Physical and Mechanical Properties of Single and Large Crystal High-RRR niobium

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SRF 2005 Workshop
Cornell University

Collaborators

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Introduction

- **SNS Cavity RRR Niobium Issues**
- **Hydrogen Workshop November 2002 (ISOHIM)**
- **Niobium Consortium Formation**
- **Reference Metals/CBMM CRADA**
- **Single/Large Grain Niobium Developments**

Types of high RRR bulk niobium

1. Polycrystalline niobium from standard process including rolling & recrystalization

   No apparent control on the microstructure, texture and Heterogeneity

2. High Tantalum content RRR niobium is available at reduced cost
   Measurements indicate 1300 ppm Ta cavity reaches Eacc ~ 30 MV/m

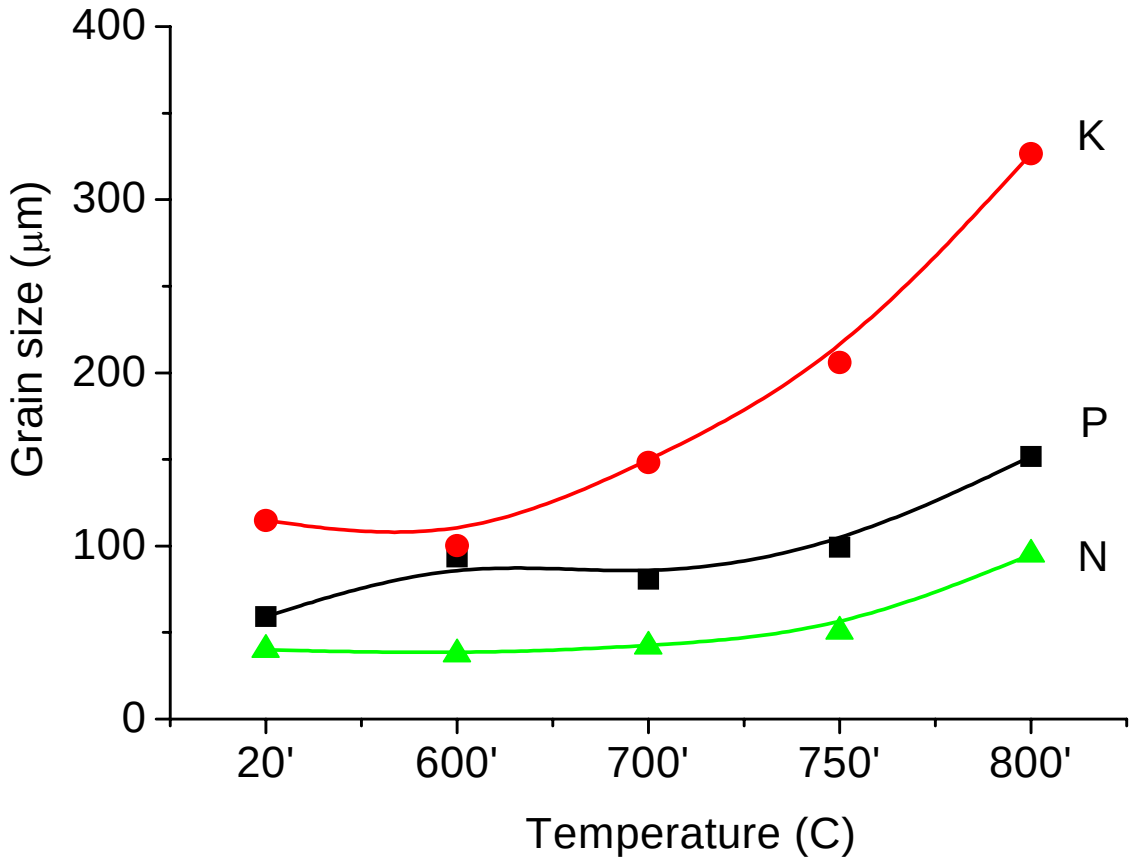
3. Single/large crystal ingots with required orientation

   One obtains the discs directly form slicing of the ingots, reduced process steps leading to lower costs and potentially very good performance

