Optimization of RRR Niobium Bulk Properties

Pushing the Limits of the RF Superconductivity

ANL RFSC Workshop

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Thomas Jefferson National Accelerator Facility
Institute for SRF Science and Technology

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Types of high RRR bulk niobium

1. Polycrystalline niobium from standard process including rolling:

    No control on the microsturcture, texture

    Heterogeneous

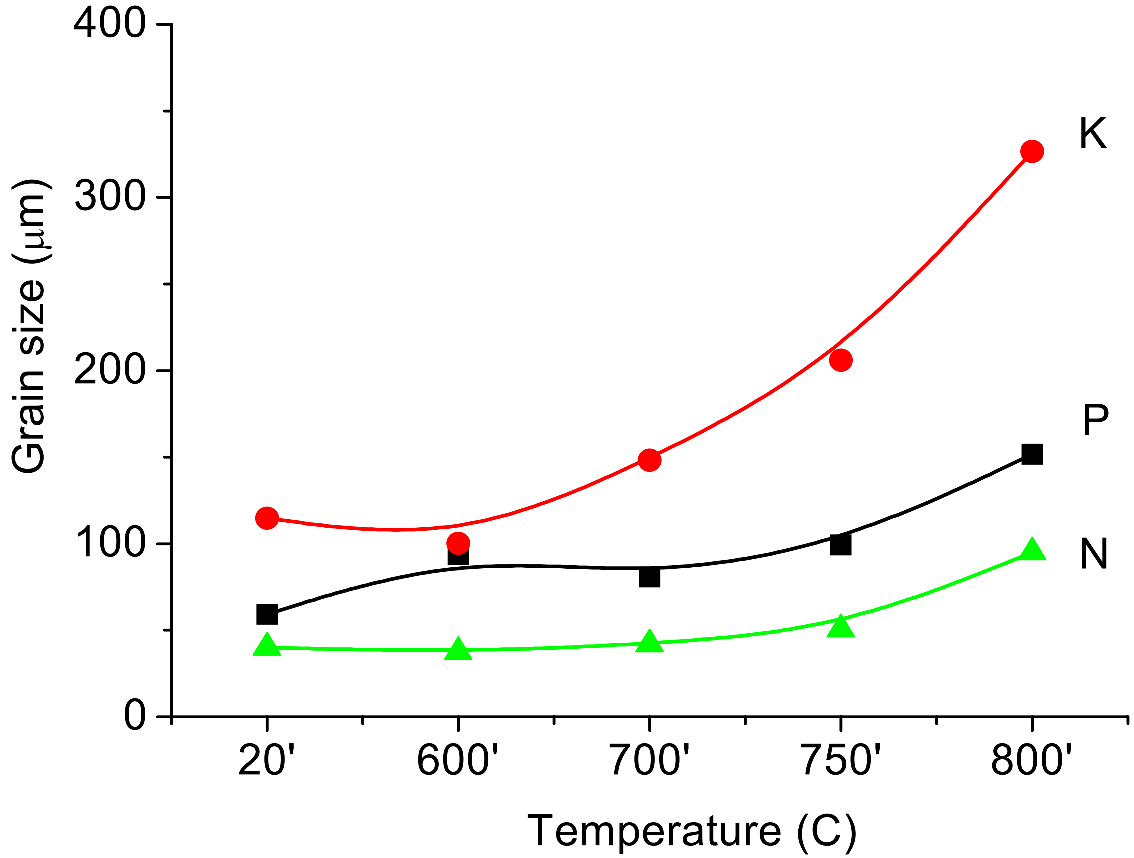
2. High Tantalum content niobium may be available at reduced cost

3. Single crystal ingots with required orientation

    One obtains the sheets directly form the slicing of the ingots, reduced process steps leading to lower costs

