SSTIN10 High-Lights and Beyond

Ganapati Rao Myneni

Accelerator Division, Jefferson Lab
&
Materials Science and Engineering and
Engineering Physics, University of Virginia

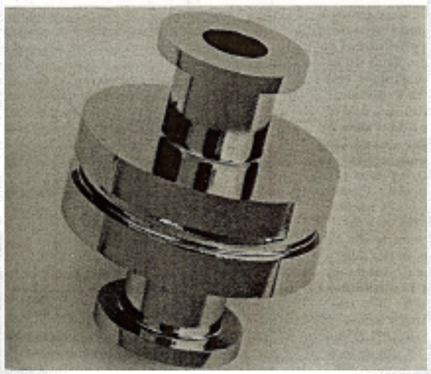
TTC Meeting
Milano, Italy
Feb 28-March 3, 2011

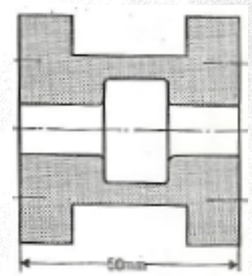
http://conferences.jlab.org/sstin/index.html

The attendees are pictured above and speakers with the program topics covered can be found in the above web link


SSTIN10
PROGRAM COMMITTEE:
Ganapati Rao Myneni Chair, UVa/JLab – USA
Bob Rimmer JLab – USA
Chris Adolphsen SLAC – USA
Ilan Ben-Zvi BNL – USA
Walter Hartung MSU – USA
Kwang-Je Kim ANL – USA
John Mammosser SNS – USA
Shekhar Mishra FNAL – USA
Sindhunil Roy RRCAT – India
Kenji Saito KEK – Japan
Friedhold Schoelz Heraeus – Germany
Waldemar Singer DESY – Germany
Marcos Stuart CBMM – Brazil
Kui Zhao PKU – China
INTERNATIONAL ADVISORY COMMITTEE
Tadeu Carneiro CBMM – Brazil
Andrew Hutton JLab – USA
Srikumar Banerjee BARC – India
Reinhard Brinkman DESY – Germany
Swapan Chattopadhyay Cockcroft Institute – UK
Helen Edwards FNAL – USA
Manouchehr Farkhondeh DOE – USA
Ron Graham ATI Wah Chang – USA
Georg Hoffstaetter Cornell Uni. – USA
Carlos Pagani Univ Milan/INFN – Italy
Amit Roy IUAC – India
Akira Yamamoto KEK – Japan
Richard York MSU – USA
Organizing Committee
Ganapati Rao Myneni Chair, JLab/ISOHIM – USA
Gianluigi Ciovati JLab – USA
Ruth Bizot JLab – USA
Carolyn Camp JLab – USA
Marty Hightower JLab – USA
Cynthia Lockwood JLab – USA
Stephanie Schatzel JLab – USA
International Symposium On Hydrogen In Matter (ISOHIM) Board Members:
Jim Miller - Co-Chair, ANL USA
Ganapati Rao Myneni - Co-Chair, JLAB, USA
Guenter Luepke - Secretary, College of W&M, USA
Srikumar Banerjee - AEC-DAE, India
Bob Bowman - JPL - Caltech (Retired), USA
Tadeu Carneiro - CBMM, Brazil
Christian Day - KIT, Germany
Rod Gerig - ANL, USA
Peter Lindblad - Uppsala University, Sweden
Richard Ricker - NIST, USA
John Wallace - Casting Analysis Corporation, USA
Myneni
Ciovati
Stuart
Symposium on the Superconducting Science & Technology of Ingot Niobium
2010
AIP Conference Proceedings
AIP
International Symposium On Hydrogen In Matter (ISOHIM)
Jefferson Lab
CBMM
Symposium on the Superconducting Science & Technology of Ingot Niobium
Jefferson Lab • Newport News, Virginia, USA
September 22-24, 2010
Editors:
Ganapati Rao Myneni
Gianluigi Ciovati
Marcos Stuart
CP 1352
AMERICAN INSTITUTE OF PHYSICS
AIP CONFERENCE PROCEEDINGS

