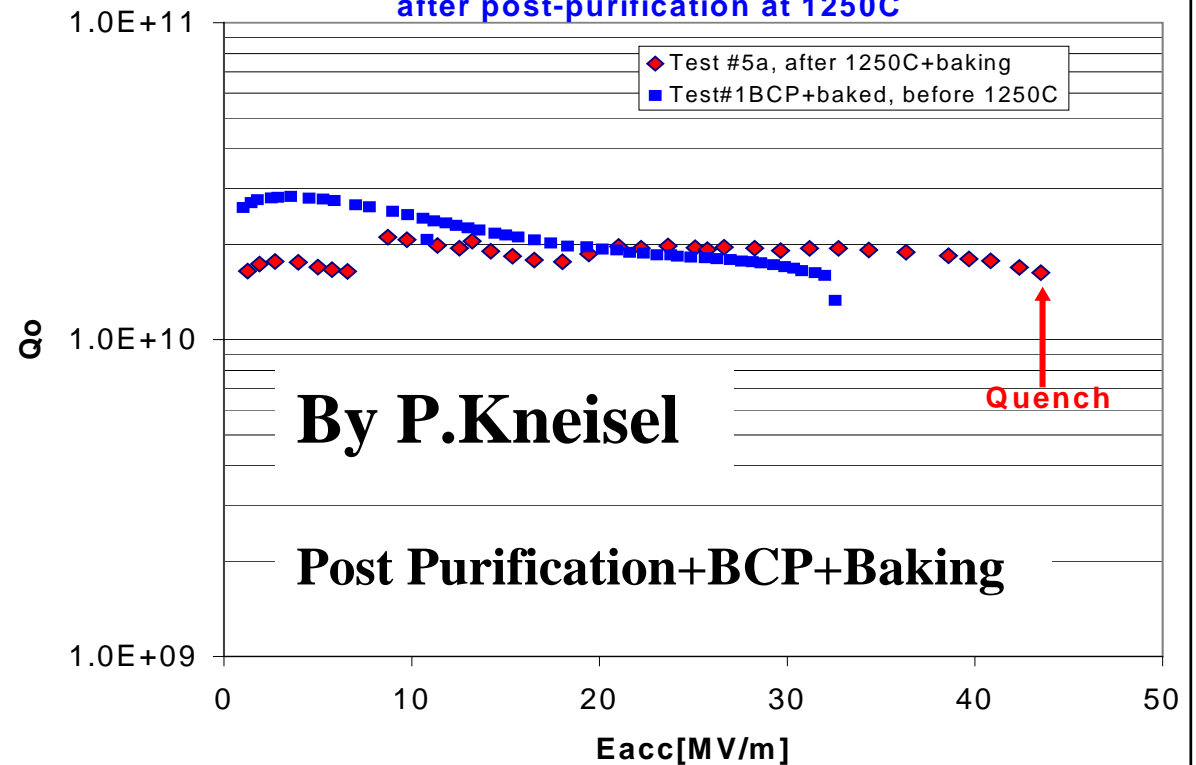


PKU activities on LG material

Ningxia LG material, fabricated by PKU, tested in Jlab (P.Kneisel)



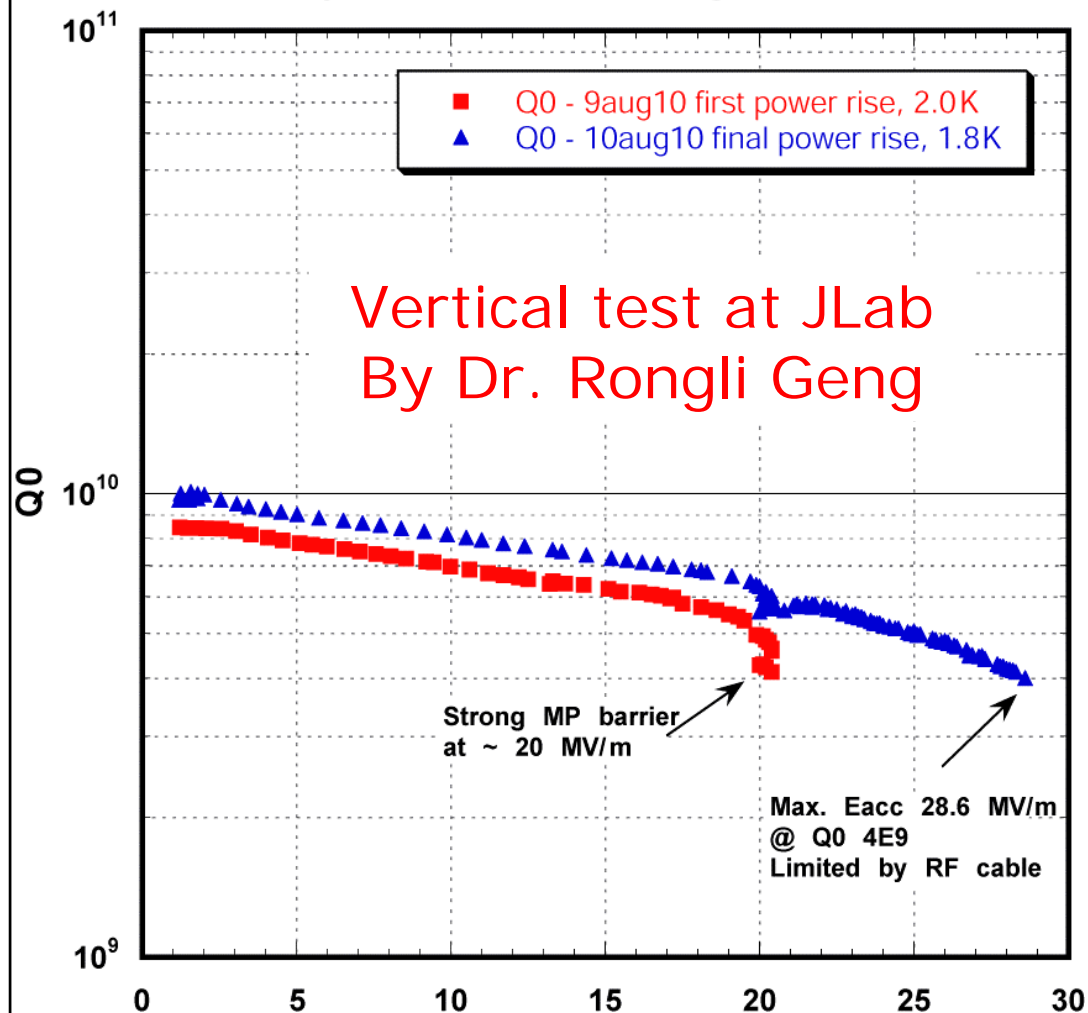
PKU Large Grain cavity
after post-purification at 1250C



