High performance niobium cavities

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Motivation

- ┬┬Specifications of the e-LINAC

  ~ 25 MV/m, high Q and CW ingot niobium cavities

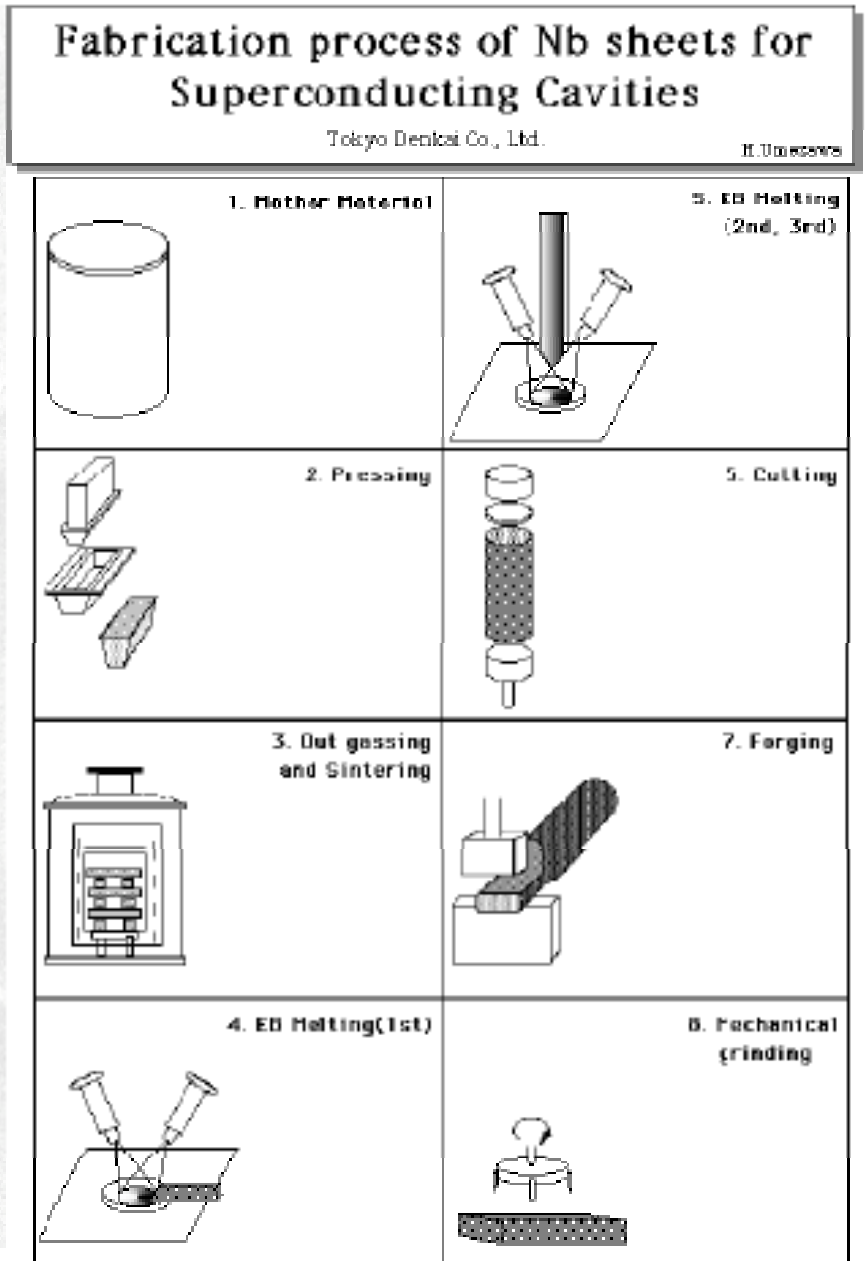
- Demonstrate high performance ingot niobium technology