Introductory Remarks on historical data





Stanford ca. 1970

BCP

Qo ~ 1e11 @ 1.2 K CW

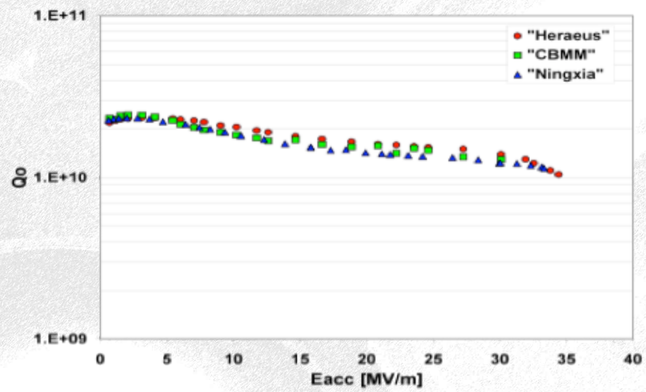
Hpk ~ 108 mT

Siemens ca. 1973

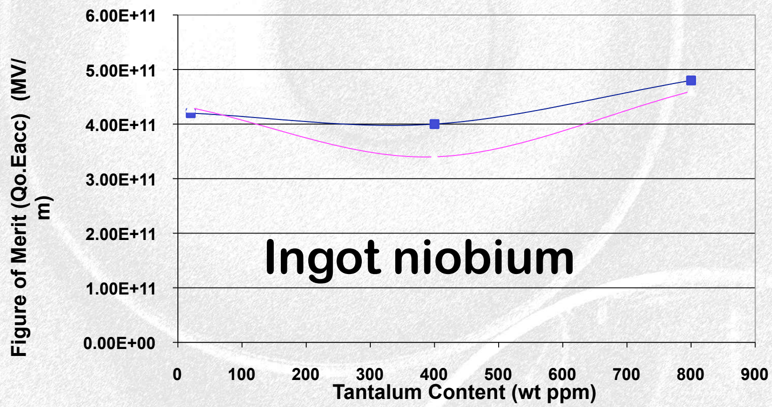
EP	BCP
130 mT	109 mT

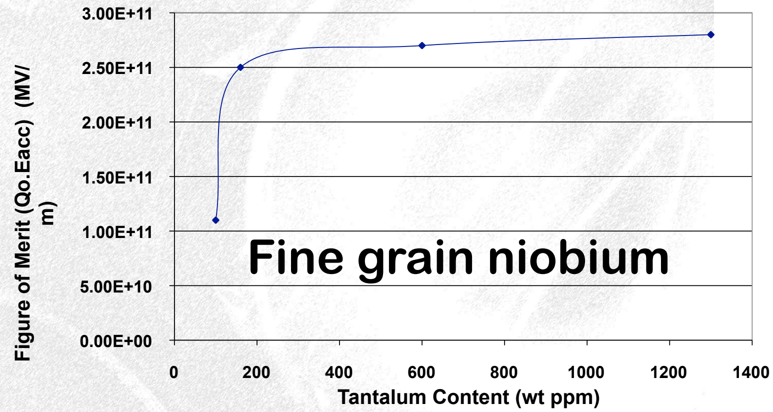
Reactor grade Ep'd Siemens fine grain cavity Hpk ~ 159 mT Qo ~ 1e10 @ 1.45 K

Introductory Remarks on recent data



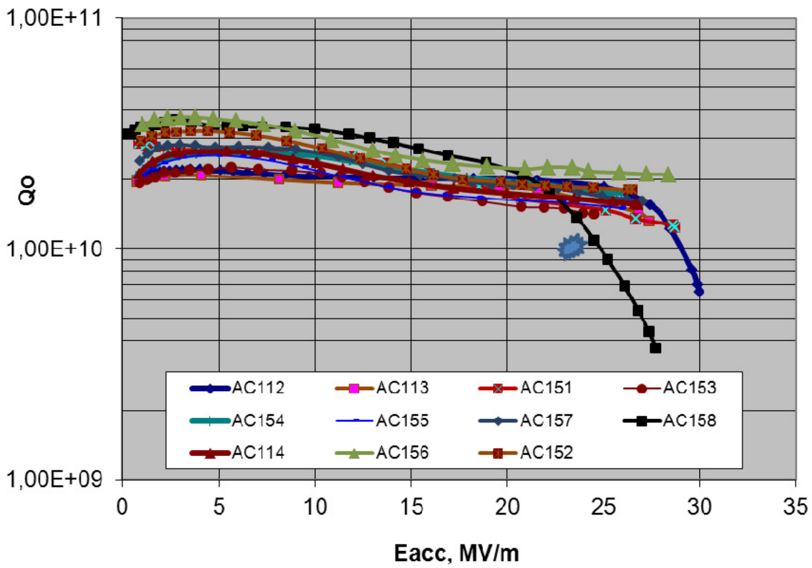
Ingot niobium cavities of different RRR performed equally well – un optimized processes