What Do We Know About RRR Nb

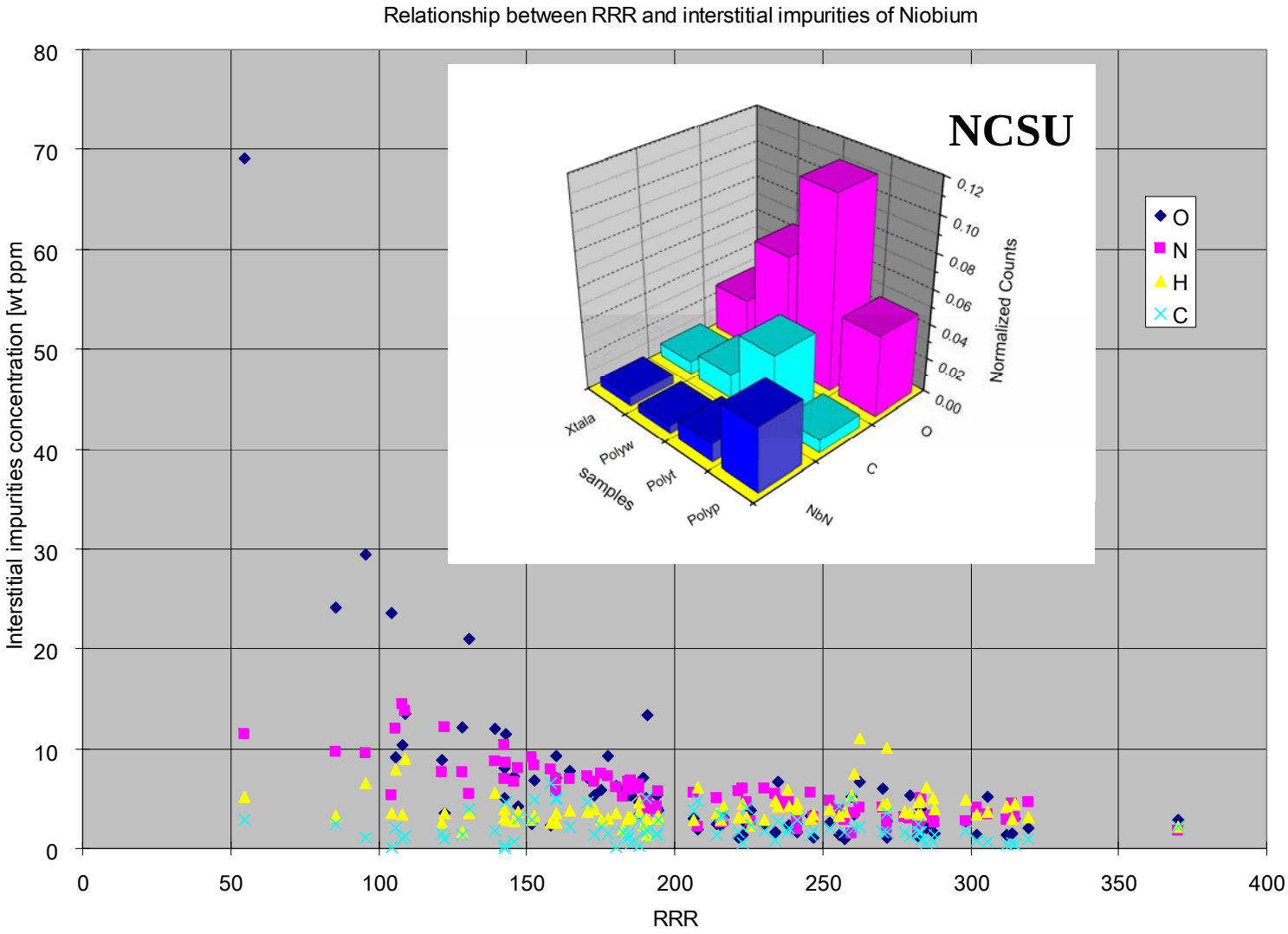
- We like to have highest RRR (Thermal Conductivity for Thermal Stability) @4.3 K Spec.
- 30 – 40 % Percentage of Elongation for forming the half cells
- We specify certain Yield Strength
- We have Specifications for impurity content (But can't Verify with the available techniques)
- We have no control on the major properties of RRR Nb as produced today in the form of sheets
- So there are opportunities to optimize these properties

UVa Measurements

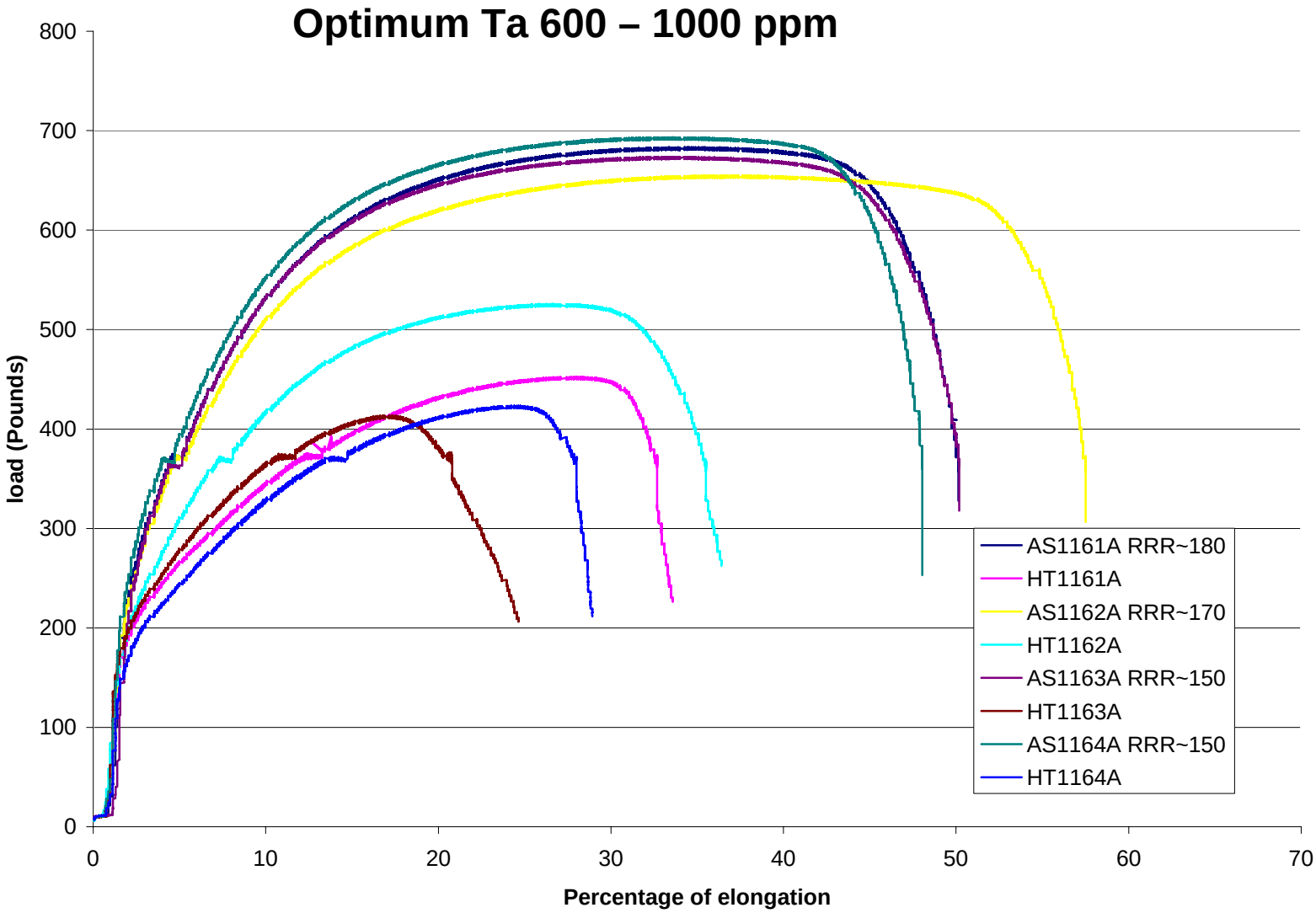


Lineal intercept grain size as a function of annealing temperature for the three lots of high-purity niobium