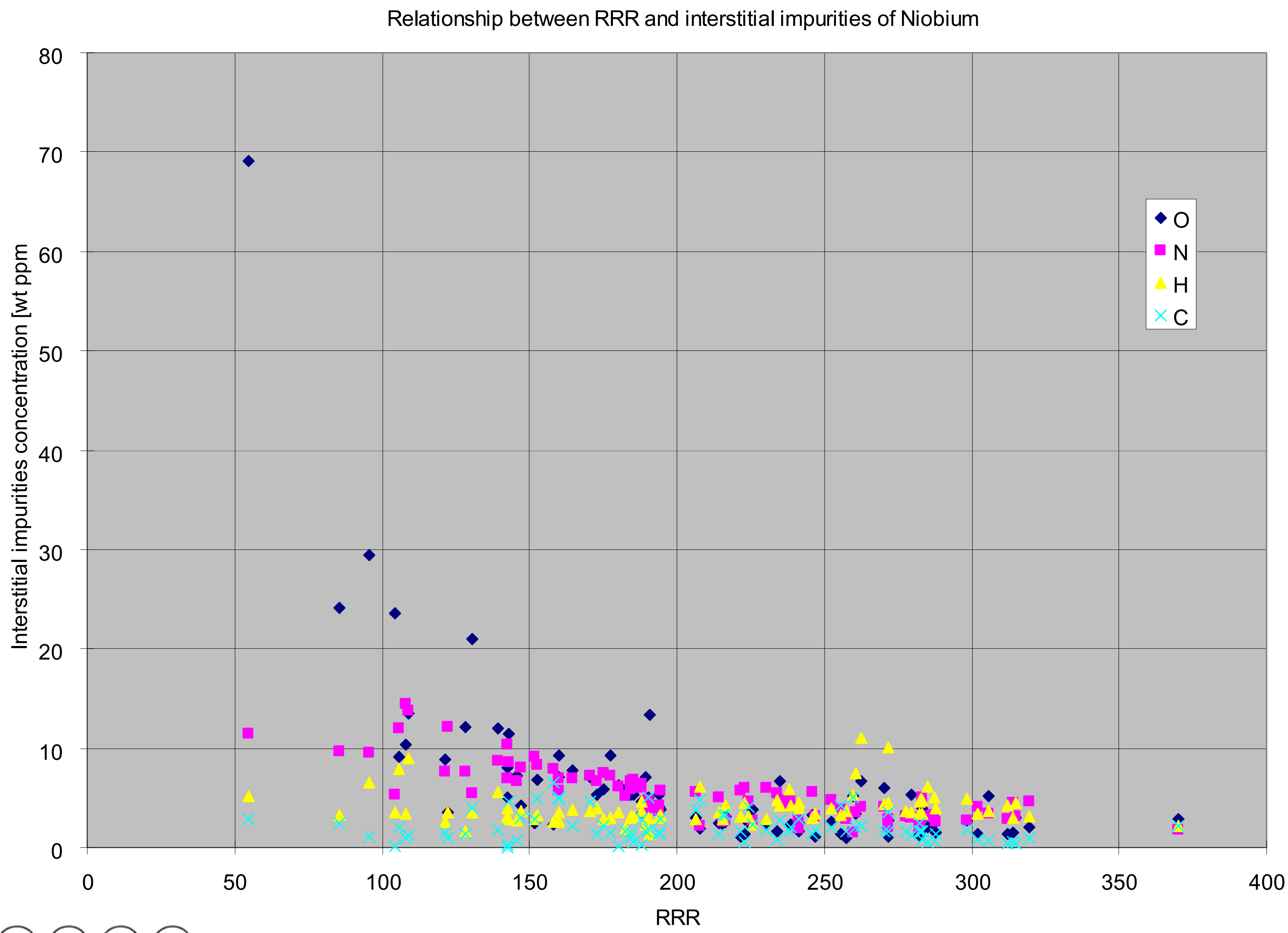
What do we know about RRR Nb !?

- We like to have highest RRR (Thermal Conductivity for Thermal Stability)
- 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!!!!
- So there are opportunities to optimize these properties



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

Interstitials vs RRR



Dynamic Mechanical Analysis

(Internal Friction)