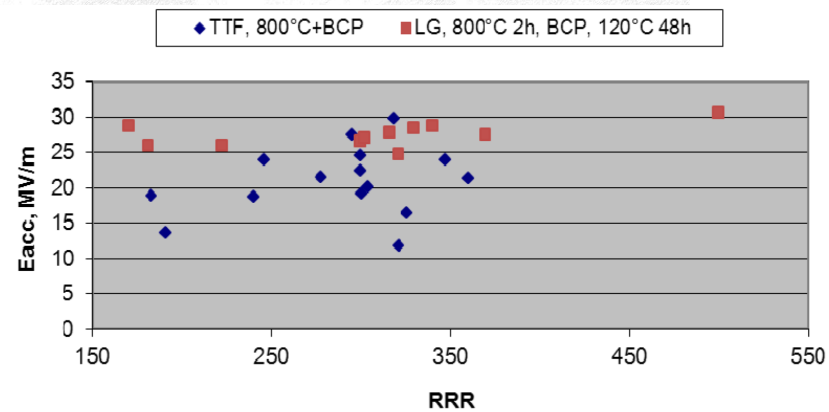




Ingot niobium has higher figure of merit than fine grain

Ingot niobium technology successfully implemented in FLASH cryomodule

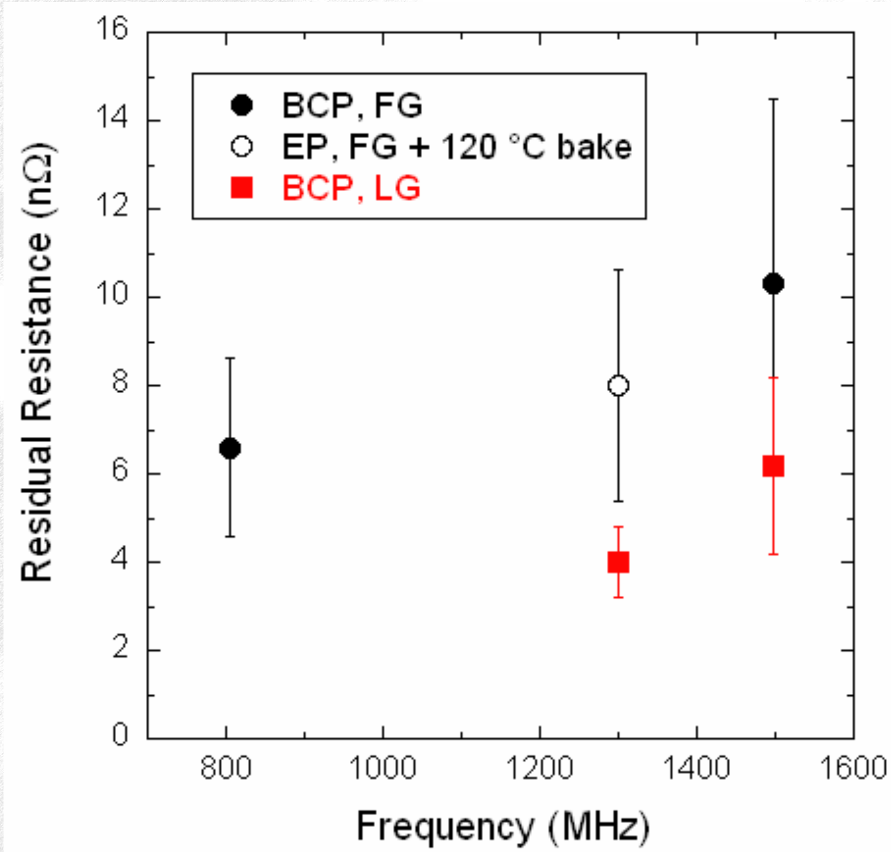




All ingot niobium cavities met XFEL specifications with BCP irrespective of RRR

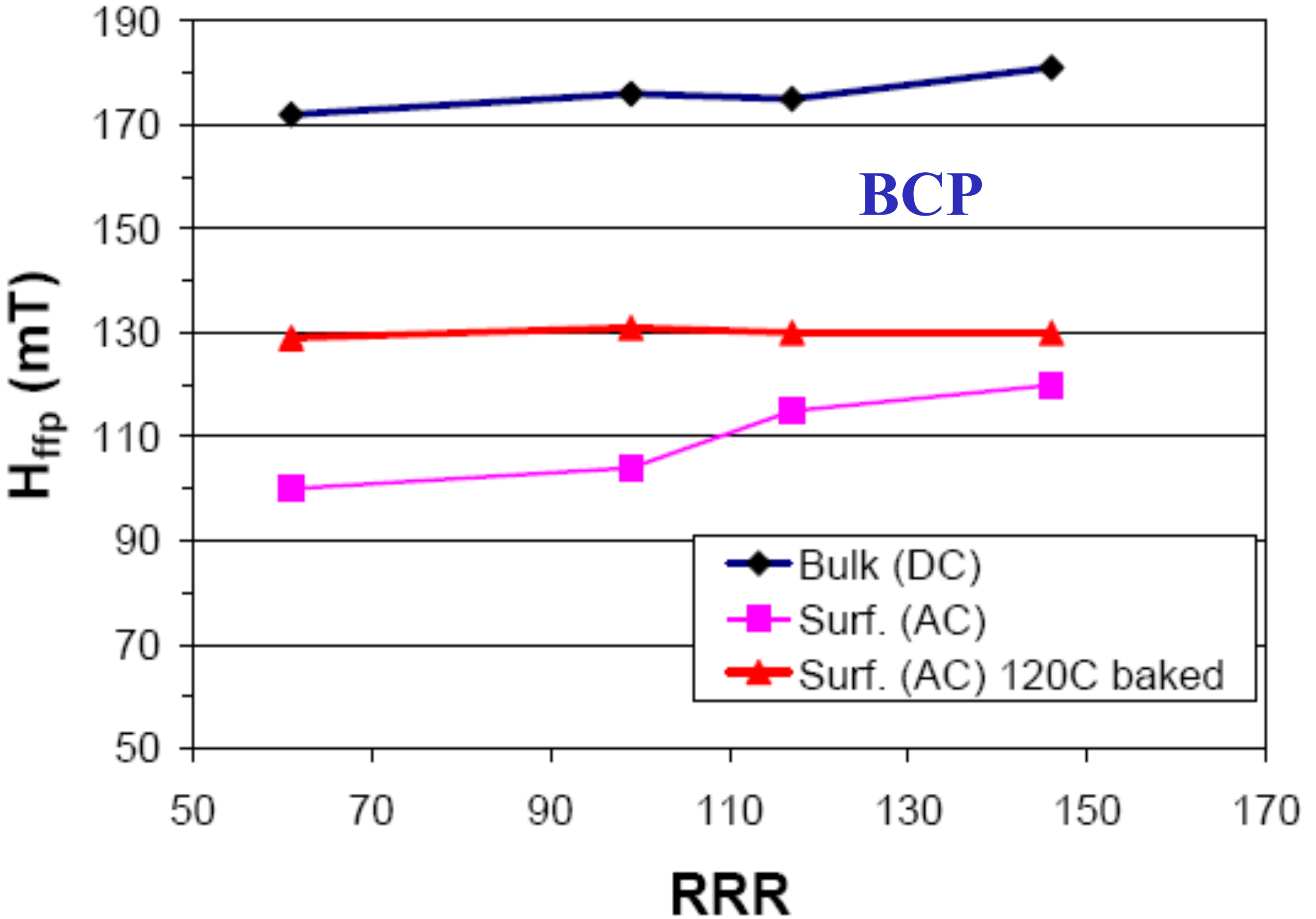
DESY, RI, Heraeus

Ingot niobium-low residual resistance



JLab

Ingot niobium RRR does not influence first flux penetration



JLab/BARC

Tantalum and RRR influence on bulk & surface critical fields

Bulk

Sample	EP		EP + LTB (120 °C, 48 h)	
	H_{ffp} (mT)	H_{c2} (mT)	H_{ffp} (mT)	H_{c2} (mT)
A	174	405	177	390
B	182	400	184	400
C	179	400	180	400
D	186	405	188	420
FG	183	380	183	400