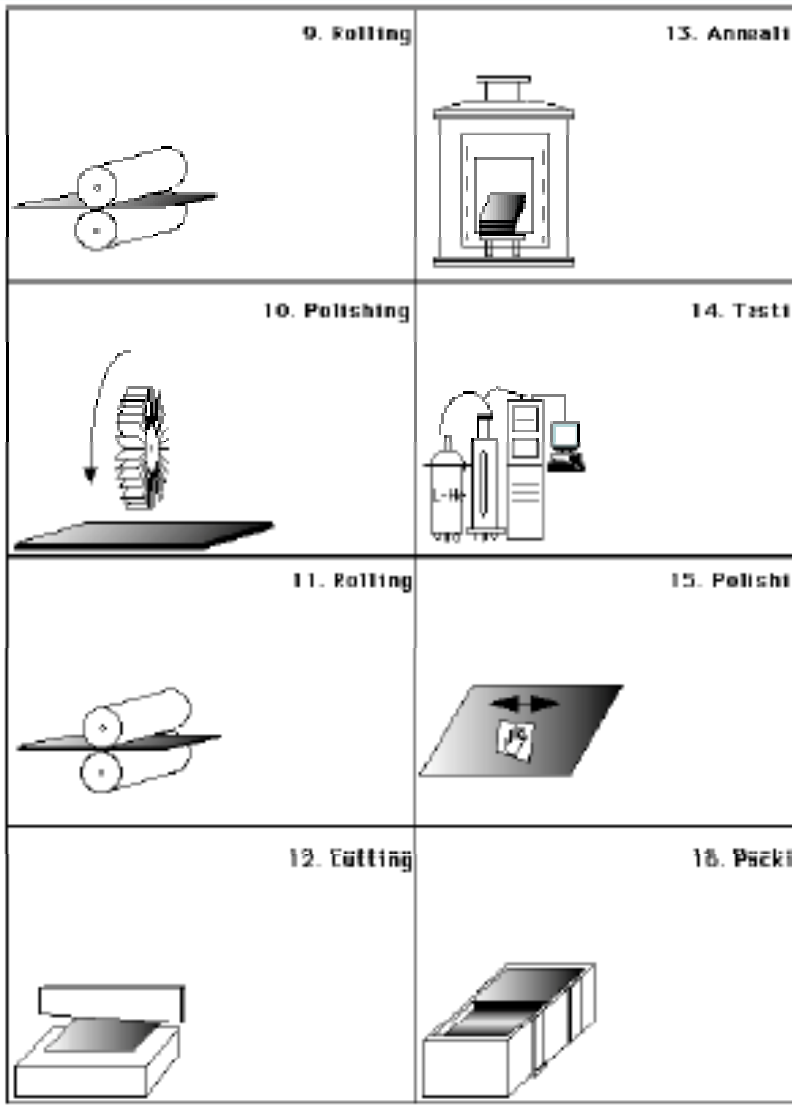
- ADS training/teaching facility

http://conferences.jlab.org/sstin/index.html

http://www.phys.virginia.edu/Announcements/LinacWorkshop/agenda.html

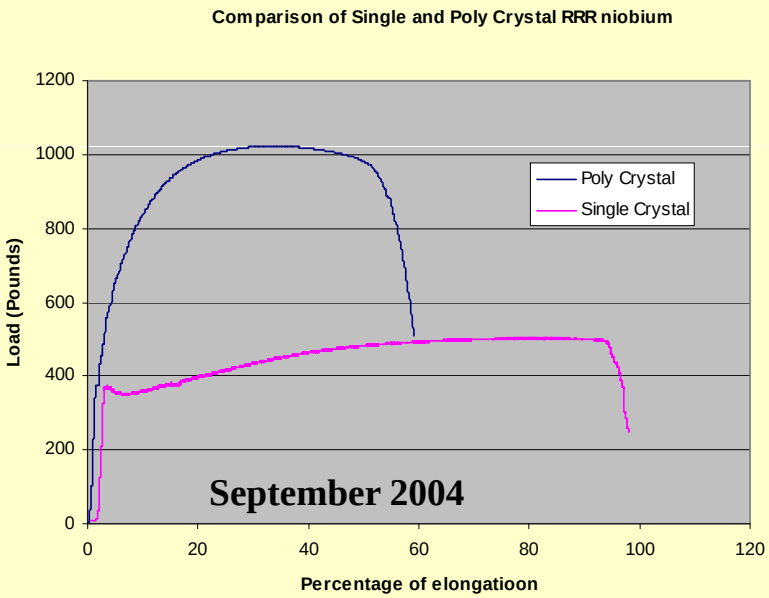
Process steps - fine grain Niobium





Note **During this process foreign material can be embedded so QA is required**

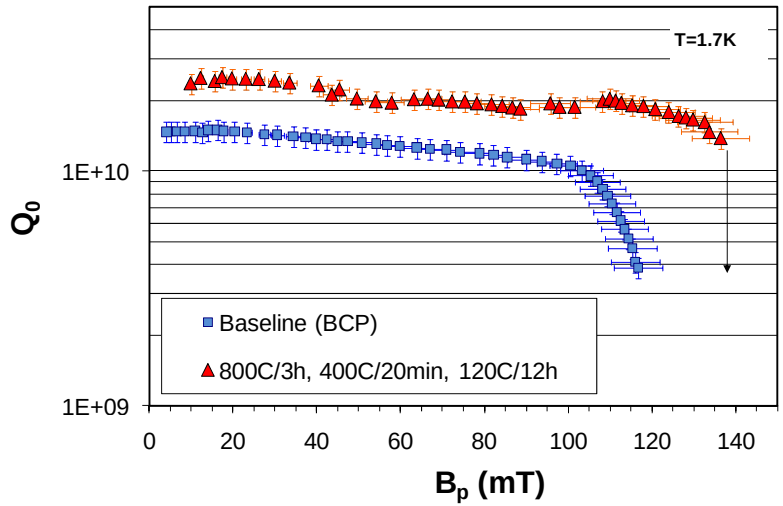
Birth of Ingot Niobium Technology
CBMM/RMCI-JLab CRADA, August 2004