Interstitials vs RRR (Tokyo Denkai)

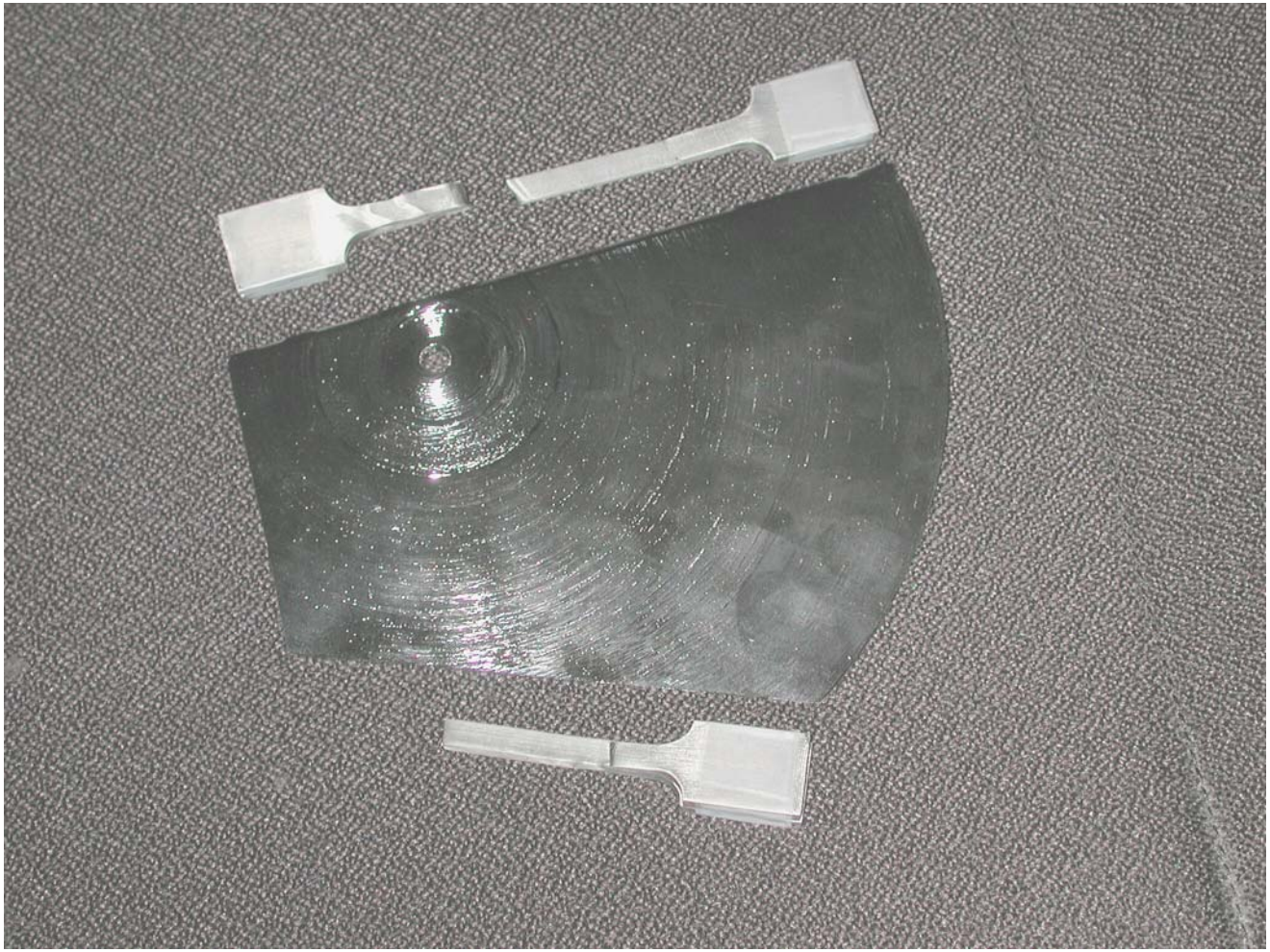


Effect of Tantalum on Mechanical Properties

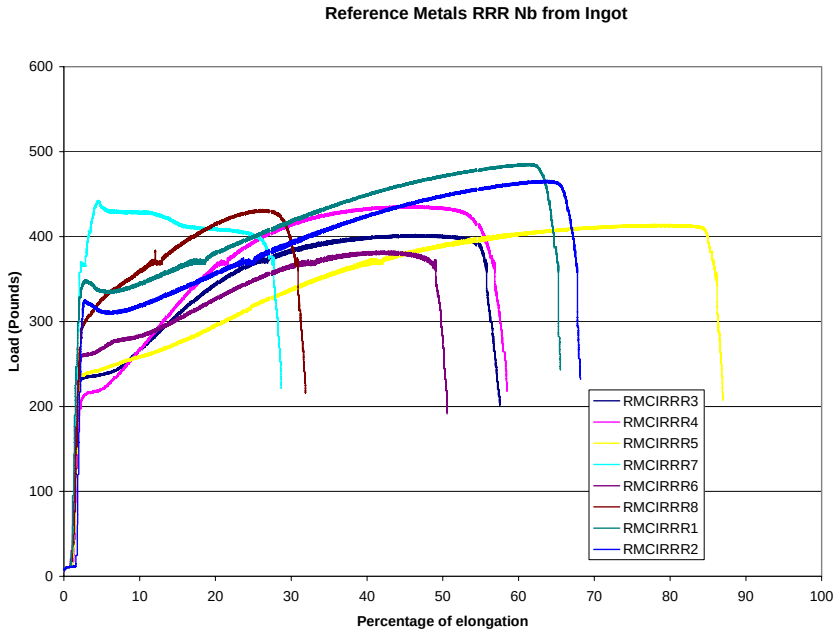


Large Grain RRR Niobium