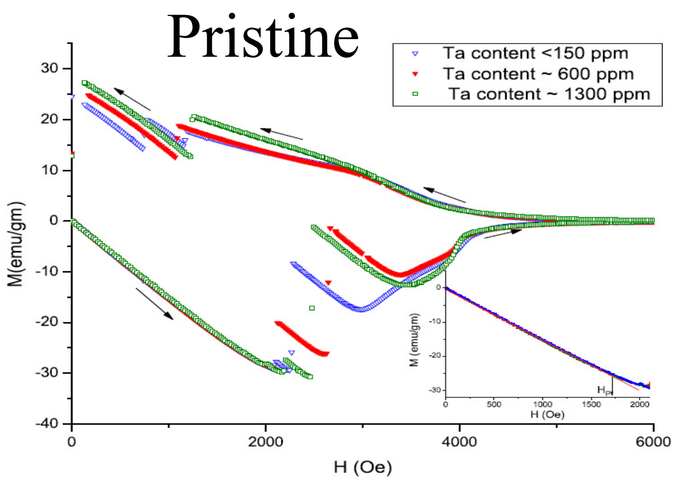
Surface

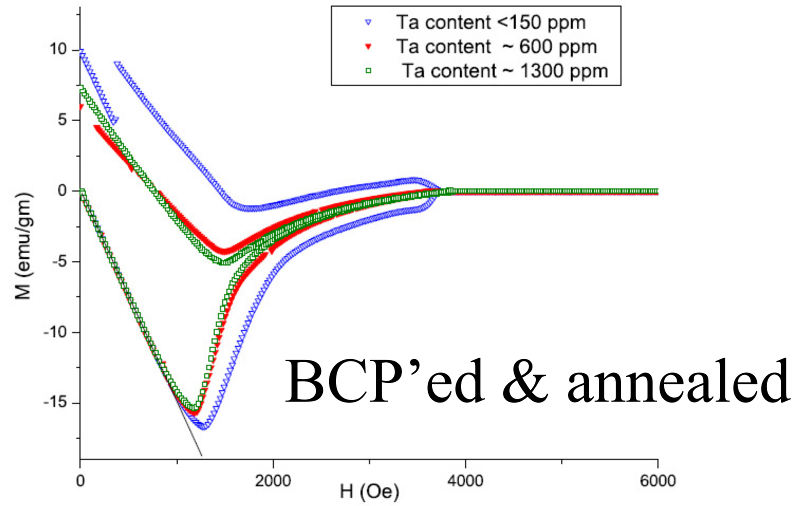
Sample	EP				EP + LTB			
	H_{ffp} (mT)	H_{c2} (mT)	H_{c3} (mT)	H^{c}_{c3}/H_{c3}	H_{ffp} (mT)	H_{c2} (mT)	H_{c3} (mT)	H^{c}_{c3}/H_{c3}
A	162	322	749	0.89	175	351	850	0.87
B	175	317	705	0.89	180	381	>1000	< 1.0
C	160	331	753	0.87	168	351	1000	0.9
D	160	330	740	0.9	166	347	750	0.93
FG	164	301	700	0.93	170	320	>1000	0.93

A (1295,62), B(1310,164), C(600, 160), D(970, 118), FG(100, 280)

Key X(y,z) = Sample (Ta, RRR) **JLab/BARC**

Tantalum-minimally effects first flux-line penetration



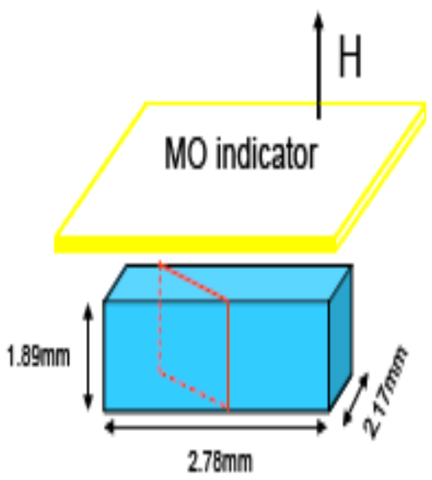


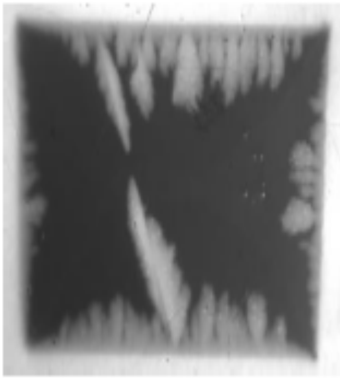
Ta-Content	Nature of the Nb sample	H_P(Oe) at 2K
< 150 ppm	Pristine	1700 Oe
≈ 600 ppm	Pristine	1600 Oe
≈ 1300 ppm	Pristine	1600 Oe
< 150 ppm	BCP treated & annealed	1050 Oe
≈ 600 ppm	BCP treated & annealed	950 Oe
≈ 1300 ppm	BCP treated & annealed	950 Oe