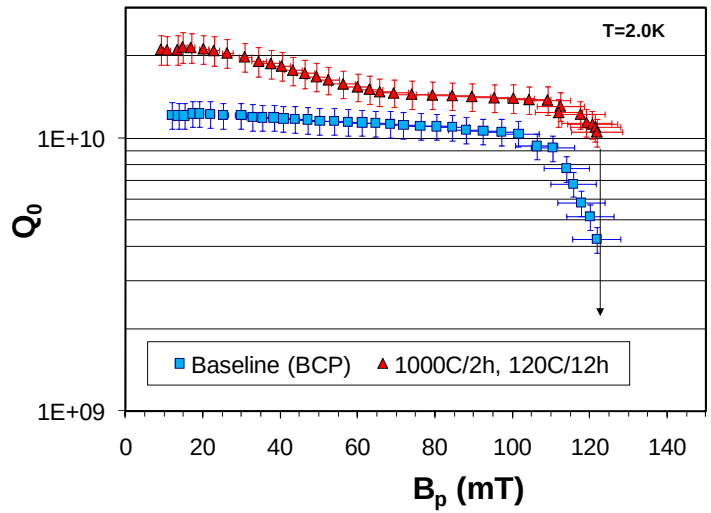


Chosen for Excellent Ductility and Surface Smoothness with just BCP

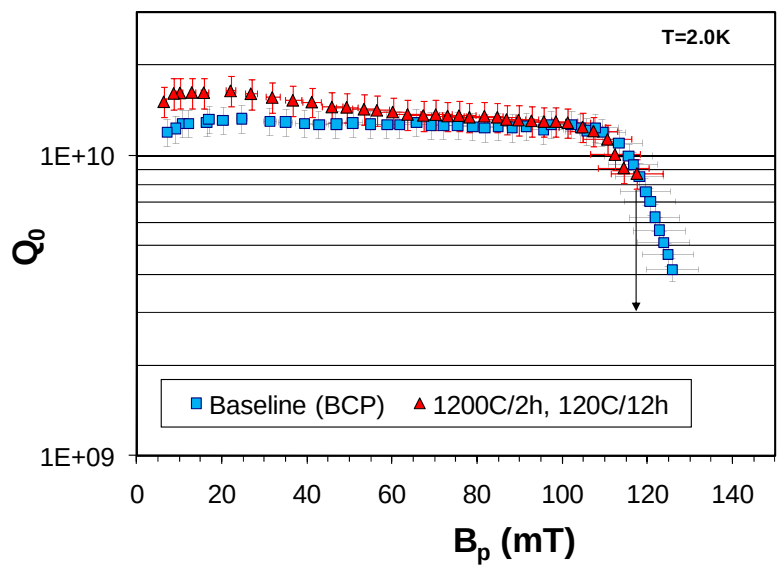
First CBMM/JLab International Patents were applied for in April, 2005