F-G Nb Cavities made by Peking University

In Aug. 2009, third 9-cell cavity at Peking University , Eacc is 28.6MV/m

Cavity PKU3 RF Test August 9-10, 2010

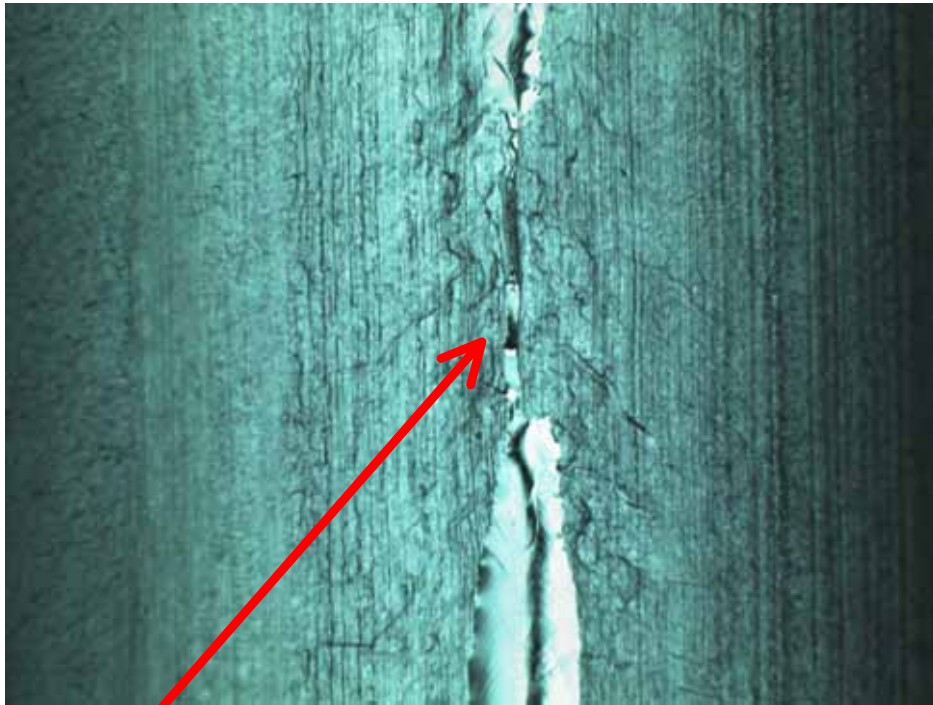


Vertical test at JLab
By Dr. Rongli Geng

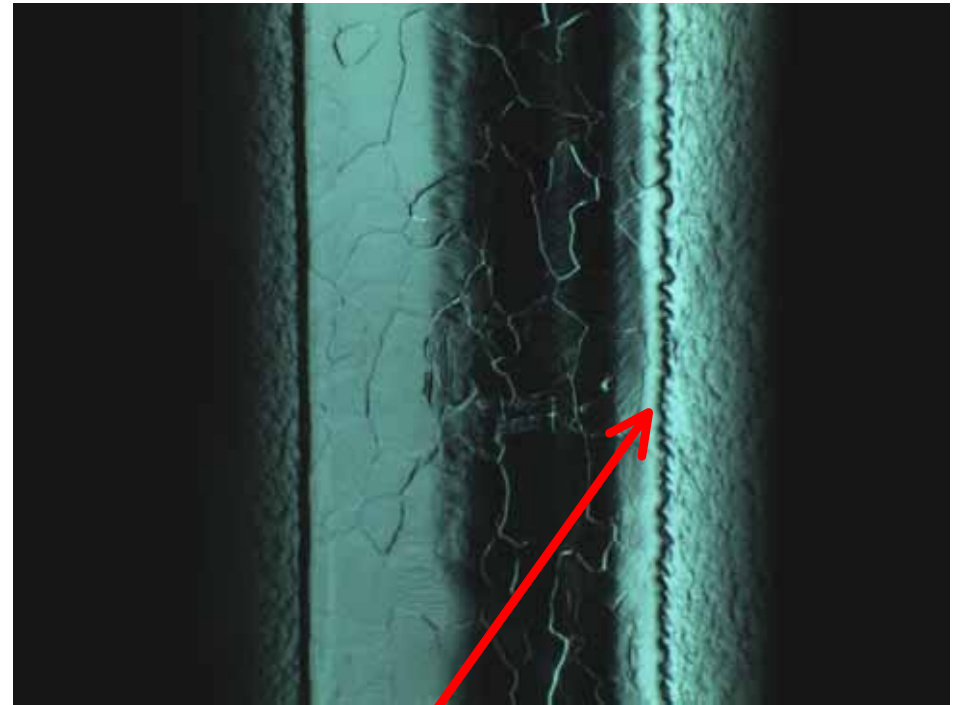
After high-pressure rinsing and clean room assembly, the first radio frequency (RF) test was done on 30 July. The maximum accelerating gradient was 20 megavolts per metre (MV/m) at an unloaded quality factor of 2.3×10^9 , limited by field emission. After partial disassemble, additional high-pressure water rinsing was done, followed by the second RF test on 9 August. The maximum accelerating gradient reached 28.6 MV/m at an unloaded quality factor of 4×10^9 , limited by RF cable heating.



Observations of As-built Surface Reported on May 9, 2010 @ 1st WebEx Meeting



Lack of full penetration at equator EBW



Sharp steps at iris EBW

from Rongli's file

KEK/Tokyo Denkai Activities

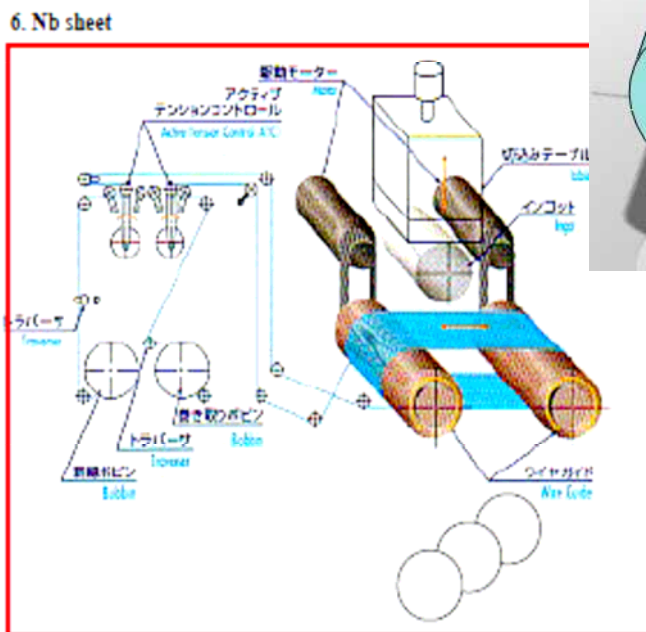
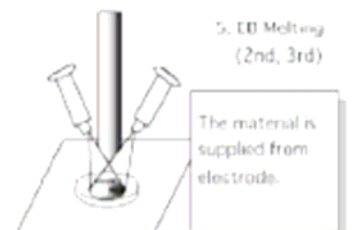
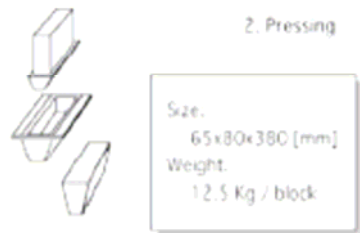
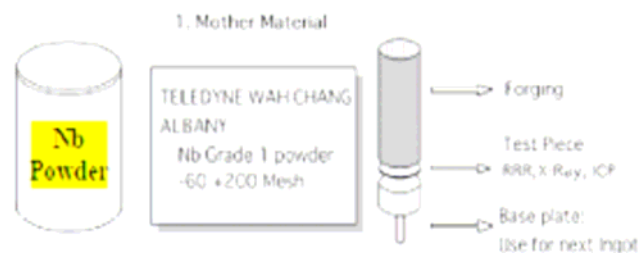
Large Grain Sheet Production at Tokyo Denkai



Multi-Wire Slicing

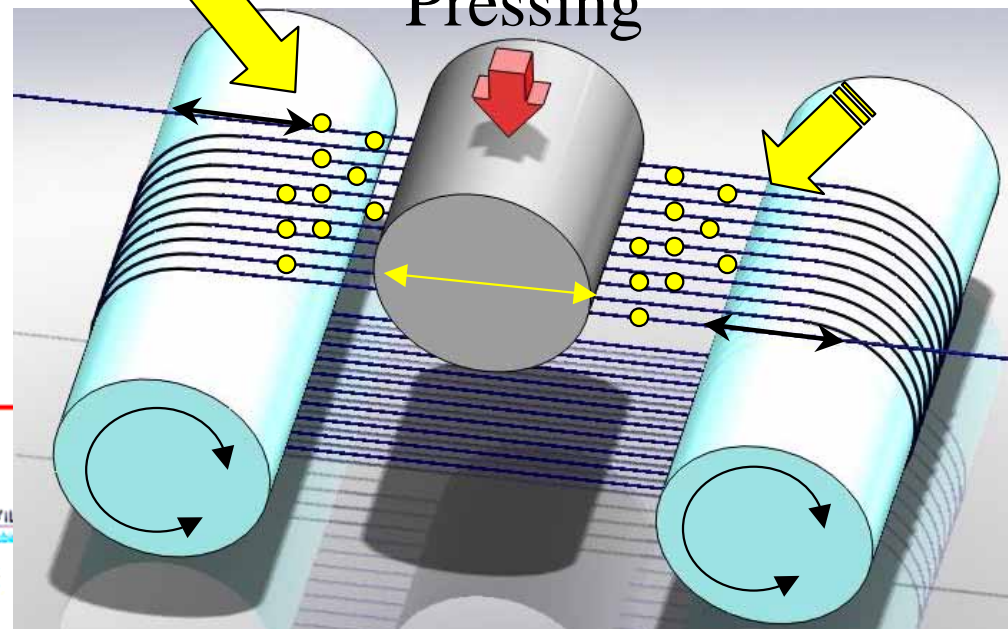
K.Saito

Single Crystal-Large Grain Niobium
Technology Workshop in Brazil 2006



Splay liquid abrasives

Pressing



Slicing used very thin piano wire (0.16)
and liquid abrasive

This technology is well established on silicon wafer slicing.

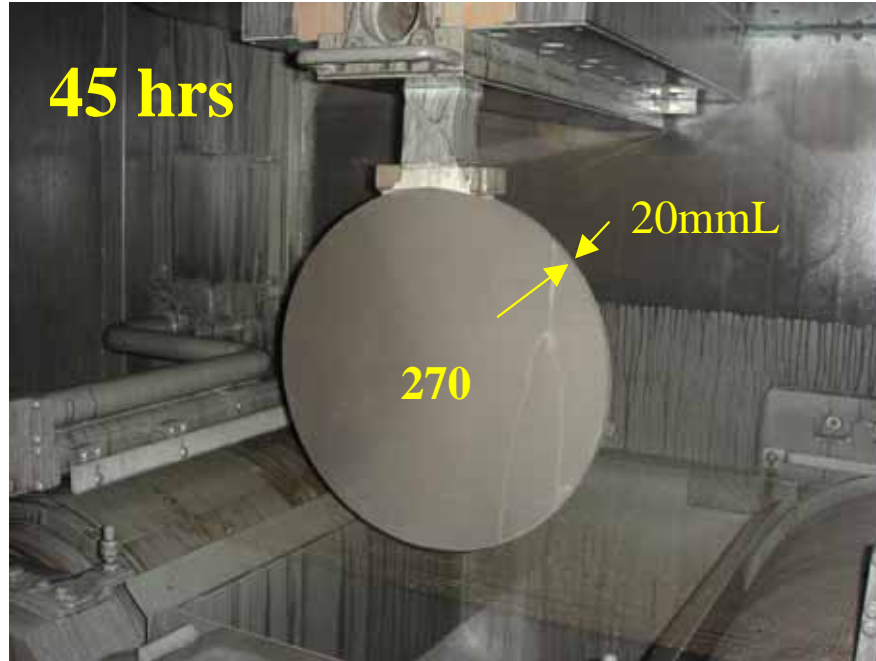
R&D of Multi-Wire Slicing @ KEK/Tokyo Denkai

The first trial for niobium ingot slicing after small sample cuttings

Conventional Silicon wafer slicing machine



45 hrs



Tokyo Denkai RRR=480



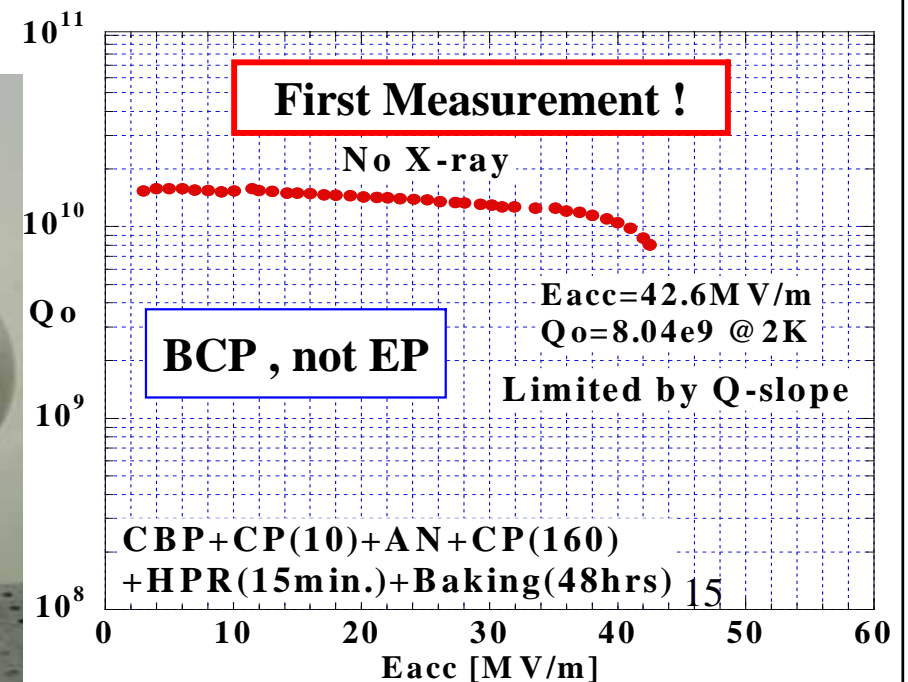
The surfaces have wire traces but no problem for cavity fabrication.