1250 C anneals improve Hp as expected **JLab/RRCAT**

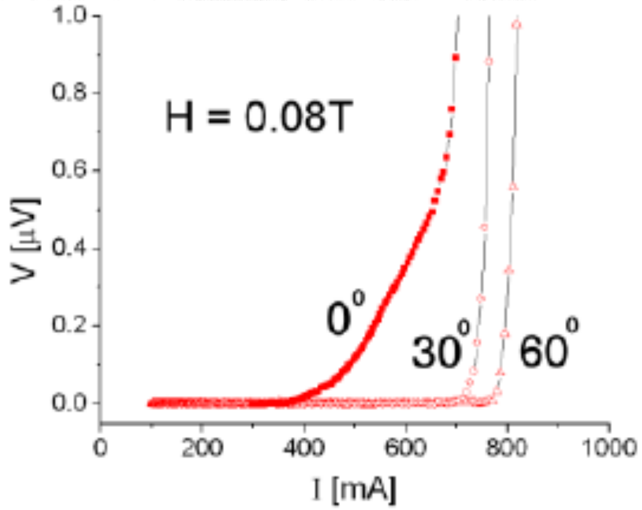
Flux penetration – grain boundaries

Magneto optical imaging





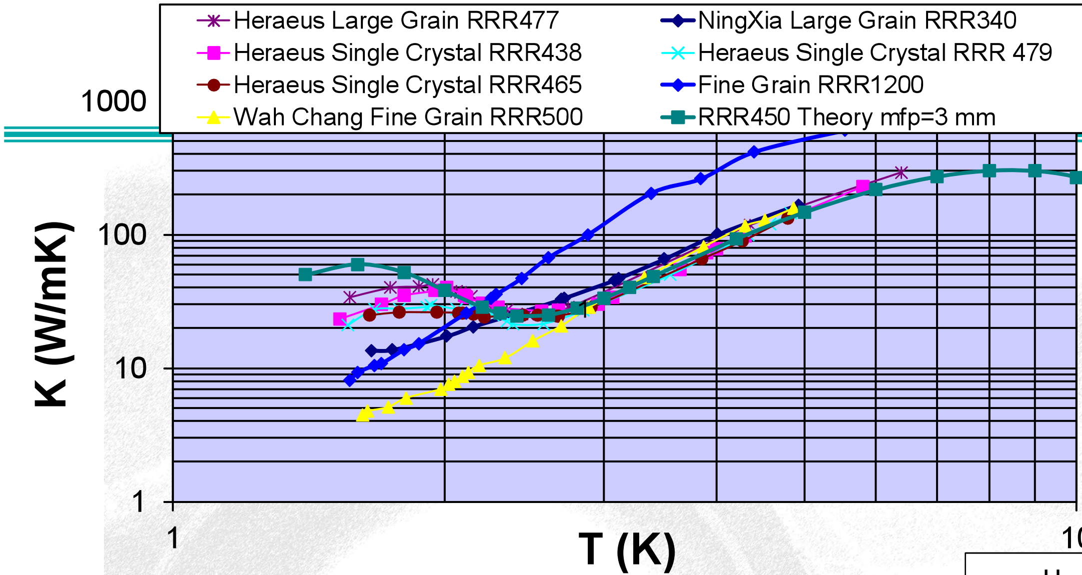
Transport measurements



Sensitive to the orientation of the external field to the grain boundary plane

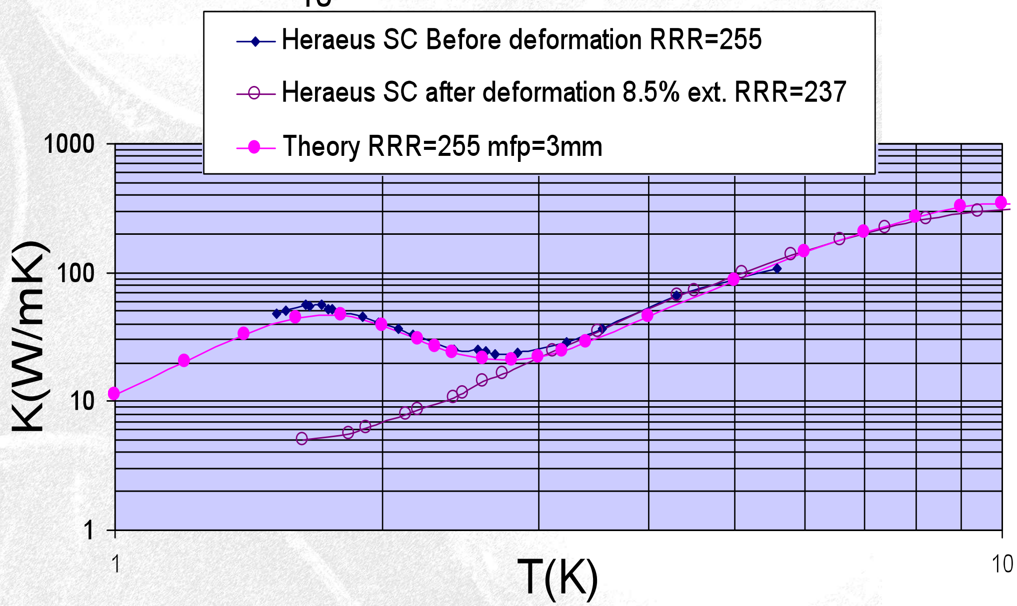
MSU

DESY earlier thermal conductivity data



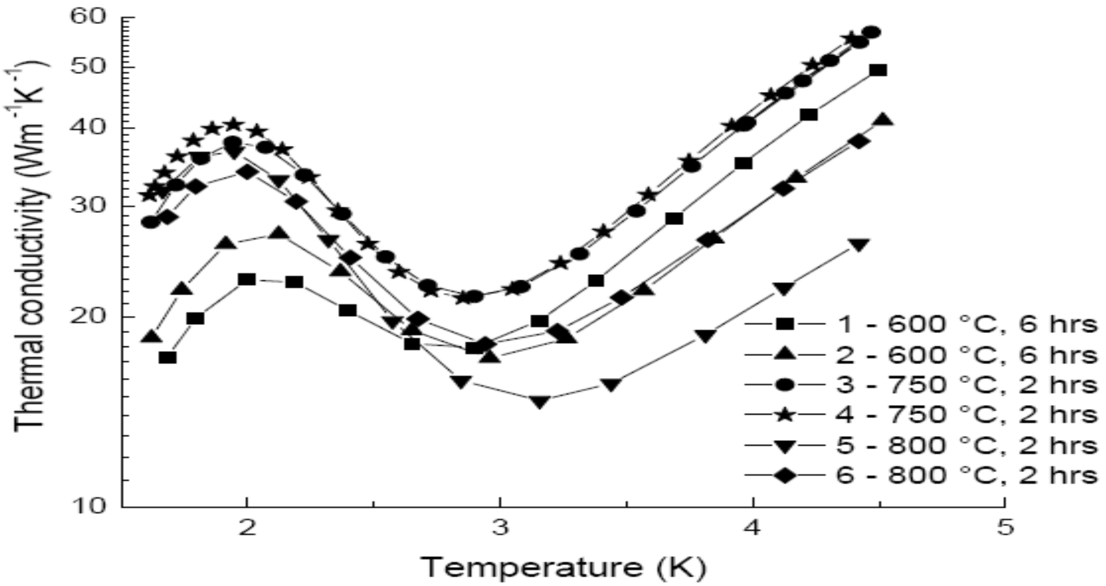
Thermal conductivity of fine grain, large grain and single crystal niobium (mfp: phonon mean free path)