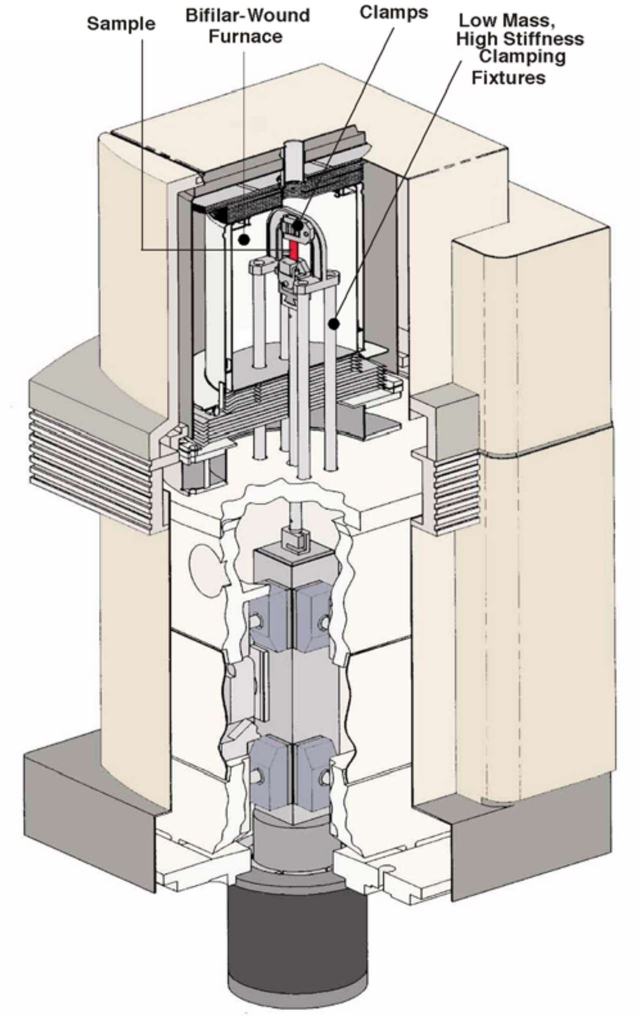
Measures the phase shift between stress and strain as a function of temperature

Hydrogen and Other Interstitials can Have Four Different Types of Interactions:

1. Snoek - Dislocation drag (diffusion)
2. Precipitation - Hydrides, etc.
3. Pairing Effects - solute-solvent or solute-solute pair interactions (e.g. Zener effect)
4. Gorsky - Large scale diffusion effects

Other Peaks:

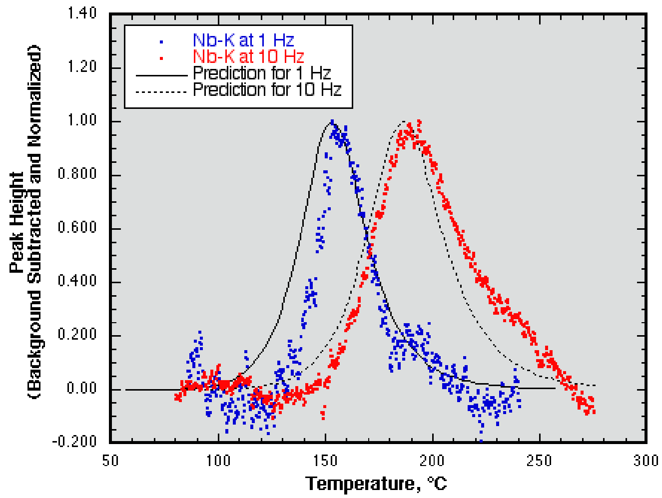
1. Bordoni - Cold work and dislocation density related
2. Grain Boundary - Interface sliding

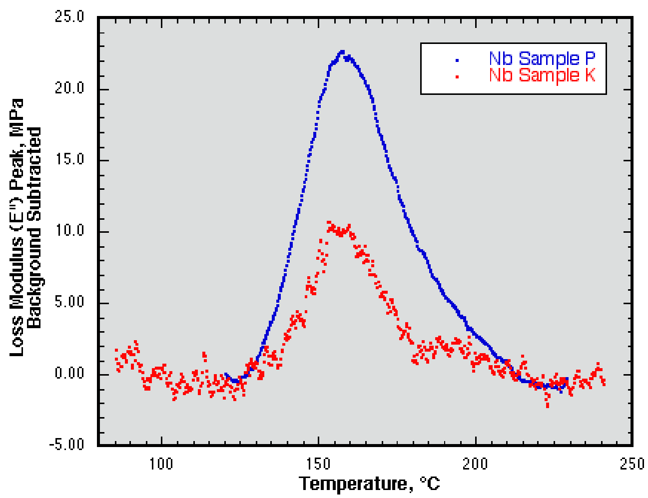


Note diagram shows tensile grip. The measurements of this study were conducted in 3 point bend.

Dynamic Mechanical Analysis (Contd.)