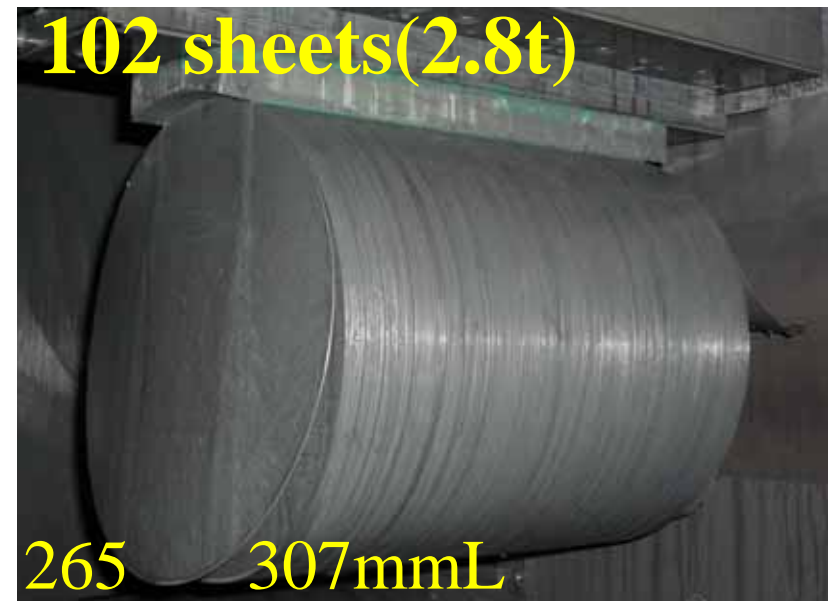
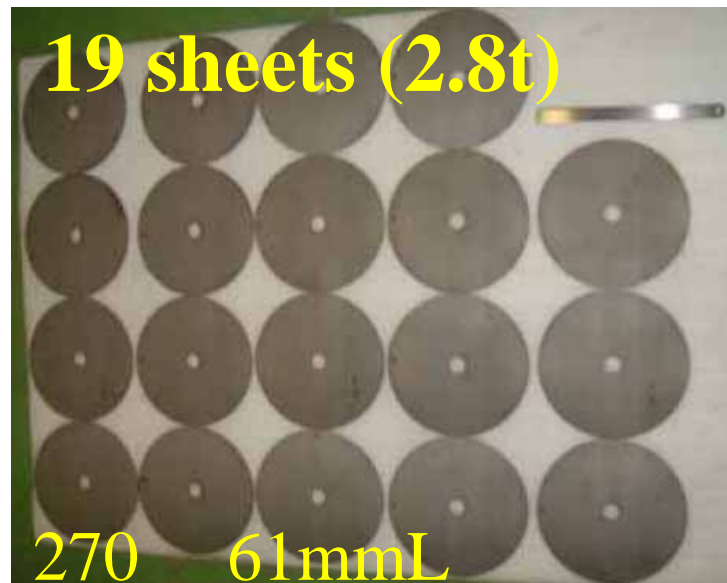
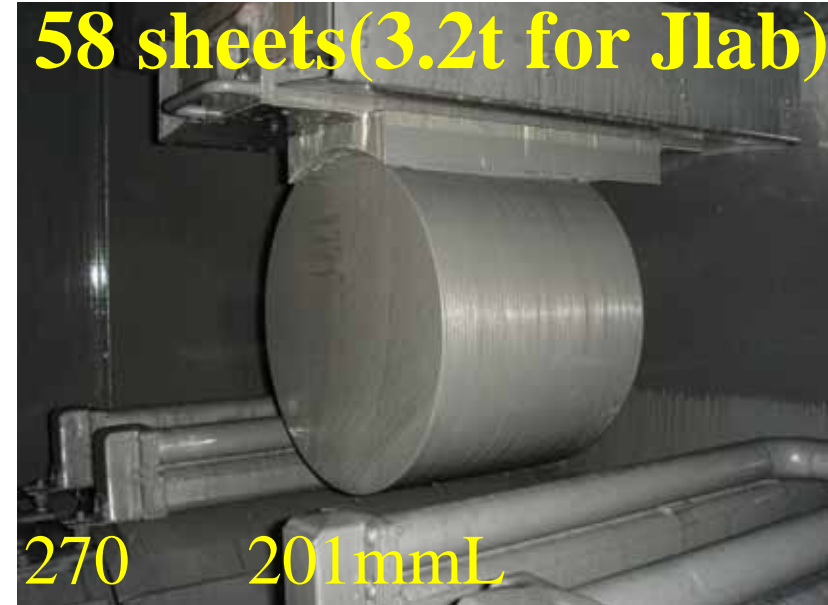
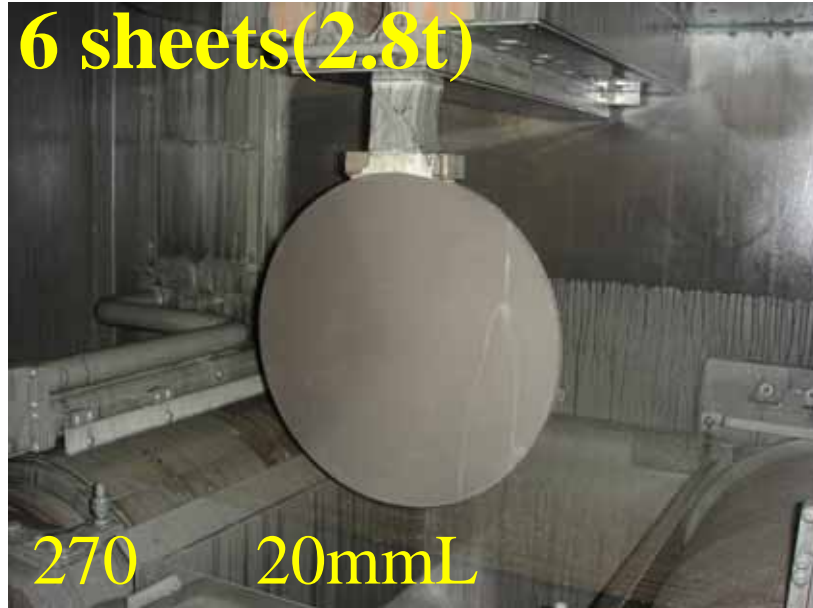
LL End single cell cavity
(End cell shape)