Plastic deformation influence on thermal conductivity of single crystal niobium



W. Singer

Tantalum and RRR have minimal influence on thermal conductivity

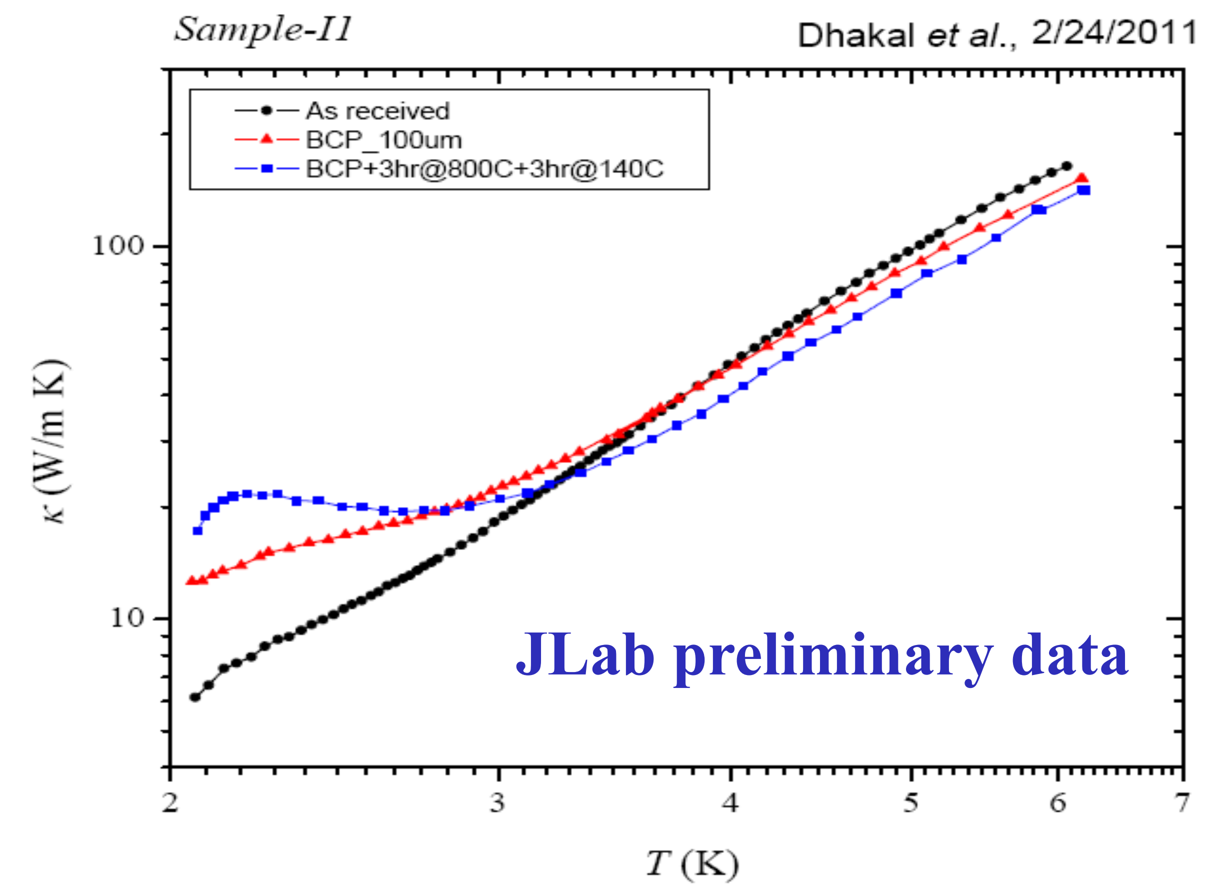


Specimen	Estimated RRR	Tantalum content (ppm) [3]	Heat Treatment	Titanium getter
1	191	1275	600 °C, 6 hrs	No
2	131	668	600 °C, 6 hrs	No
3	190	756	750 °C, 2 hrs	Yes
4	196	756	750 °C, 2 hrs	Yes
5	104	1322	800 °C, 2 hrs	No
6	143	523	800 °C, 2 hrs	No