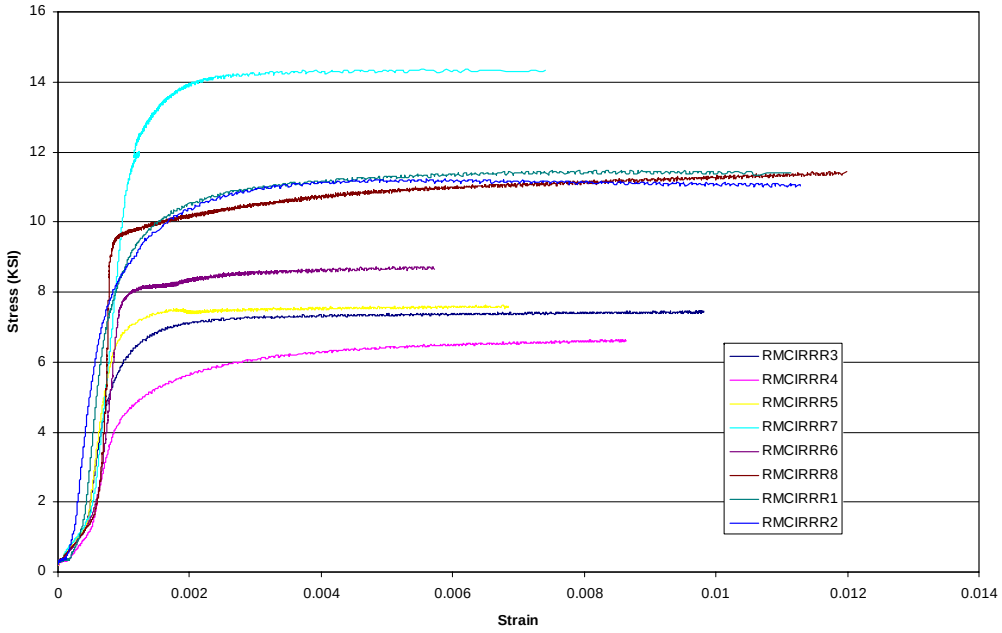
Single Crystal Niobium



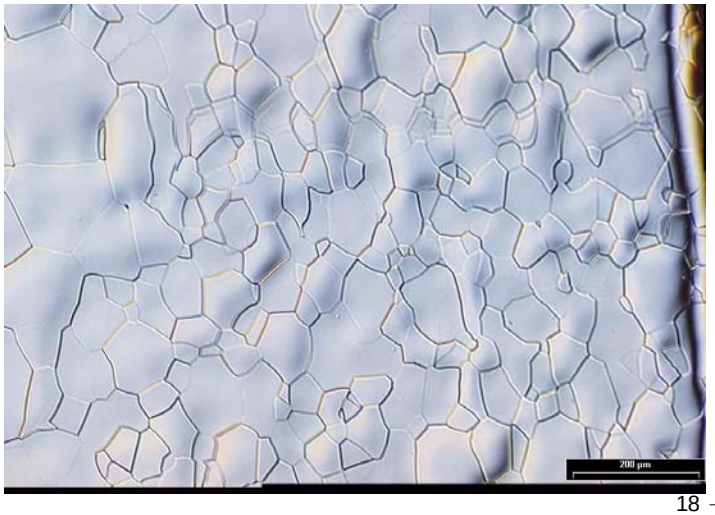
RRR Nb from Ingot



Ta ~ 800 ppm, RRR ~ 280

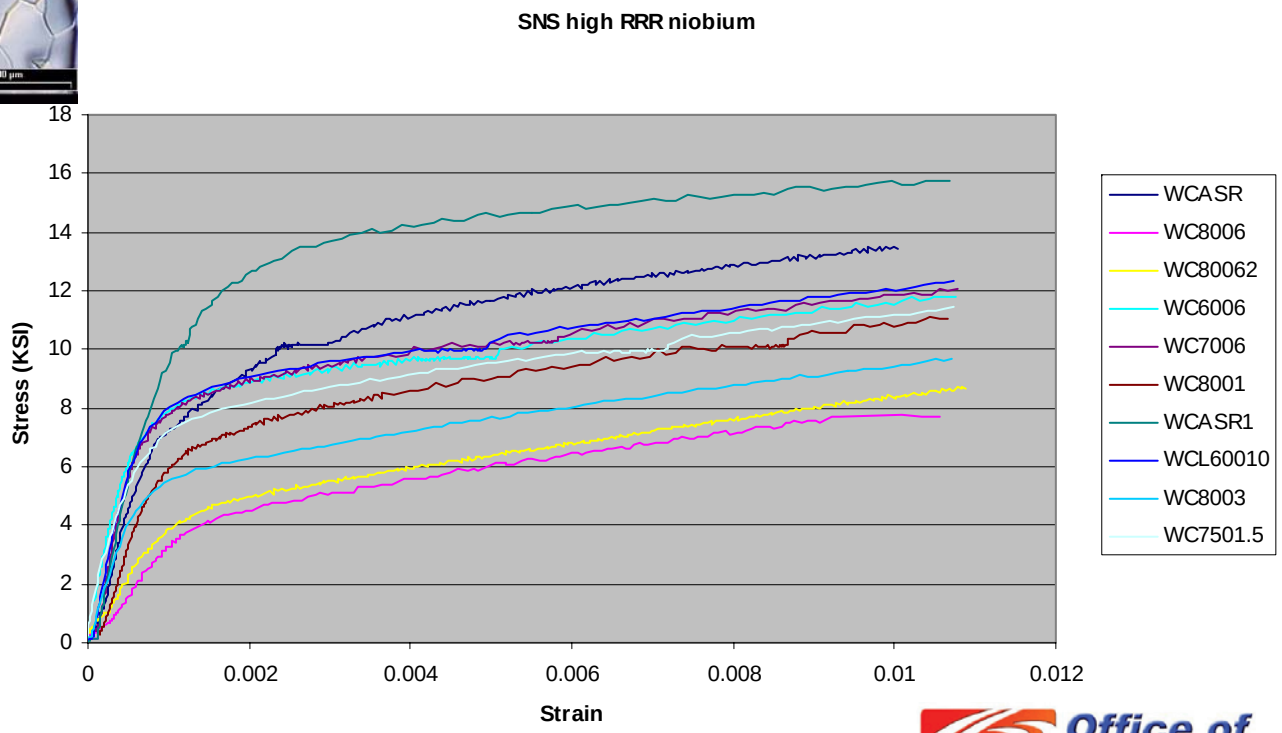