Heat Treatment Temperature Study on Single-Cell





"Ningxia"
LG Nb,
1470 MHz



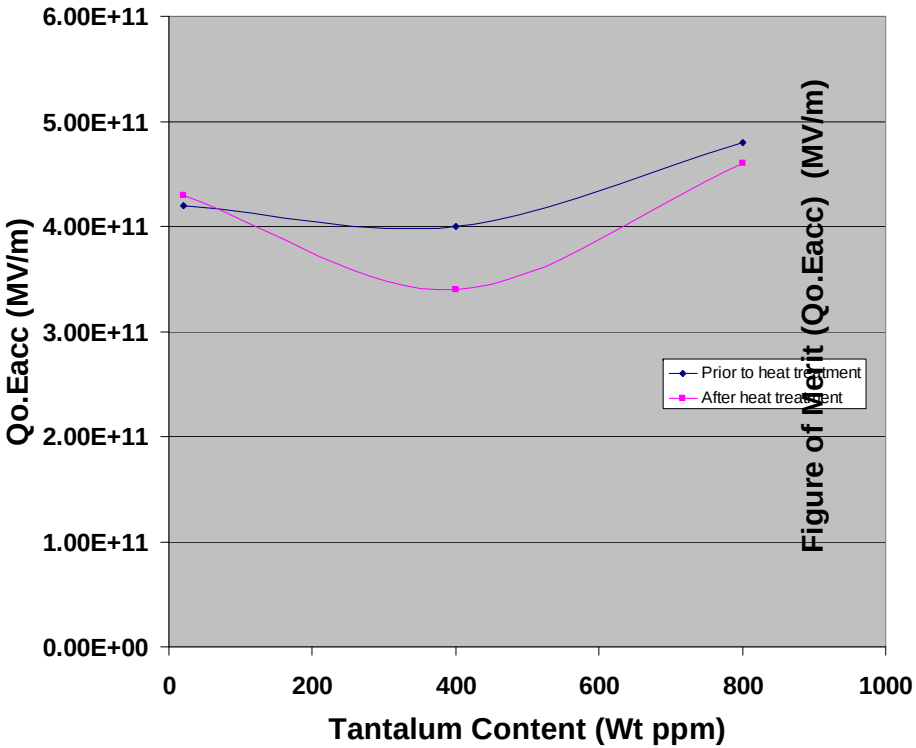
- **Largest improvement of Q_0 after 800 ° C heat treatment**
- **Reduction of quench field above 800 ° C (furnace contamination?)**

Gigi Ciovati

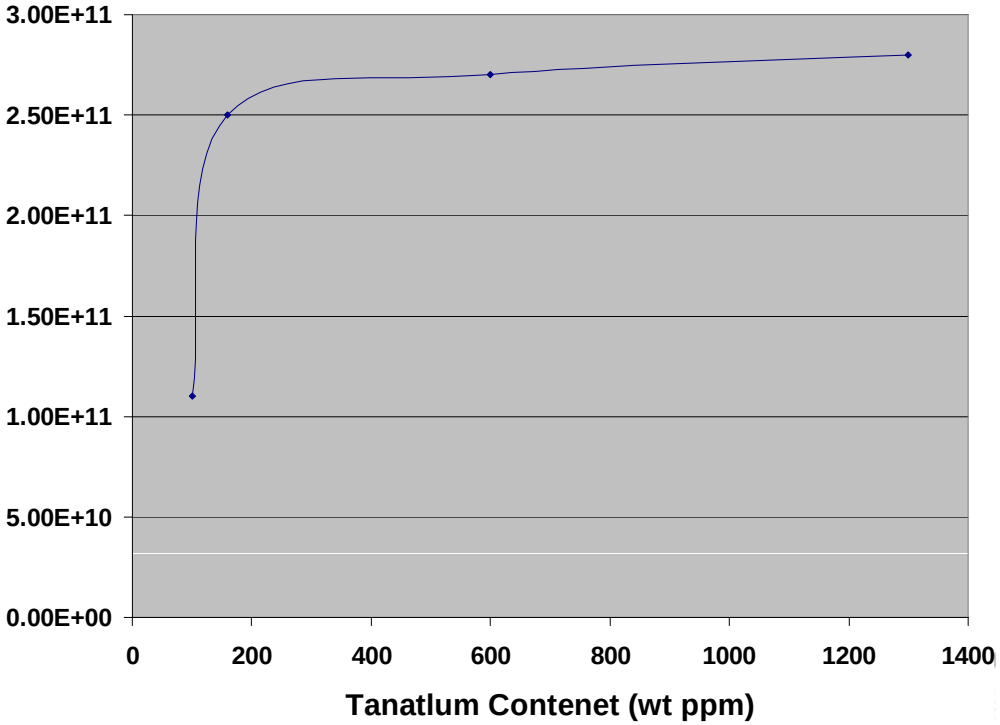
Figure of merit of large & fine grain Niobium

Figure of merit is the product of (Eacc* Qo) at the quench limit
Currently magneto thermal quench limits the performance