Ingot niobium

MSU

Annealing recovers phonon peak



Unclean furnaces are likely to contaminate the cavities

Niobium – hydrogen affinity

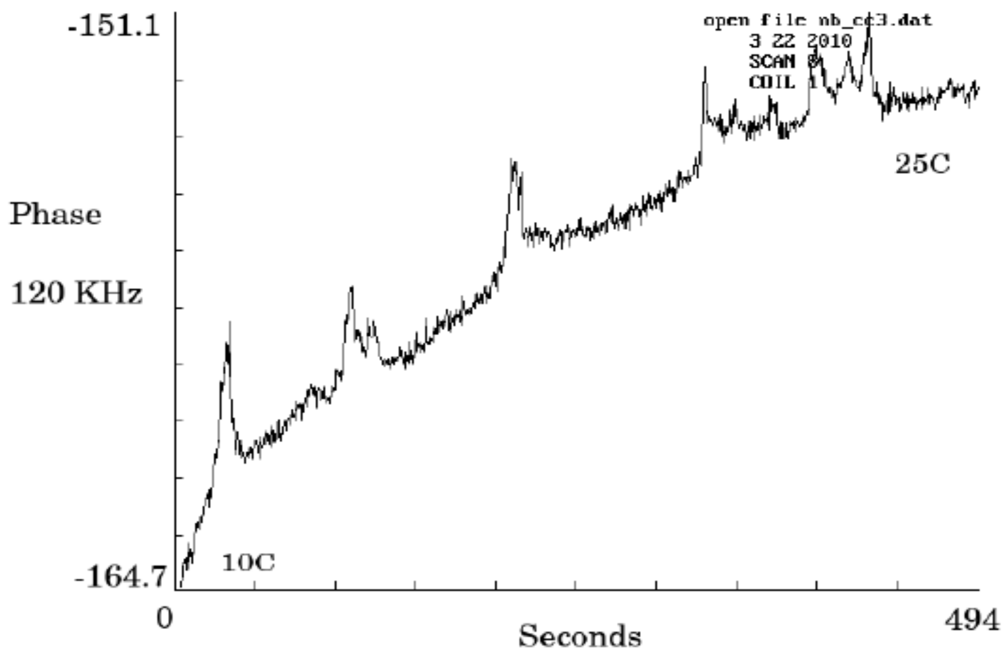
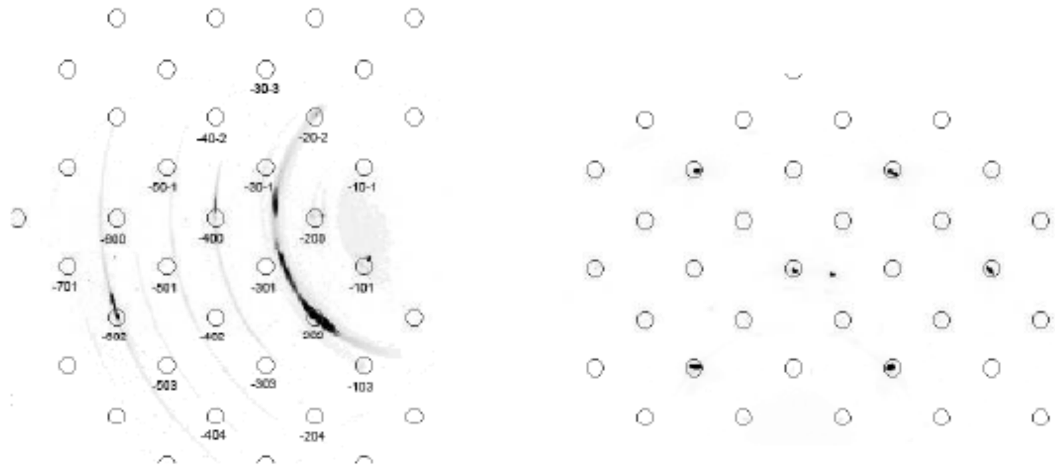


FIGURE 1. Induction refelection method for detecting conductivity and permeability changes in a sample of fine grain SRF niobium. Vacuum melted fine grain niobium, high purity niobium, EDM cut face and BCP treated. The sample was cooled to 77K and was allowed to warm to room temperature and was being monitored by a single coil weak field induction reflection. Normally over the very narrow temperature range of 15^oC the phase would have increased possibly $.2^o$ or less not 13^o which was measured. But in addition to that there are a number of transient responses indicating that regions of the material have had temporary surges in the value of the magnetic permeability. This behavior is not typical of a nominally pure metallic conductor but it is just one of the many anomalous responses found in SRF prepared niobium.

Casting Analysis, JLab, W&M

XRD comparison of EDM cut and polished and unprocessed ingot Nb



EDM cut and metallurgically polished niobium

unprocessed pure niobium

FIGURE 3. This is an X-ray diffraction comparison of EDM cut and polished SRF niobium ready for forming and BCP treatment on the left and a virgin piece of large grain material not EDM cut. Shown are pseudo-precessional images composited from multiple diffraction frames. Circled locations are predicted diffraction locations (including those from systematic absences) for the BCC niobium lattice. The patterns are remarkably different in the very large continuous mis-orientation of the diffraction planes in the EDM cut samples.