Polycrystalline RRR niobium



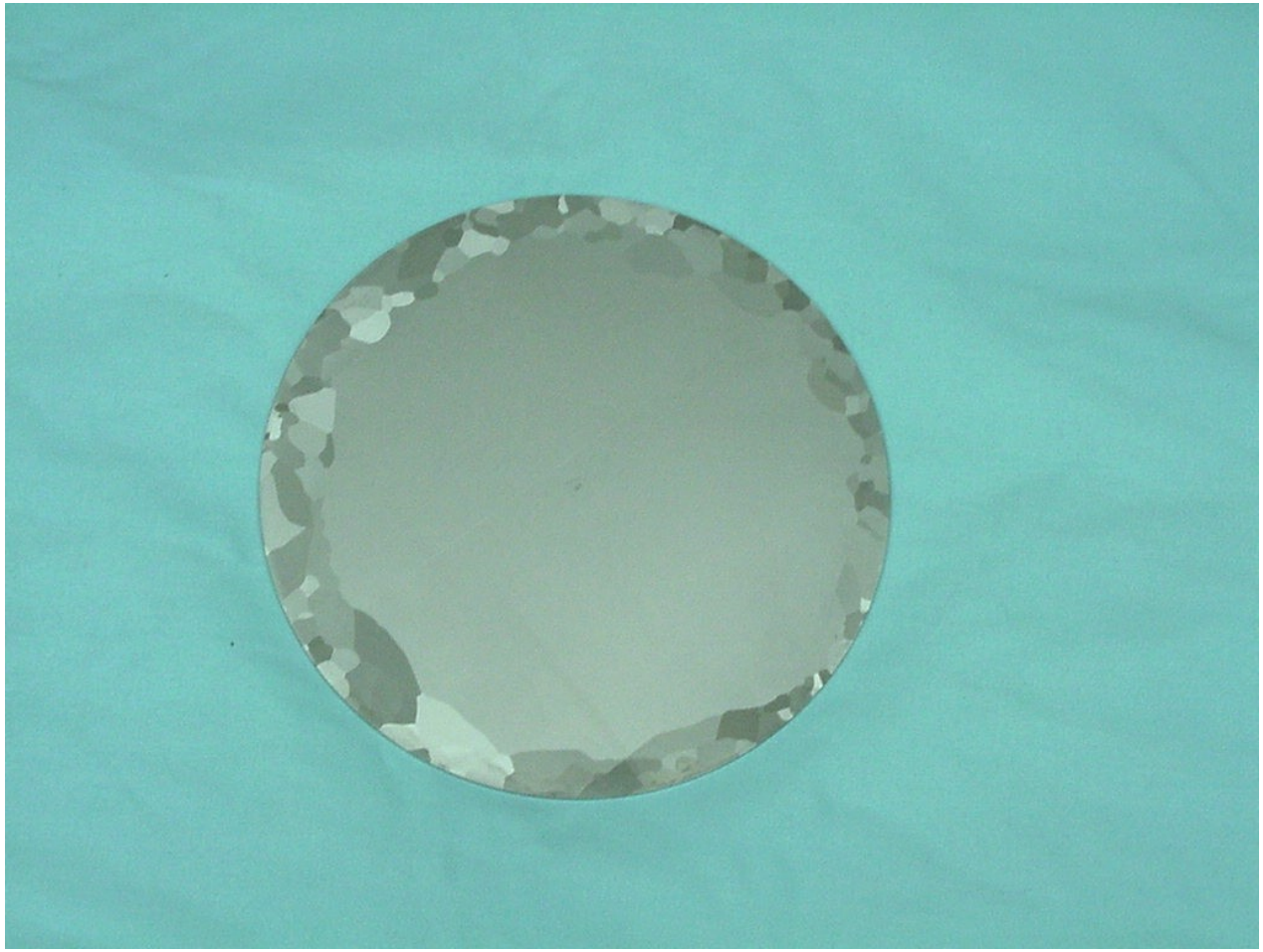
Damage layer ~ 200 to 300 microns

Elastic Modulus
~110 GPa



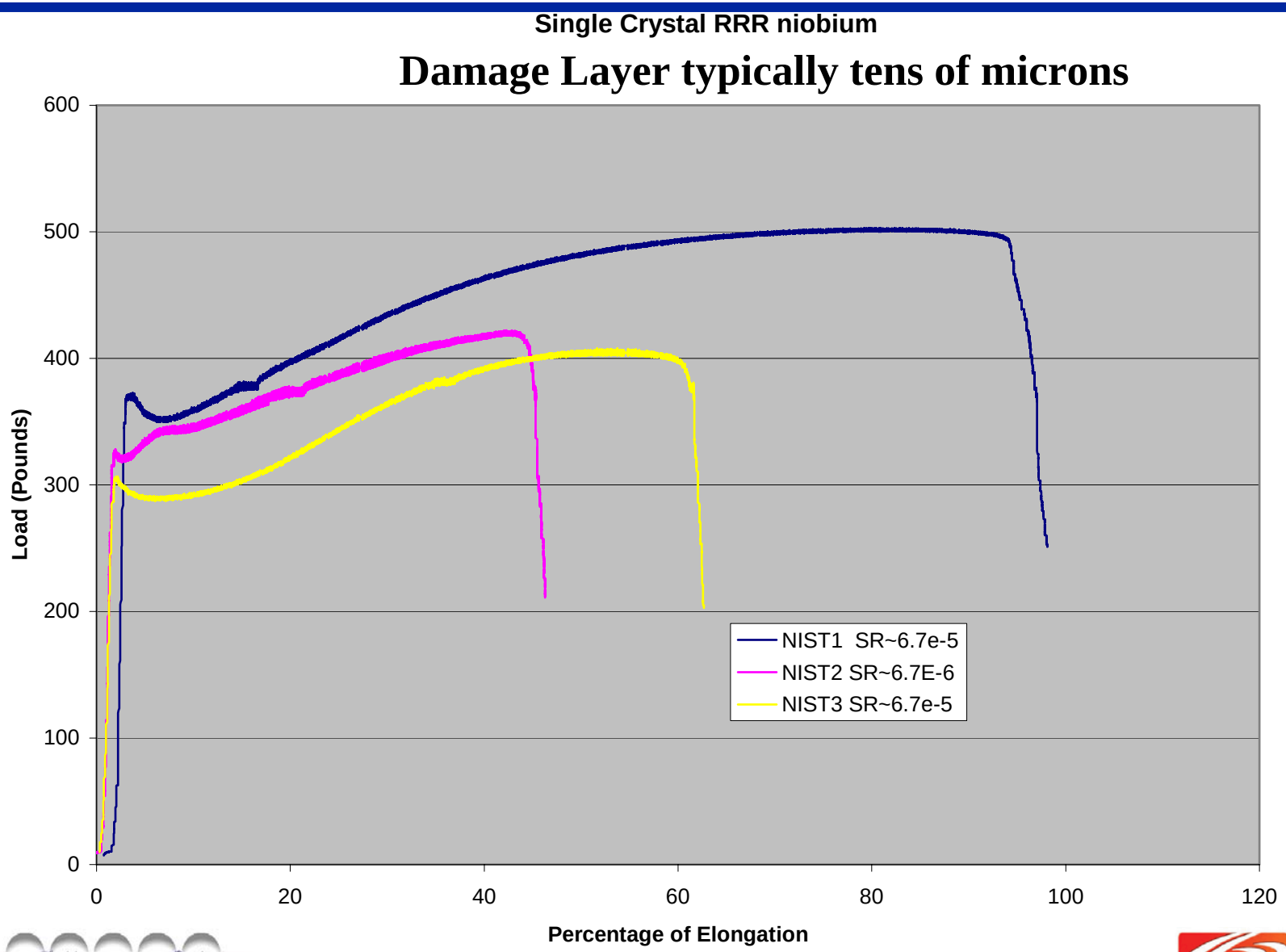