Temperature - Relaxation Mechanism Kinetics
Magnitude - Proportional to Concentration





Peak Temperature = f(Frequency)

Comparison of peaks predicted from diffusion data for two frequencies to measurements.

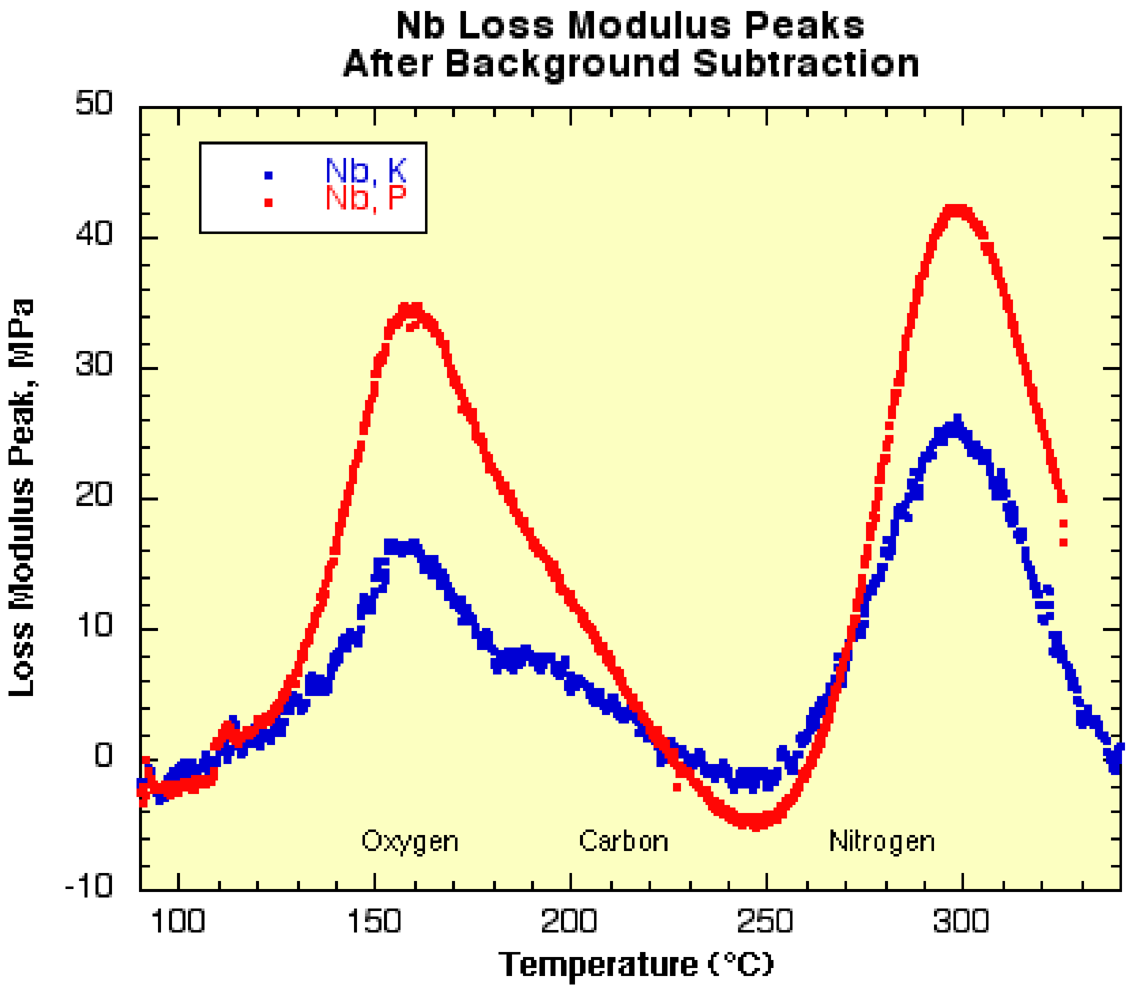
Estimated Snoek Peak Temperatures (K) in Nb for Different Loading Frequencies

Solute	0.1 Hz	1.0 Hz	10 Hz
H	50	53.5	58
C	477	511	550
N	494	528	567
O	397	426	459

Peak Magnitude = f(Concentration)

Comparison of the oxygen Snoek peak in two samples of Nb indicated a difference in the oxygen concentration