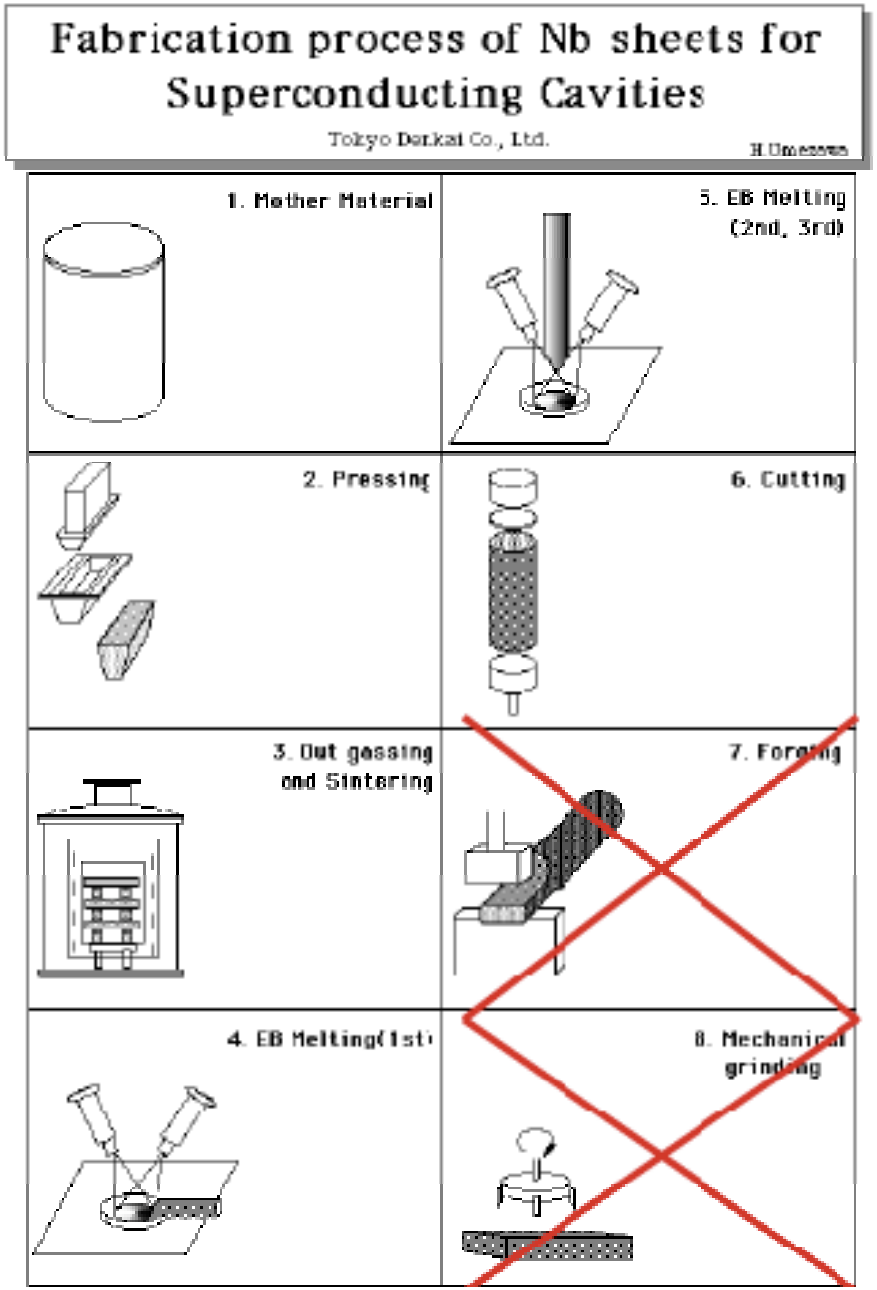
Large grain ingot niobium

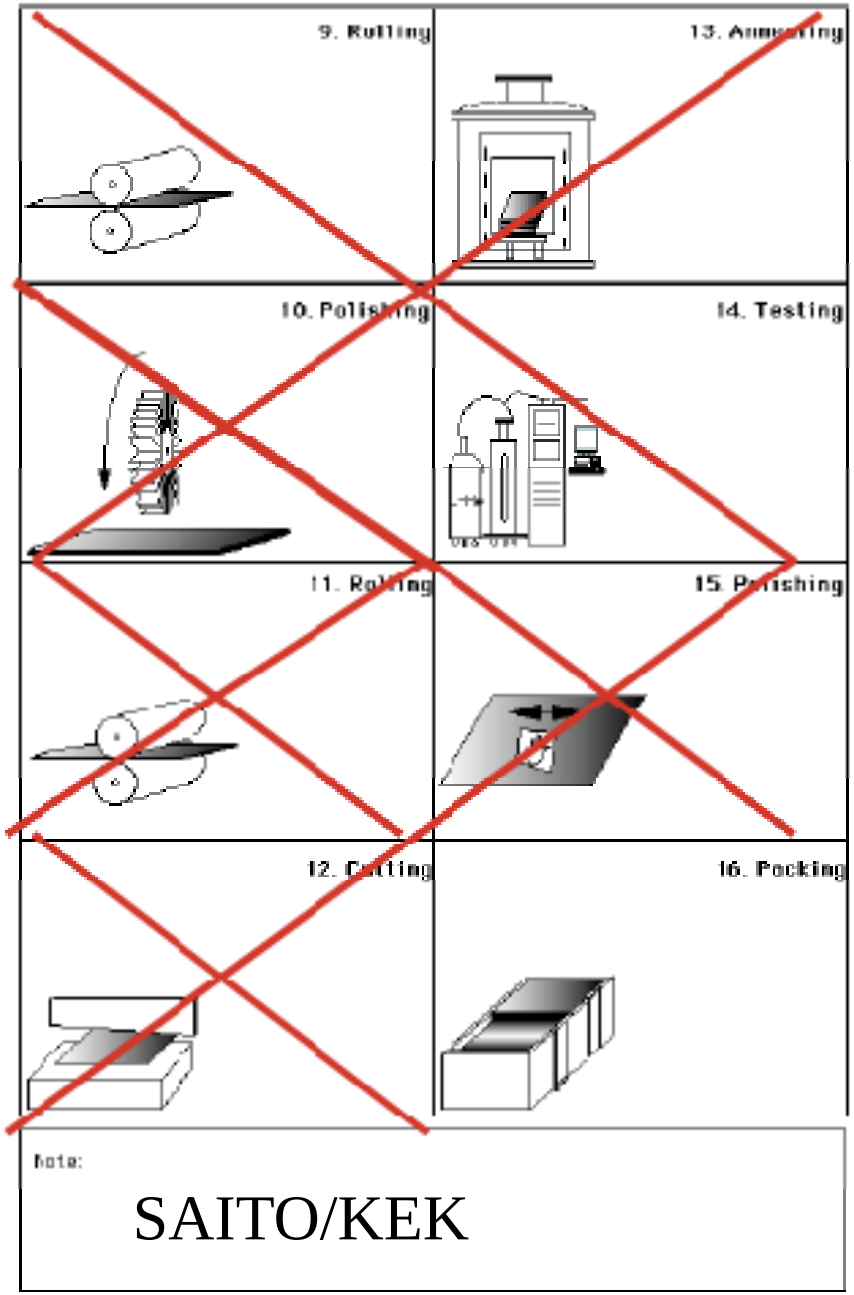


Polycrystalline niobium



Simplified Nb production by this slicing method