Large Crystal RRR Niobium

After ~ 80 micron BCP 1:1:2

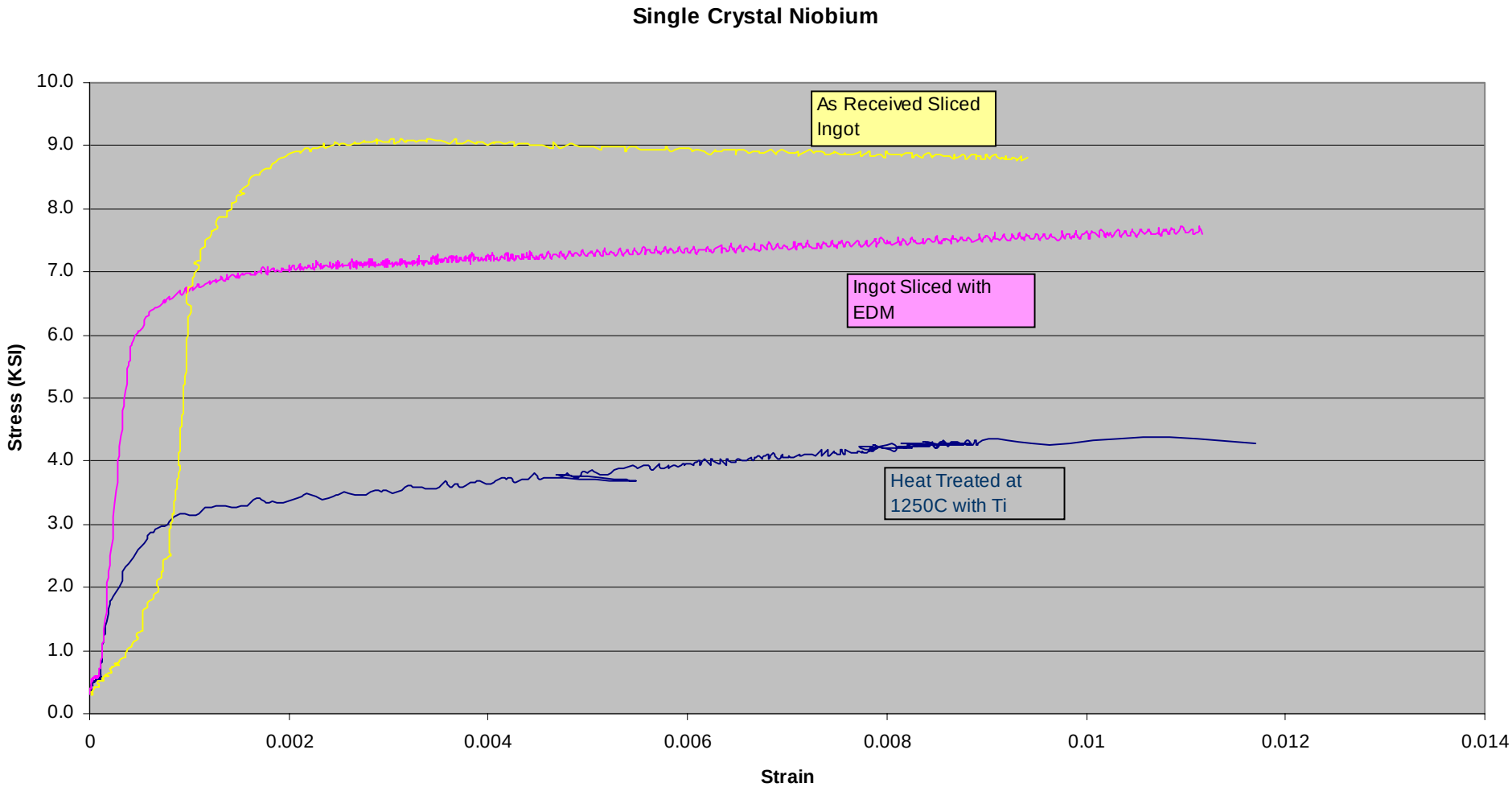


RMS Surface Roughness 27 nm per A. WU/JLAB on a 0.2 X 0.2 mm area

Single Crystal