Loss Modulus Peaks for Nb



Peak Ratios

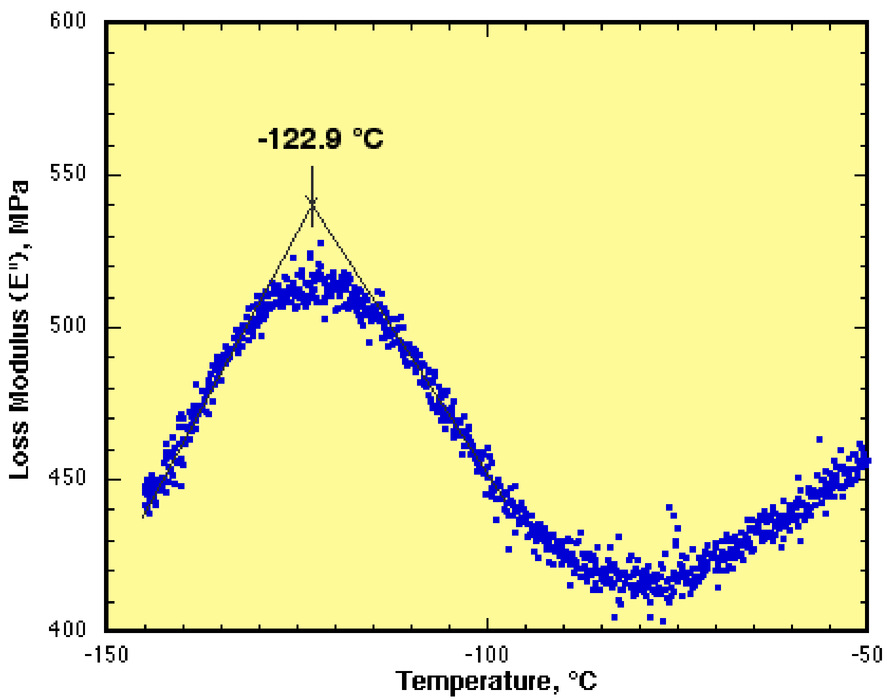
Oxygen: P/K ≈ 1.94

Nitrogen: P/K ≈ 1.6

Carbon: P/K NA

Dynamic Mechanical Analysis (Contd.)

Example of other types of interactions and peaks



H-O Interaction Peak

A peak was found at a temperature between that expected for the H and O Snoek peaks. Previous investigators postulated this peak to be due to H-O interstitial interaction.