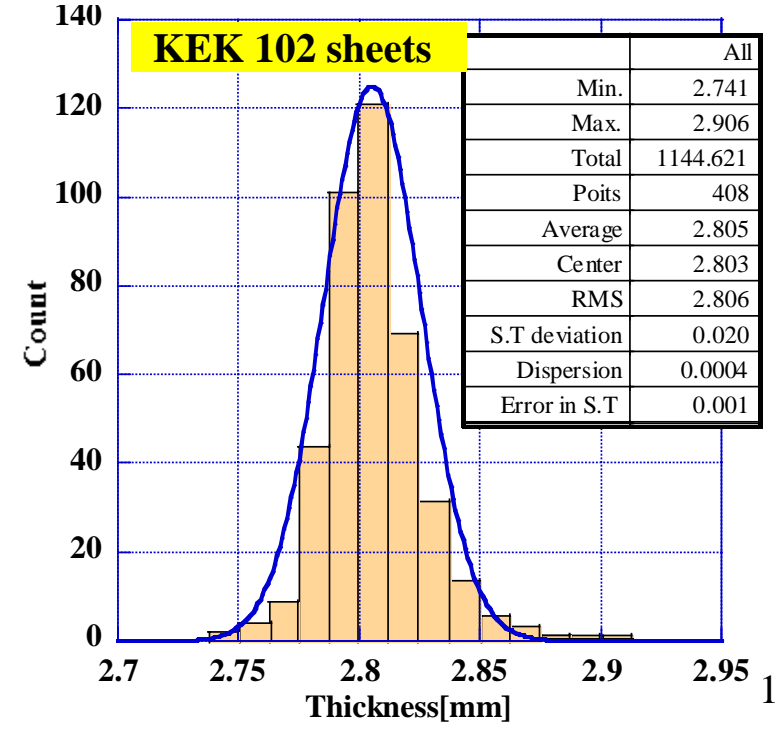
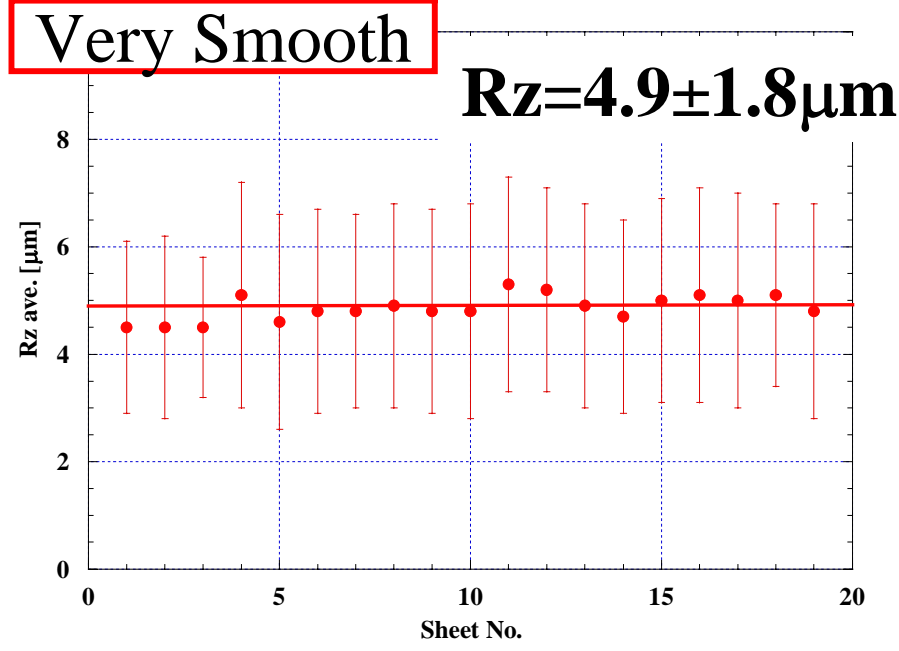
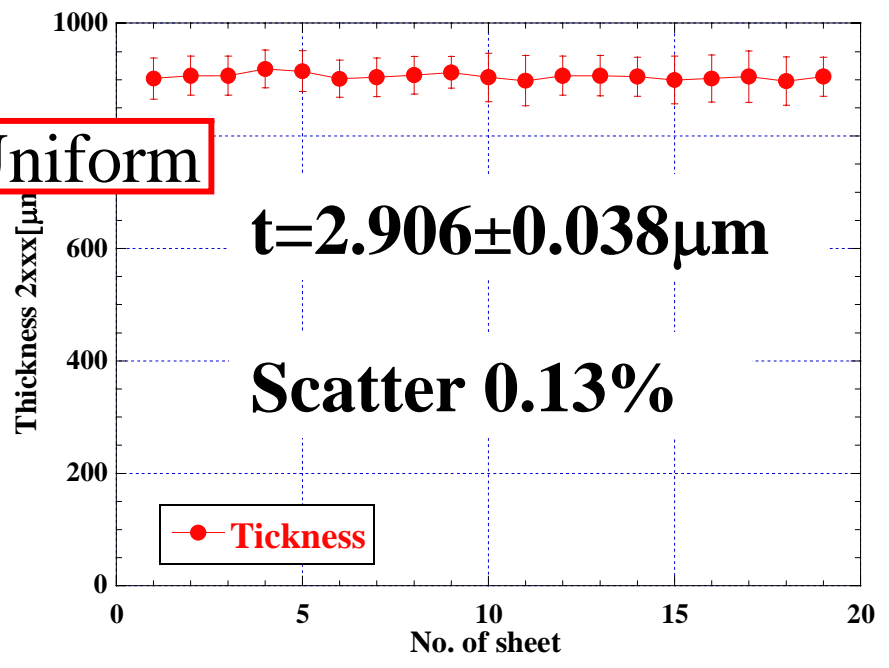
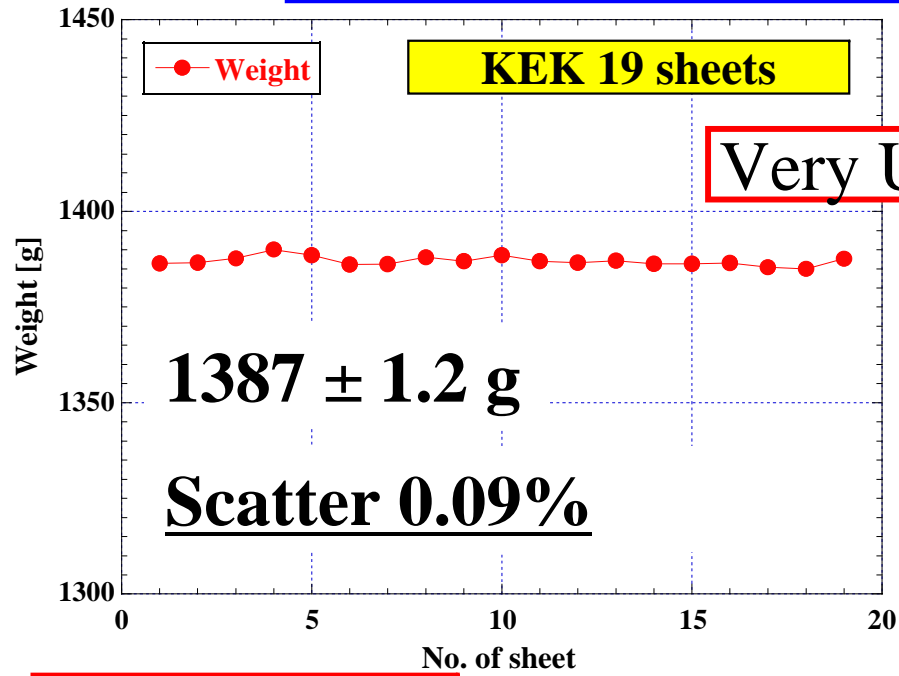
Directly formed the sliced sheets.
No annealed the sheets.



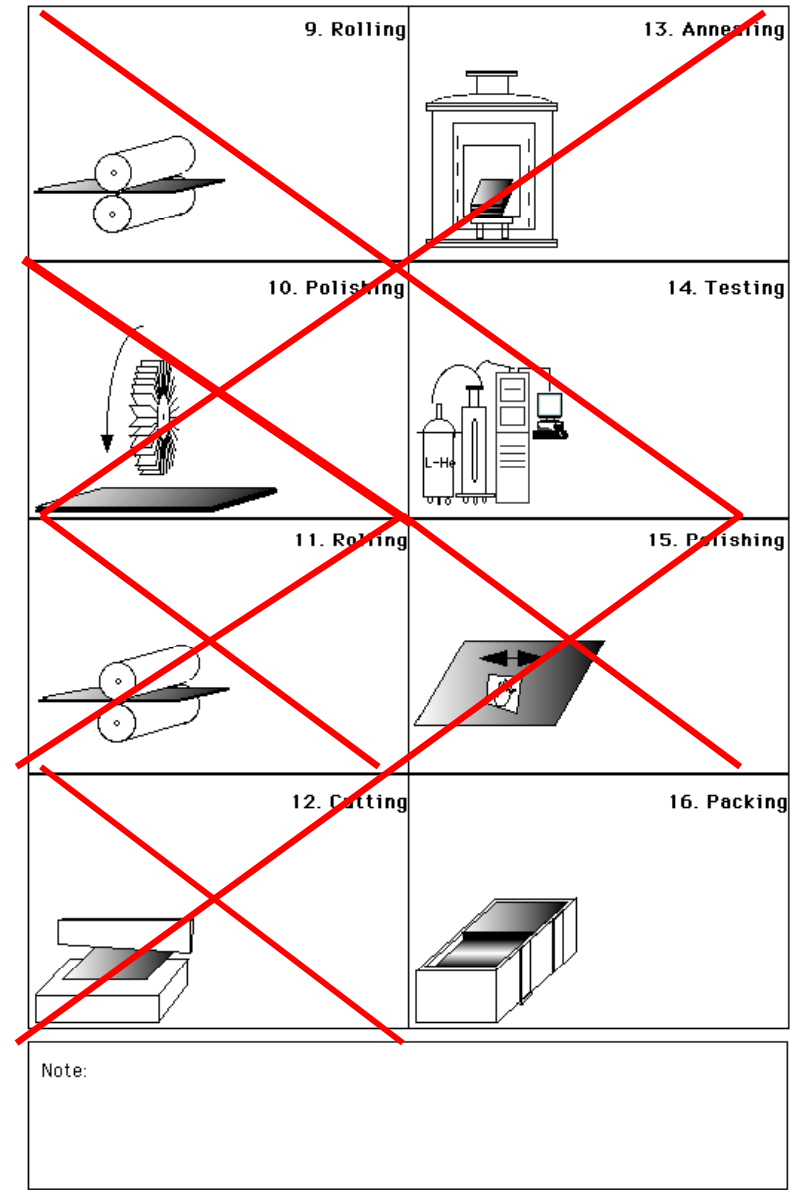
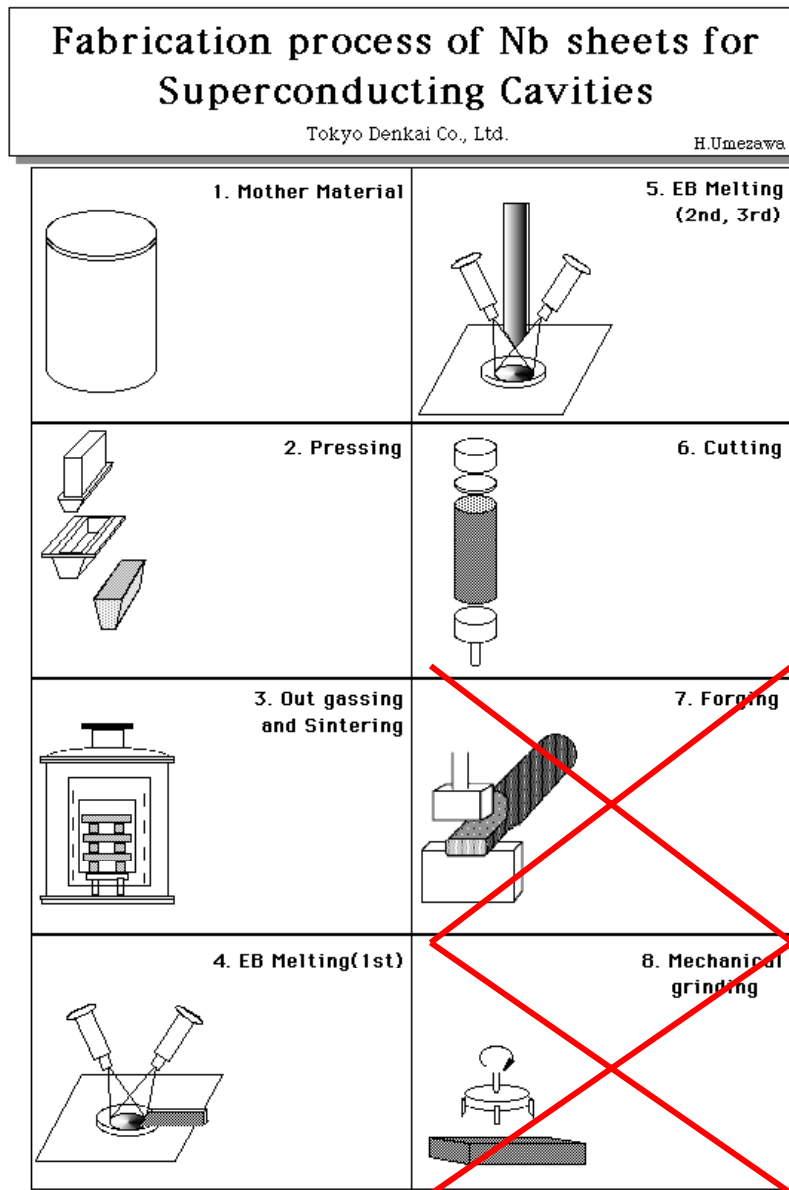
Step by step tests for more sheets production