Elastic Modulus, Single Crystal RRR Nb



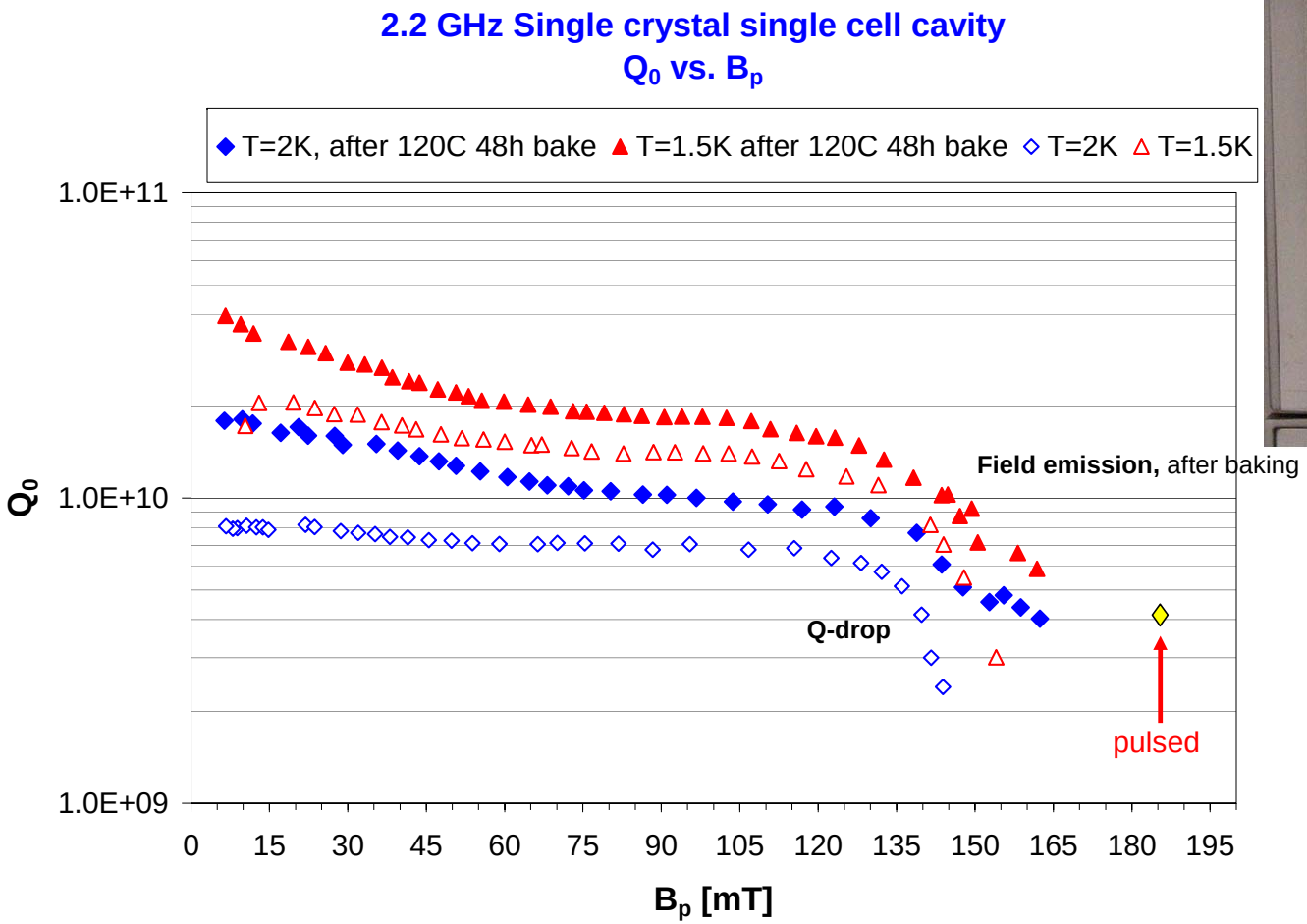
Elastic Modulus ~ 120 GPa

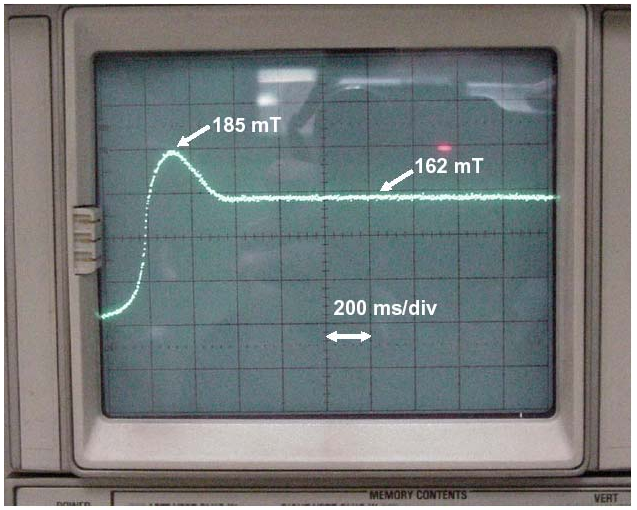
SRF Cavity Performance With Various Nb's