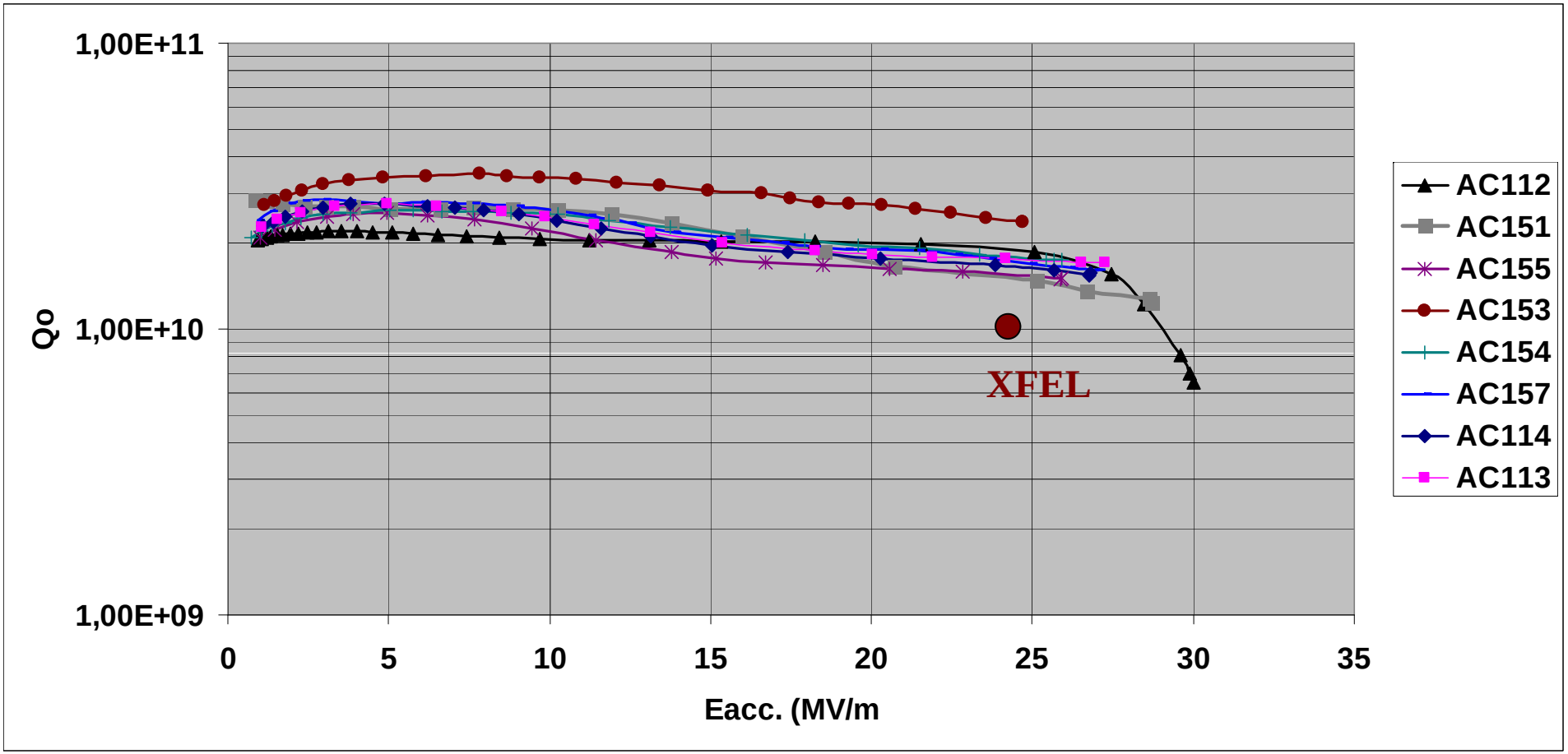




SAITO/KEK

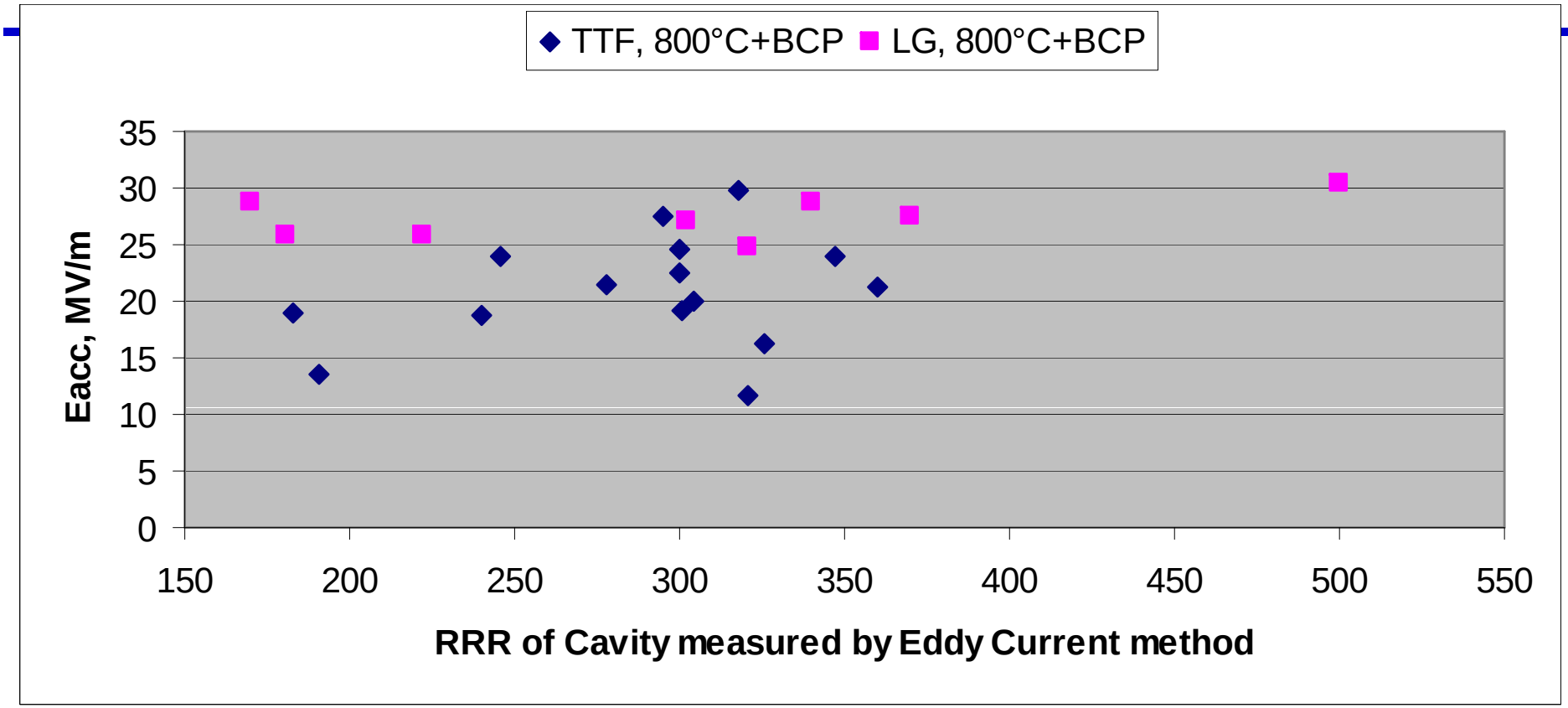
All available at DESY up to now Q(Eacc) of LG 9-cell cavities (AC112 was not baked)

DESY



XFEL requirements Eacc =24,3 MV/m fulfilled in first test.
Eacc 25 - 30 MV/m stably reachable after ca. 120µm BCP

DESY



Comparison of the E_{acc} performance of large grain (LG) 9-cell cavities with similarly treated fine grain TTF cavities.