Feature of The Multi-Wire Slicing

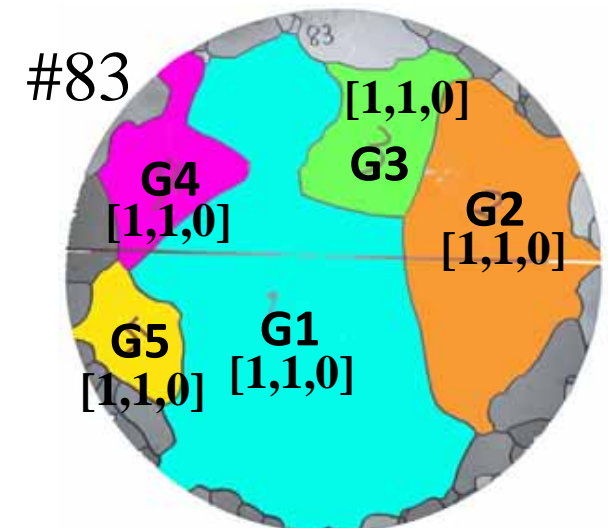
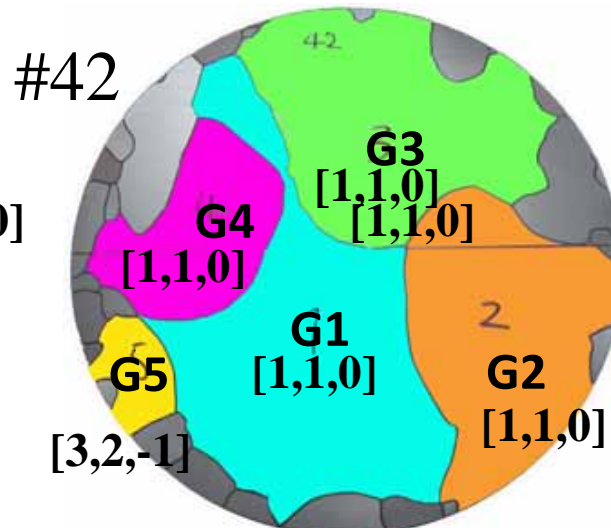
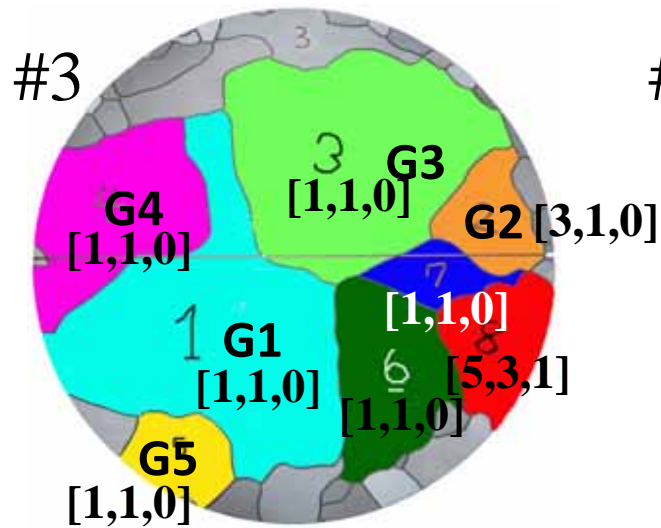
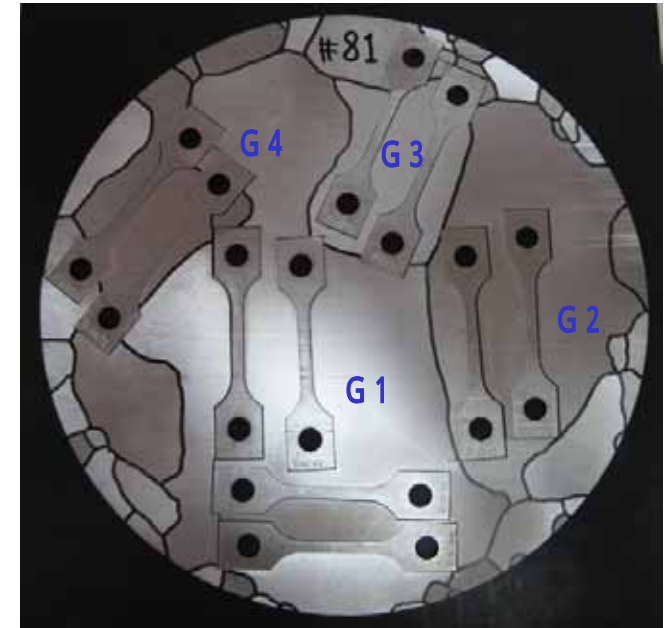
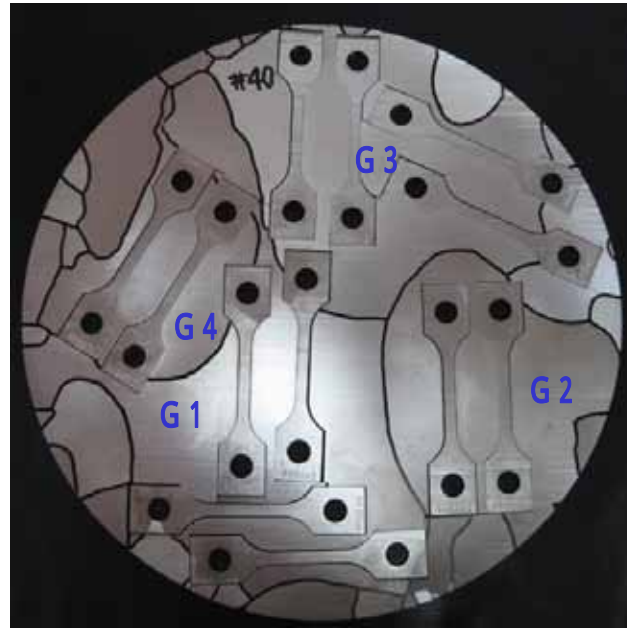
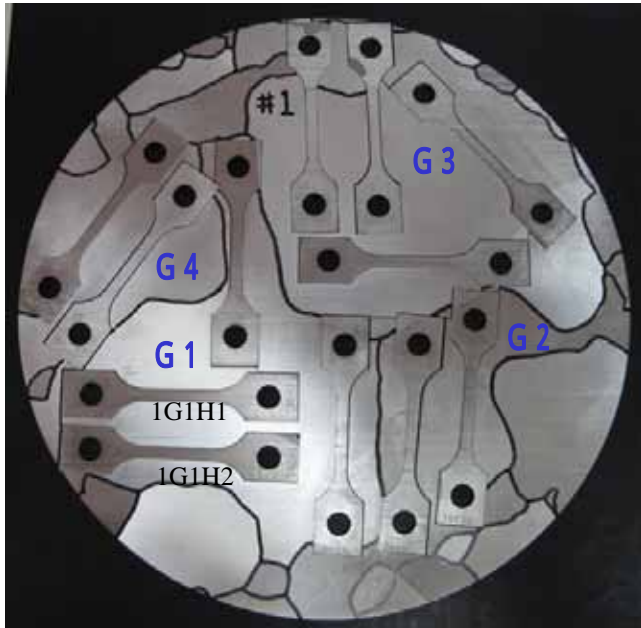