Material	Ta- contents	RRR - value	Q_0 @ $E_{acc\ max}$	$E_{acc,\ max}$ [MV/m]
Fine grain sheet	< 500 ppm	~ 700	3.6×10^9	31.8
Fine grain sheet	~ 160 ppm	323	7.5×10^9	33.5
Fine grain sheet	~ 600 ppm	345	7.5×10^9	35.9
Fine grain sheet	~ 1300 ppm	240	9.45×10^9	29.6
"single crystal" (2.2 GHz)	~ 800 ppm	~ 270	4.0×10^9	43 (pulsed) Theoretical limit (185 mT)

1500 MHz Cavities at 2 K

Theoretical Limit Reached

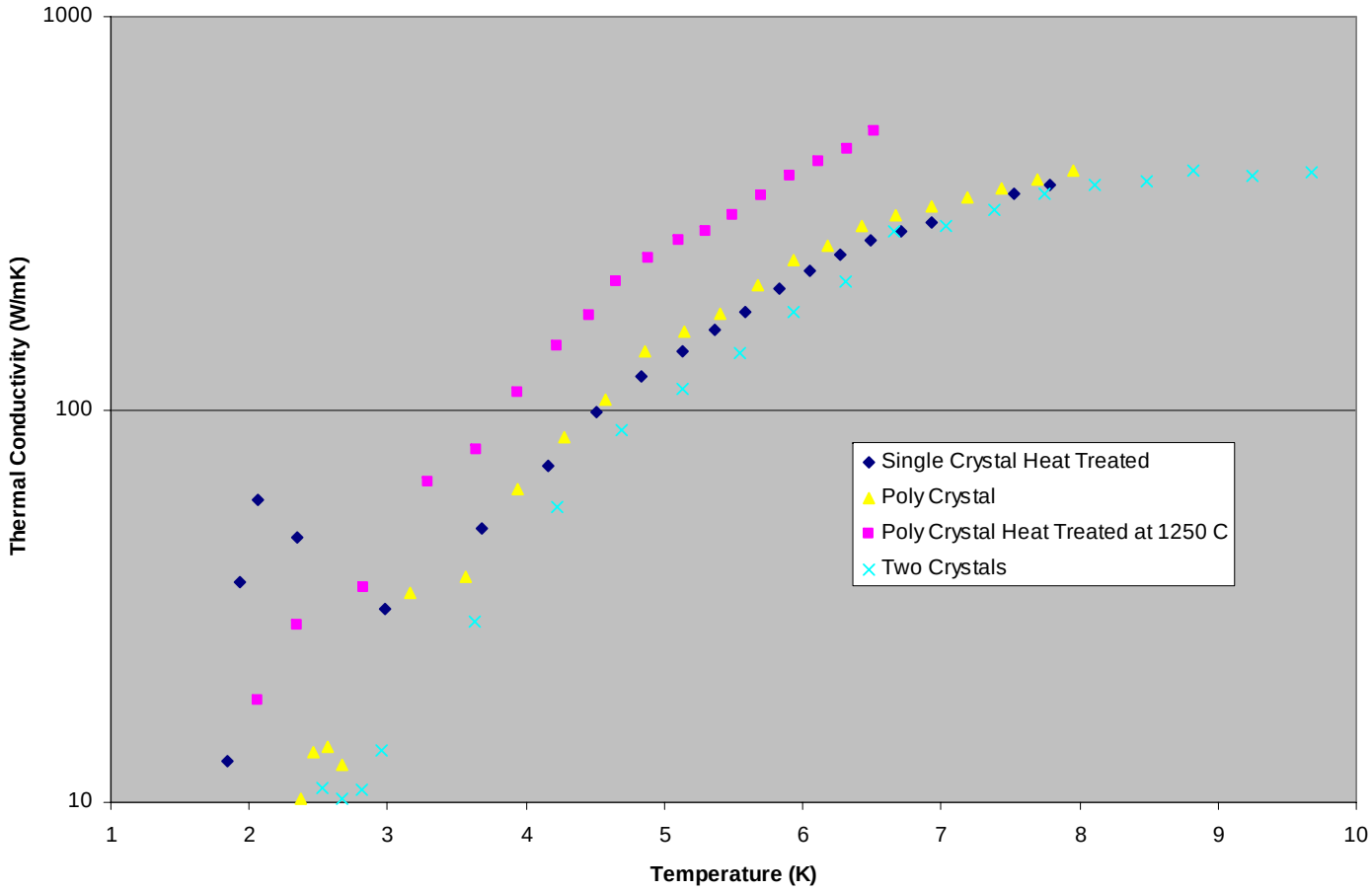




P. Kneisel, G. Ciovati, G. Myneni, J. Sekutowicz, T. Carneiro, Proc. of the 2005Part. Acc. Conf., Knoxville, TN, USA (2005) paper TPPT076

Thermal Conductivity

Specification should be Thermal Conductivity at 2 K



Road Map to High Performance, Low Cost SRF Accelerator Structures

- **Slice the discs from single crystal ingots**
- **Remove several tens of microns of damage layer from the completed cavities**
- **Degass hydrogen at 600 C for several hours and deposit a passivating nitride of several monolayer thickness**
- **Optimize the operating temperature ~ 1.8 K**

Conclusions

- **The presently used high RRR niobium properties appear to be not consistent from batch to batch, from sheet to sheet and even from different locations on the same sheet**

- **High tantalum content RRR niobium appears to meet all the needs of presently planned projects except ILC at much reduced costs**

- **Single crystal niobium discs sliced directly from the ingots can be expected to have consistent properties from batch to batch, be less expensive and can be expected to provide high performance and amenable to automated production due to simpler processing steps**

Papers related to Single Crystal Niobium on Tuesday Poster Session

- **TuP54: Grain Boundary Flux Penetration and Resistivity in Large Grain Niobium Sheet, P. Lee et al**
- **TuP56: Contamination Analysis of Polycrystalline and Single Crystal Niobium used in Accelerator Cavities by SIMS, F. A. Stevie et al**
- **TuP57: Comparison of Deformation in High-Purity Single/Large Grain and Polycrystalline Niobium Superconducting Cavities, R.E. Ricker et al**
- **TuP58: Investigation of Ingot Material with Large Grain for Cavities, X. Singer et al**