BCP works for LG better compared to fine grain cavities

US007151347B1

(12) **United States Patent**
Myneni et al.

(10) **Patent No.: US 7,151,347 B1**
(45) **Date of Patent: Dec. 19, 2006**

(54) **PASSIVATED NIOBIUM CAVITIES**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 36 days.

(21) Appl. No.: **11/168,198**

(22) Filed: **Jun. 28, 2005**

(51) **Int. Cl.**
H01J 25/00 (2006.01)
H01J 25/10 (2006.01)

(52) **U.S. Cl.** **315/500**; 315/5.41

(58) **Field of Classification Search** 315/500, 315/505, 5.41, 5.42

See application file for complete search history.

(56) **References Cited**

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Primary Examiner—Trinh Vo Dinh

(57) **ABSTRACT**

A niobium cavity exhibiting high quality factors at high gradients is provided by treating a niobium cavity through a process comprising: 1) removing surface oxides by plasma etching or a similar process; 2) removing hydrogen or other gases absorbed in the bulk niobium by high temperature treatment of the cavity under ultra high vacuum to achieve hydrogen outgassing; and 3) assuring the long term chemical stability of the niobium cavity by applying a passivating layer of a superconducting material having a superconducting transition temperature higher than niobium thereby reducing losses from electron (cooper pair) scattering in the near surface region of the interior of the niobium cavity. According to a preferred embodiment, the passivating layer comprises niobium nitride (NbN) applied by reactive sputtering.

16 Claims, No Drawings

FIELD WORK PROPOSAL

1. WORK PROPOSAL NO.: JLAB-NP09-02	2. REVISION NO.:	3. DATE PREPARED: 5/09
4. WORK PROPOSAL TITLE: SRF Q_0 Improvement Program		5. BUDGET AND REPORTING CODE: KB
6. WORK PROPOSAL TERM: Begin _____ End _____		
7. HEADQUARTERS OFFICE PROGRAM MANAGER: Dr. Manouchehr Farkhondeh, (301) 903-4398 Manouchehr.Farkhondeh@science.doe.gov		8. HEADQUARTERS ORGANIZATION: Office of Science
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13. Proposal Description

The future NP programs require at least a factor of three improvements in the quality factor of the CW superconducting radio frequency accelerating cavities at an accelerating gradient of about 25 MV/m, in order to reduce the cryogenic refrigeration losses by a similar factor. Such an improvement will afford us to lower the electric power consumption and thereby reducing the operating costs of the future facilities. These advanced CW SRF cavities will find application in a wide variety of programs in BES, HEP, advanced reactor cycles using thorium as nuclear fuel, DoD, commercial and University compact linacs and FEL's. This program is a collaborative effort among Jefferson Lab, commercial enterprises and Universities and is multidisciplinary research in nature thereby amply satisfying DOE NP ARRA objectives. In addition this program is expected to create long term jobs in the private sector and also provides opportunities for training future generation scientists, engineers and technical staff in a demanding and fulfilling environment. We seek to develop green processes and apparatus for ingot niobium based SRF accelerator structures in order to improve their quality factors by a factor of three or more. During the first phase, we will study the interaction of surface and bulk hydrogen with the natural surface niobium oxides and the influence of passivating nitrogen layer on the surface – bulk hydrogen and the reduction of surface oxides during the passivation process. For these studies we will develop special experimental apparatus for the direct investigation of surface conductivity and micro magnetic properties of niobium in the temperature range 600 and 2 K using eddy current technique in the frequency range 1 kHz to 2 GHz. In addition we will also simultaneously employ reflection spectroscopy from the infrared through visible wave lengths. The second phase goal is to build special apparatus for not only economically and efficiently stress relieving the deep drawn and machined cavity half cells but also for passivating the surfaces of the cavity. The design and development of this special apparatus and its eventual request for supply from other SRF Institutions in the world is expected to provide long term jobs for the partner US Company, Casting Analysis Corp., VA.

Conclusions

- **JLab introduced ingot niobium technology in 2004**
- **High tantalum in ingot niobium is not expected to negatively impact the performance of the cavities but will reduce the cost of accelerator structures considerably**
- **A clean UHV furnace with induction heating will eliminate contamination of cavity surfaces and avoid the final chemistry (Development with Casting Analysis Corporation)**
- **Optimized low cost CW linacs built with ingot niobium will pave the path for future R&D and industrial applications**