Simplified Nb production by this slicing method

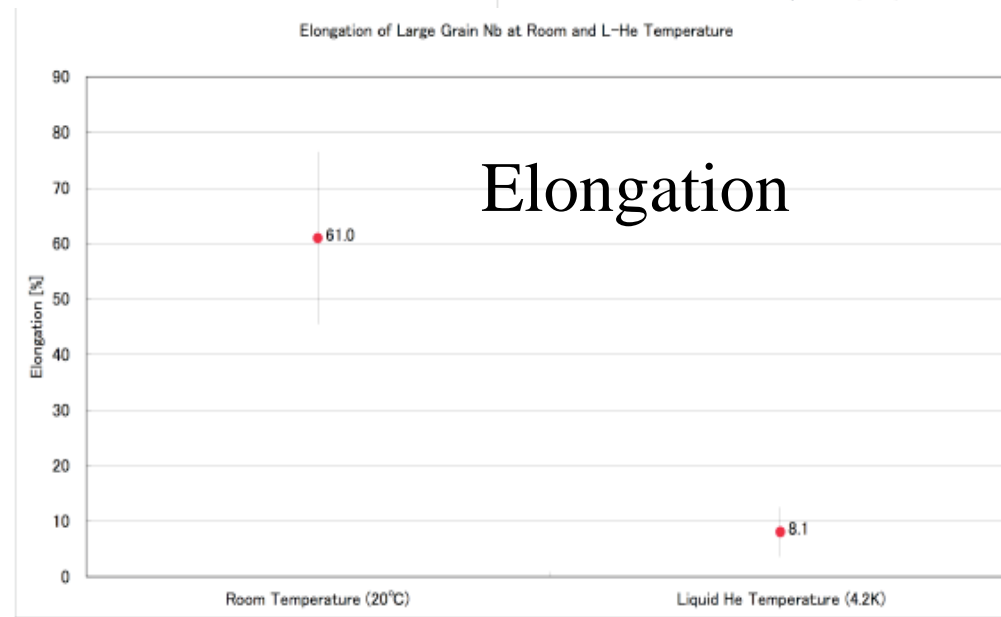
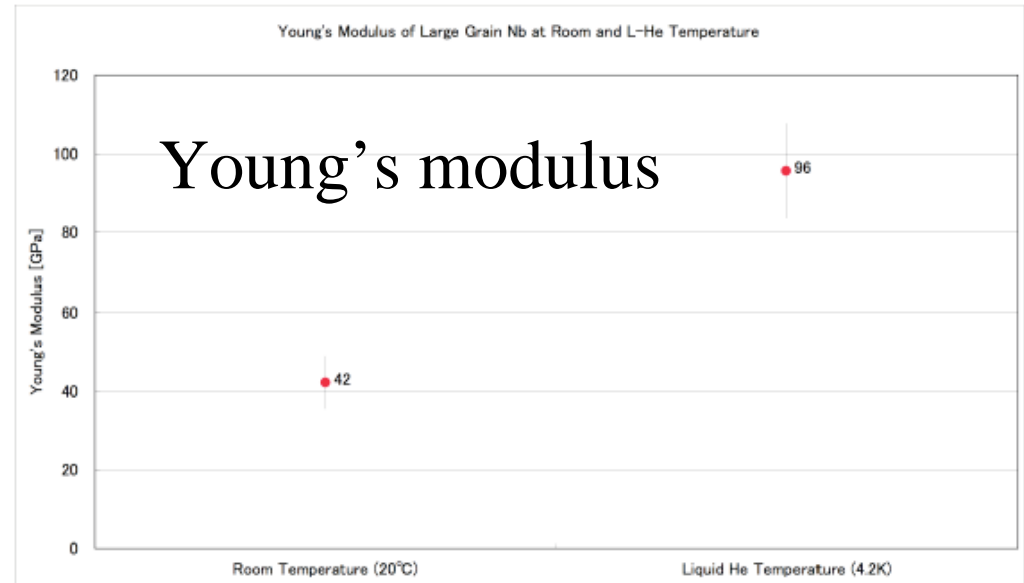
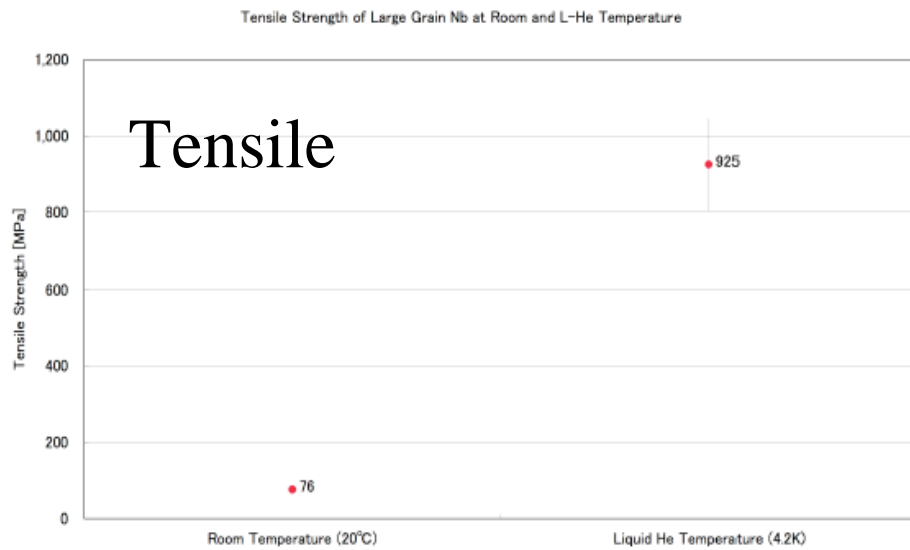


150 sheets can be produced in 48hrs, if you have a 270φx 450L Nb ingot.

Crystal Orientation and Cut out Samples

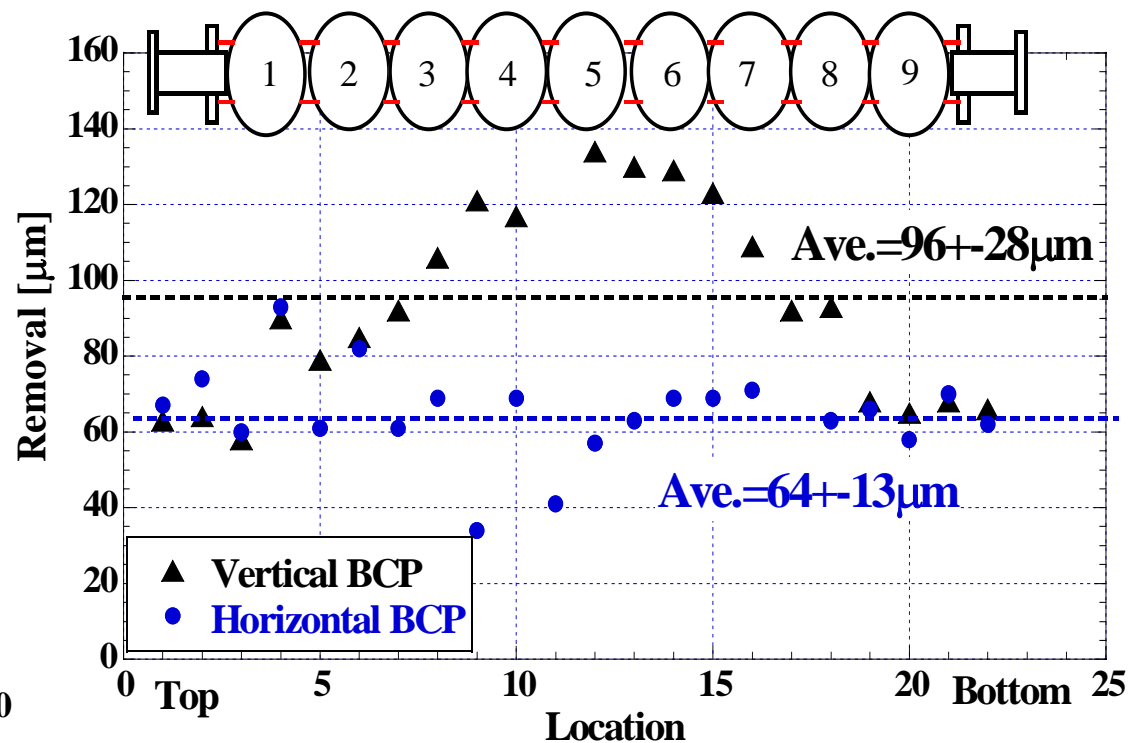
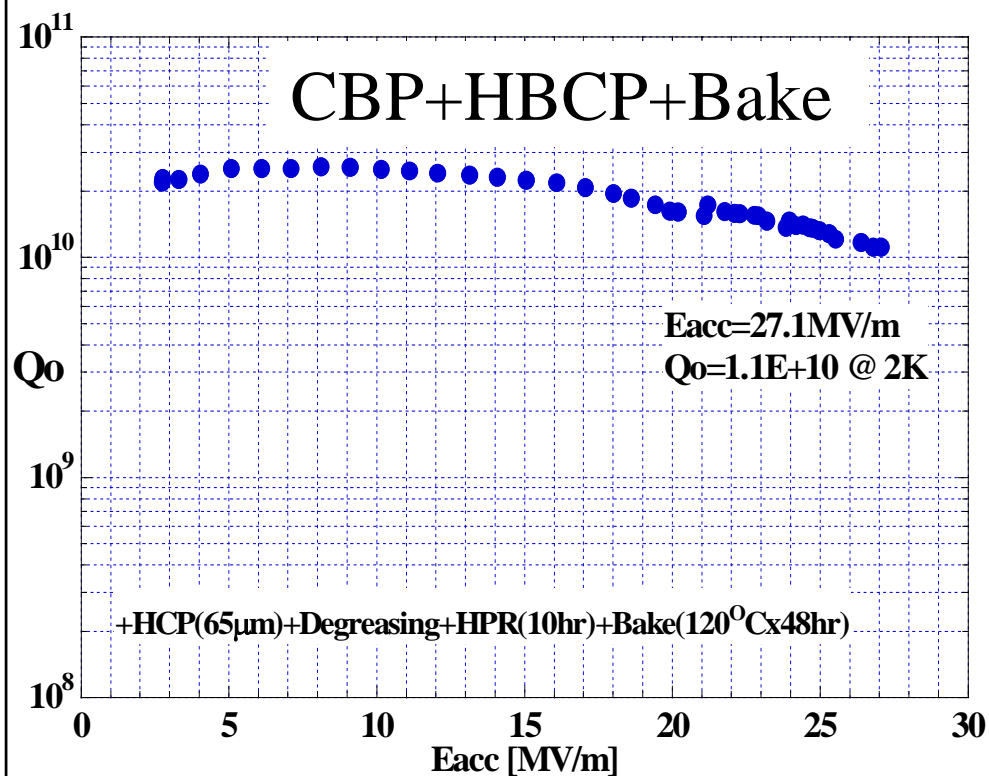


Mechanical Properties of LG niobium at RT&4.2K



Tensile becomes higher about 10 times, Young's modulus 2 times larger, and Elongation 7 times smaller at 4.2K.