XRD is a useful tool for determining the hydrogen induced damage

Casting Analysis, JLab, W&M

High temperature annealing removes gross hydrogen

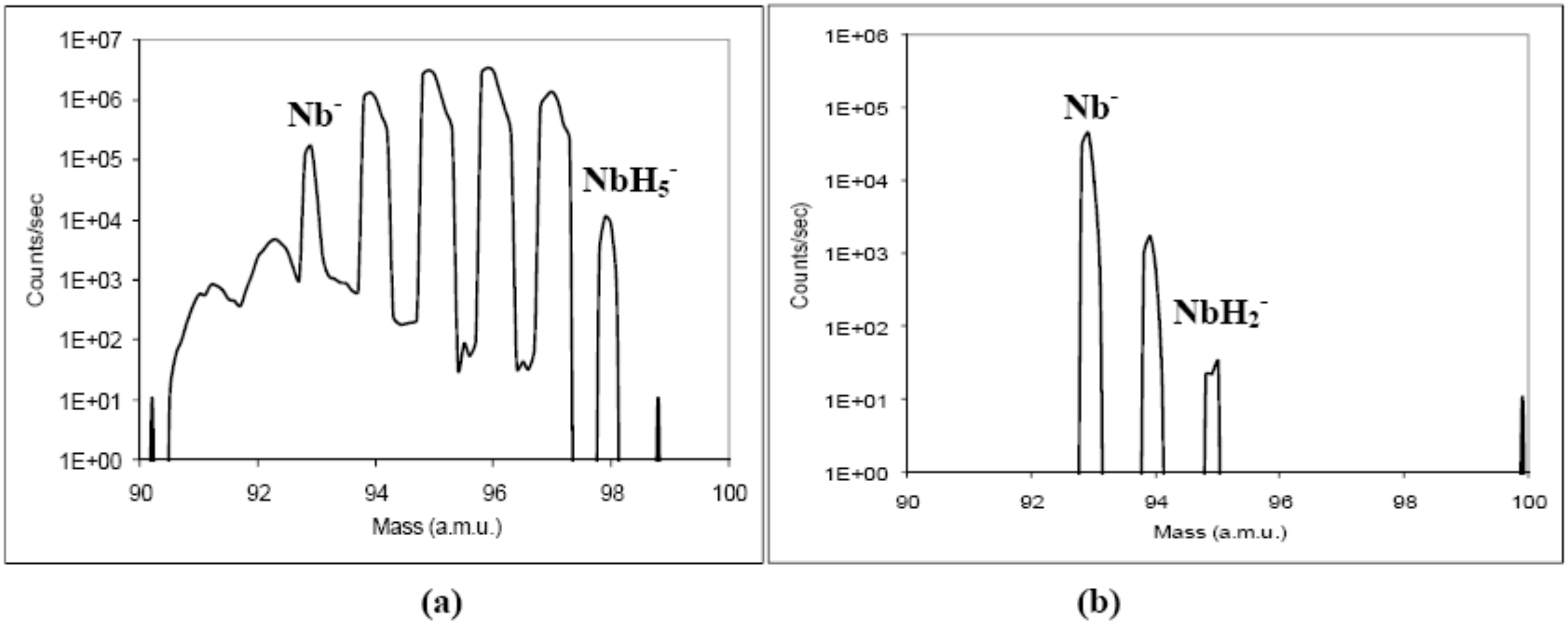


FIGURE 1. SIMS mass spectra showing difference in H between (a) non-heat treated and (b) heat treated sample.

NbH is very much in existence after anneals

NCSU/JLab

Hydrogen absorption with BCP and EP

Very high equilibrium hydrogen activities (fugacity) have been estimated when Nb metal is in contact with water or BCP solution

Hydrogen is readily absorbed into Nb when the protective oxide layer is removed

Lower H fugacities are obtained due to an anodic polarization of Nb during EP and hence lower hydrogen absorption

Fine grain Nb has high energy grain boundary morphologies and orientations that make hydrogen induced heterogenous nucleation of second phases or micro-voids with BCP

Ingot niobium will have very few to none of the micro-voids

R.E. Ricker, G. R. Myneni J. Res. Natl. Inst. Stds. Tech 115 (8), 353-371 (2010)

NIST/JLab

More High Lights of SSTIN10

- The solidification process of ingots of various vendors is not controlled & random orientations of grains and or grain boundary misorientations result & use of Laue camera for orientation measurements is an alternative to orientation image microscopy **MSU**
- Hydrogen plays a role in low beta structures and there is a strong need for more outgassing studies in this community **TRIUMF, FNAL**
- **BARC, India** is developing low beta1056 MHZ elliptical cavities from low RRR and High Ta content ingots for ADS applications
- **SNS** is developing a demountable TM020 cavity from low RRR and high Ta content ingots for plasma cleaning procedure
- **Heraeus independently** and **Toky Denkai** in collaboration with **KEK** have implemented multi slice machines
- **KEK** is leading a major effort in collaboration with **IHEP** and **PKU** on **SSTIN** activities
- **CBMM** and **JLab** are collaborating with international partners on **SSTIN** R&D Programs
- **Casting Analysis** and **JLab** are developing unique tools for addressing **Proton in SRF niobium & the effects on superconducting and mechanical properties**

Conclusions

- DESY, RI and Heraeus have successfully implemented ingot niobium technology in FLASH cryomodules
- Low RRR and high Ta content ingots are viable for SRF CW technology applications
- Proton in SRF niobium studies are expected to create an understanding and improvement of the Qo and performance of accelerator structrues

Beyond

- A combined annual Accelerator Driven Systems (ADS) and SSTIN meetings will be hosted
- The first of such meeting is tentatively scheduled at BARC, Mumbai, India November 30-December 2, 2011
- We look forward to welcoming you to this International Workshop on ADS and Thorium Utilization
- We are striving to industrialize the high efficiency and relatively low cost ingot Nb CW SRF Systems for ADS applications
- Join us and help usher in the green nuclear energy for the benefit of the mankind