Fist LG 9-Cell Cavity Fabricated at KEK



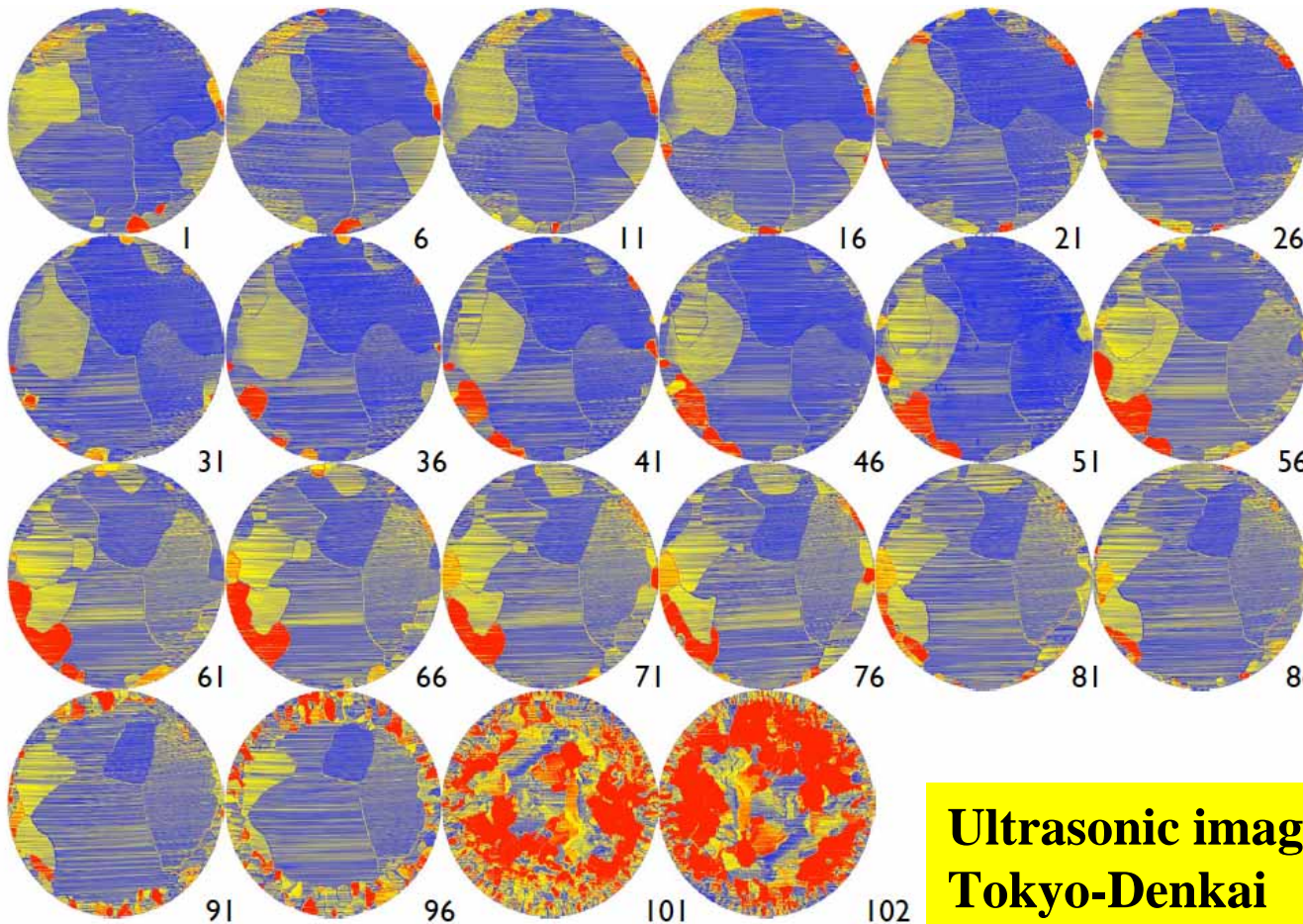
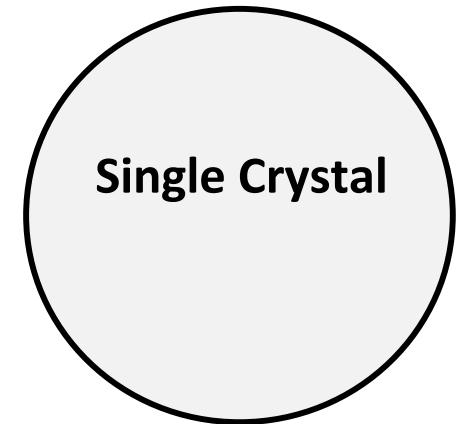
Totally 96 μm (in average) removed by BCP

Material removal distribution by the vertical BCP and horizontal one.

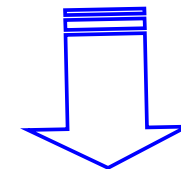
Horizontal BCP system has been successfully developed at KEK in order to improve the none-uniform material removal with vertical BCP.

Improving Crystallization of Ingot at Tokyo Denkai

Improvement of crystallization at Tokyo Denkai



Grains grow column likely in EBM.

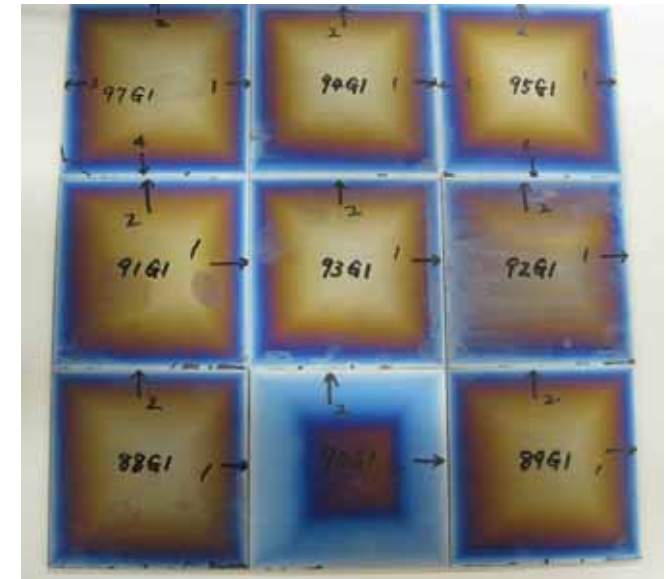
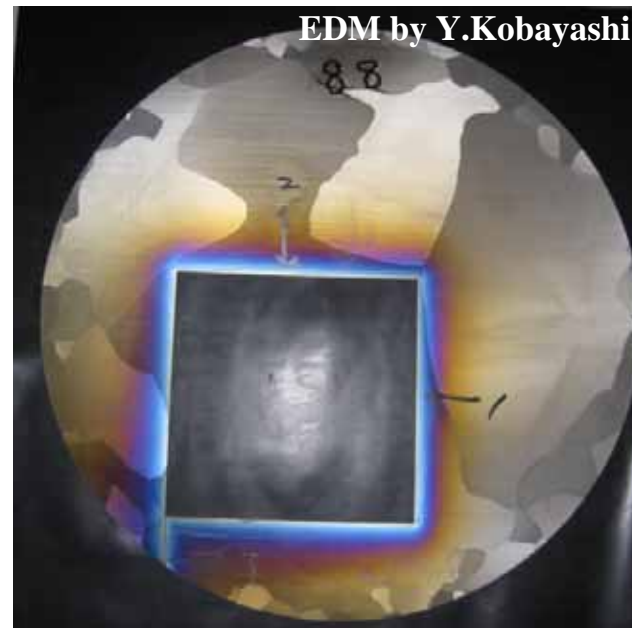
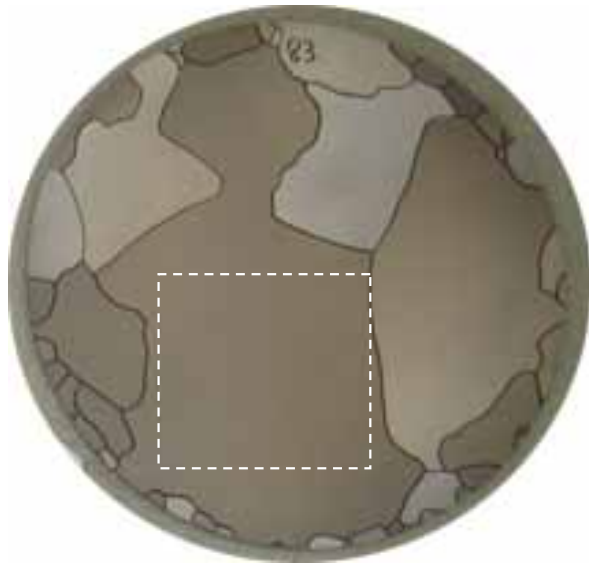


Make a seed plate for single crystal Ingot

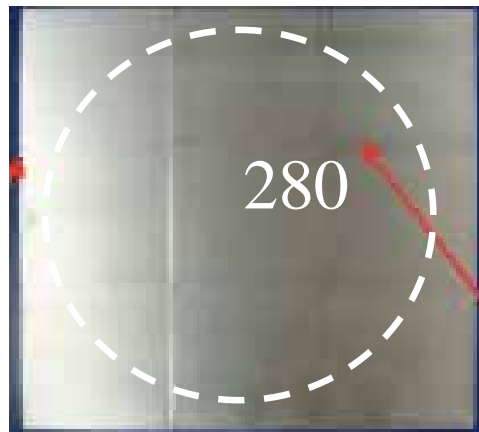
Ultrasonic images by H.Umezawa
Tokyo-Denkai

Trial of Single Crystal Seed for EBM Nb Ingot

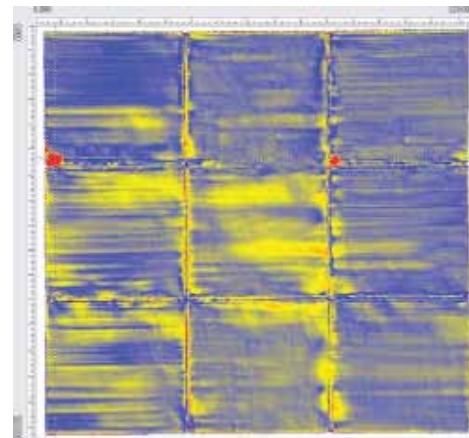
Use nearby 9 sheets Cut out large crystal piece



After BCP



Ultrasonic diagnosis
after buffing



Ultrasonic diagnosis
as received



EBW of large
crystal pieces



We are very much looking forward to see the EBM result, which will come out on the IPAC10 in Kyoto.

Seed plate 2.8mm thick on the EBM base-plate



First experiment was failed. We will hear more information here from Tokyo Denkai.

Scope of the LG/Single crystal niobium material from single cell cavity R&D

Large Grain: Benefits in material and preparation costs

- TESLA shape+LG+BCP(+bake) is hopeless for the ILC baseline performance : 35MV/m @ $Q_0=8E+9$, which has been already confirmed with 9-cell cavities at DESY.

XFEL specification is well satisfied by this scheme.

TESLA shape+LG

+ [CBP or Post purification at 1250°C]+BCP(+bake) on ILC baseline performance ?

- LL shape+LG+BCP(+bake) is hopeful for the ILC baseline performance.
- LL shape+LG+CBP+BCP(+bake) is hopeful for the ACD performance: 40MV/m @ $Q_0=8E+9$. Need more statistics.

Single Crystal

- Single crystal will make possible the ILC ACD performance without CBP on the scheme:

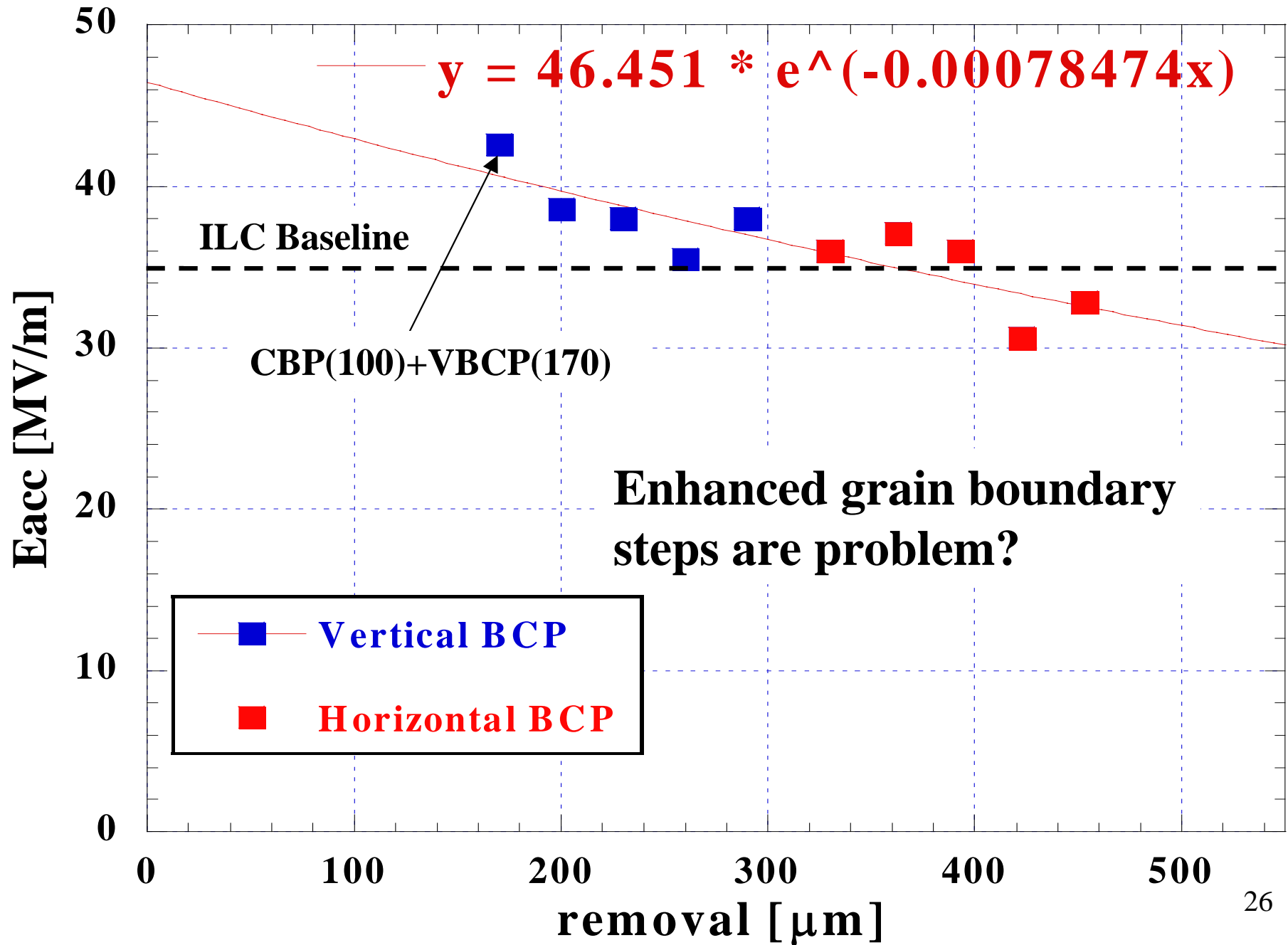
LL shape+LG+BCP(+bake) .

- Single crystal has more advantage on the cavity performance.

Single crystal is trade off CBP.

- Single Crystal R&D should be kept going.

BCP material removal vs Eacc,max on LG after CBP



Summary

- *IHEP and PKU in China keep going ILC 9-cell cavity R&D with helps other laboratories. Single crystal is already produced at Ningxia.*
- *Multi-wire slicing has been successfully developed at KEK/Tokyo Denkai, and now it is applied in the production phase in Tokyo Denkai..*

It is ready to produce 150 sheets ILC like in 48hrs, if you bring an ingot 270 ϕ -450mm L.

- *KEK has started LL 9-cell cavity fabrication LG based, and is challenging to the ILC ACD cavity performance.*
- *Single crystal R&D is trade off CBP. KEK/Tokyo Denkai have started the R&D.*

Acknowledgments

We express many thanks to KEK STF people, who made vertical test for IHEP01 9-cell cavity.

We thank Drs. Y.Higashi and S.Chan, who helped a lot to measure crystal orientation of LG niobium materials.

Niobium Workshop 2006

- ▶ **Single cell cavity R&Ds in Asia were reported:**

IHEP/KEK collaboration

Ning Xia large grain Nb material achieved $E_{acc} \sim 50\text{MV/m}$ with electropolished LL cavities.

Jlab/Pusan University/ KEK Collaboration

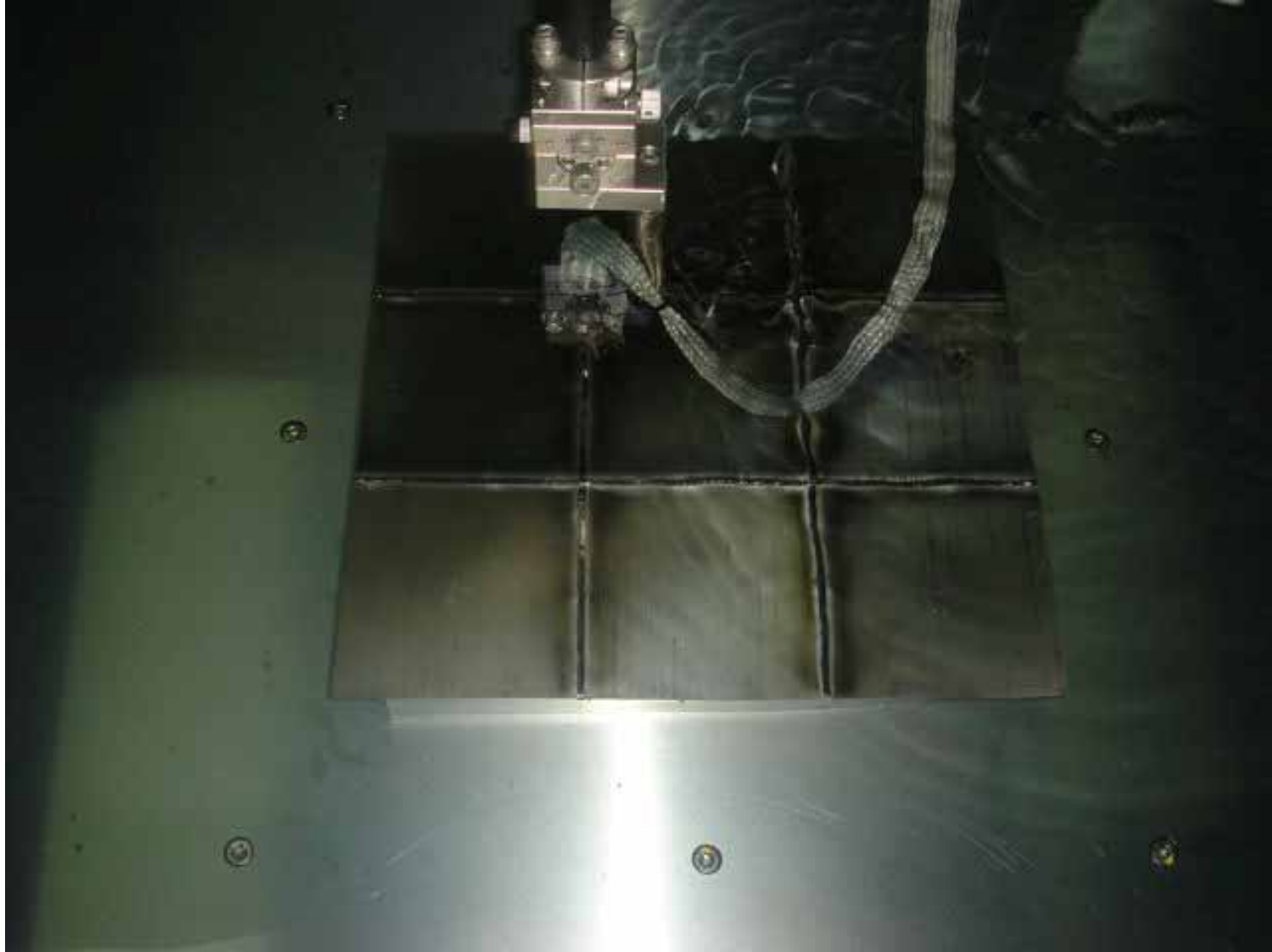
CBMM large grain material also reached $E_{acc} \sim 36\text{MV/m}$ with EP'ed LL cavity.

- ▶ **Tokyo Denkai will start large grain Nb material production.**
- ▶ **Multi wire slicing idea was proposed for industrial large grain sheet material production.**

IHEP Further R&D for LG

- **IHEP-01 is now back to IHEP, will be processed again and make 2nd vertical test early next year**
- **IHEP-02 Large Grain Low Loss 9-cell cavity with HOM couplers in fabrication, 1st vertical test early next year**
- **More IHEP cavities for ILC, ADS and ERL are coming... LG may be considered.**

Ultrasonic Imaging Machine at Tokyo Denkai



Grain boundary appearance Test using Single Crystal Coin Samples

		Grain Boundary?	
1			No
2			Yes
3			3A-(4C,4B) Yes 4C-4B Yes
4			4A-(3C,3B) Yes 3C-3B No

1. Each same crystals, doesn't make a grain boundary (GB).
2. Even if same crystal, different angle make a GB.
3. Reverses side makes GB (i.e. angle is different). Weld Bead doesn't make GB.
4. Same crystal, same direction doesn't make GB