Estimated Snoek Peak Temperatures (K) in Nb for Different Loading Frequencies

Solute	0.1 Hz	1.0 Hz	10 Hz
H	50	53.5	58
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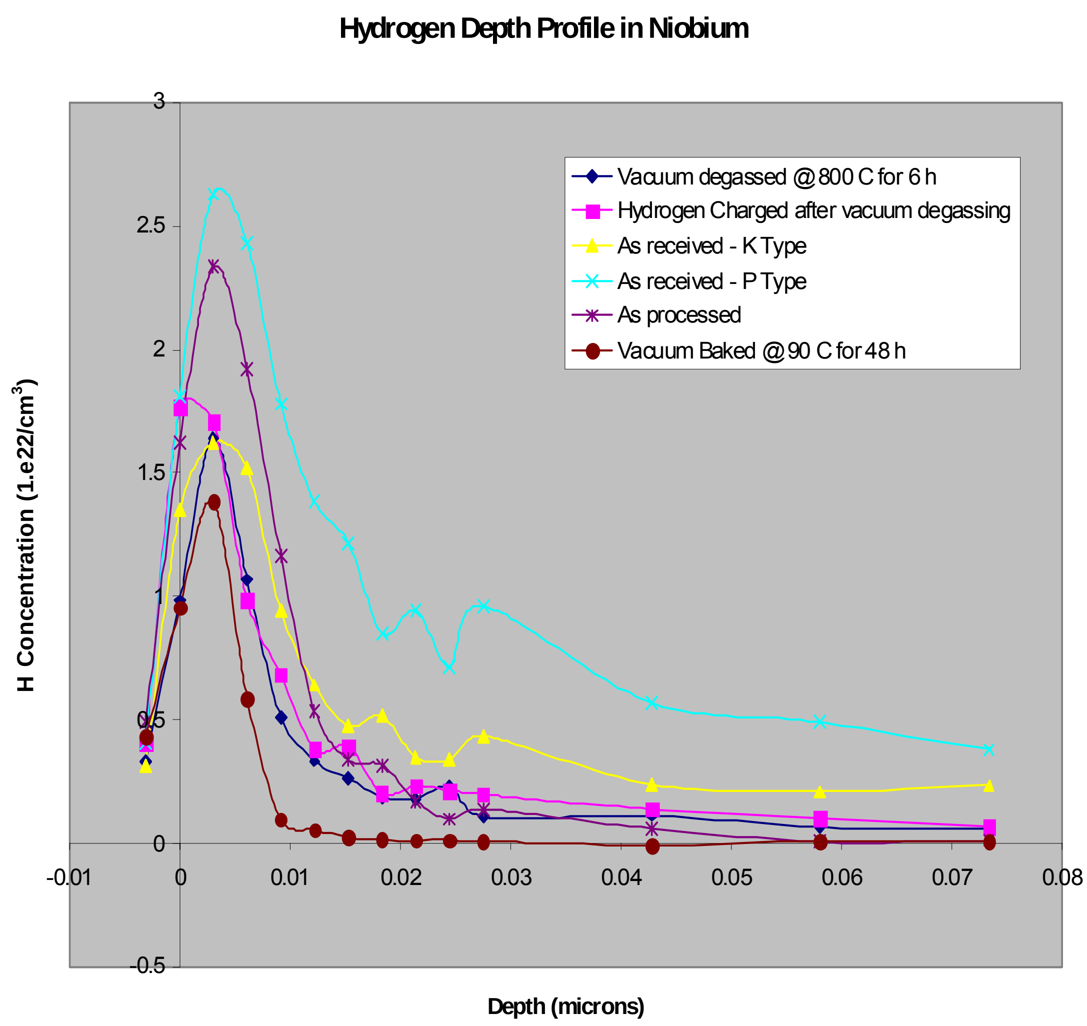
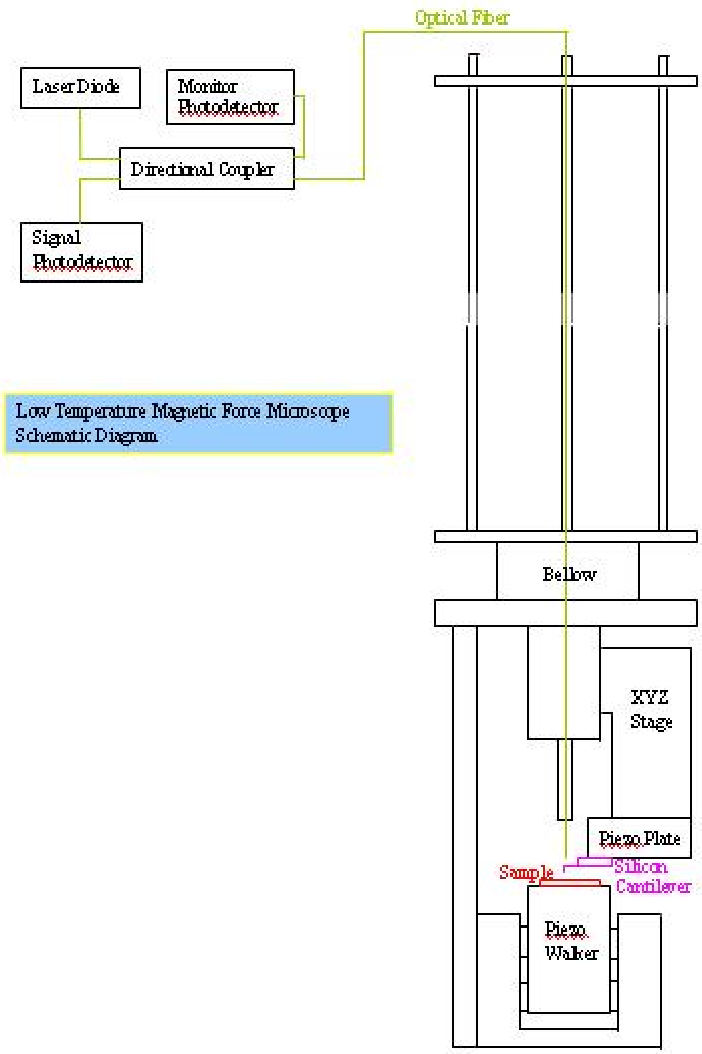
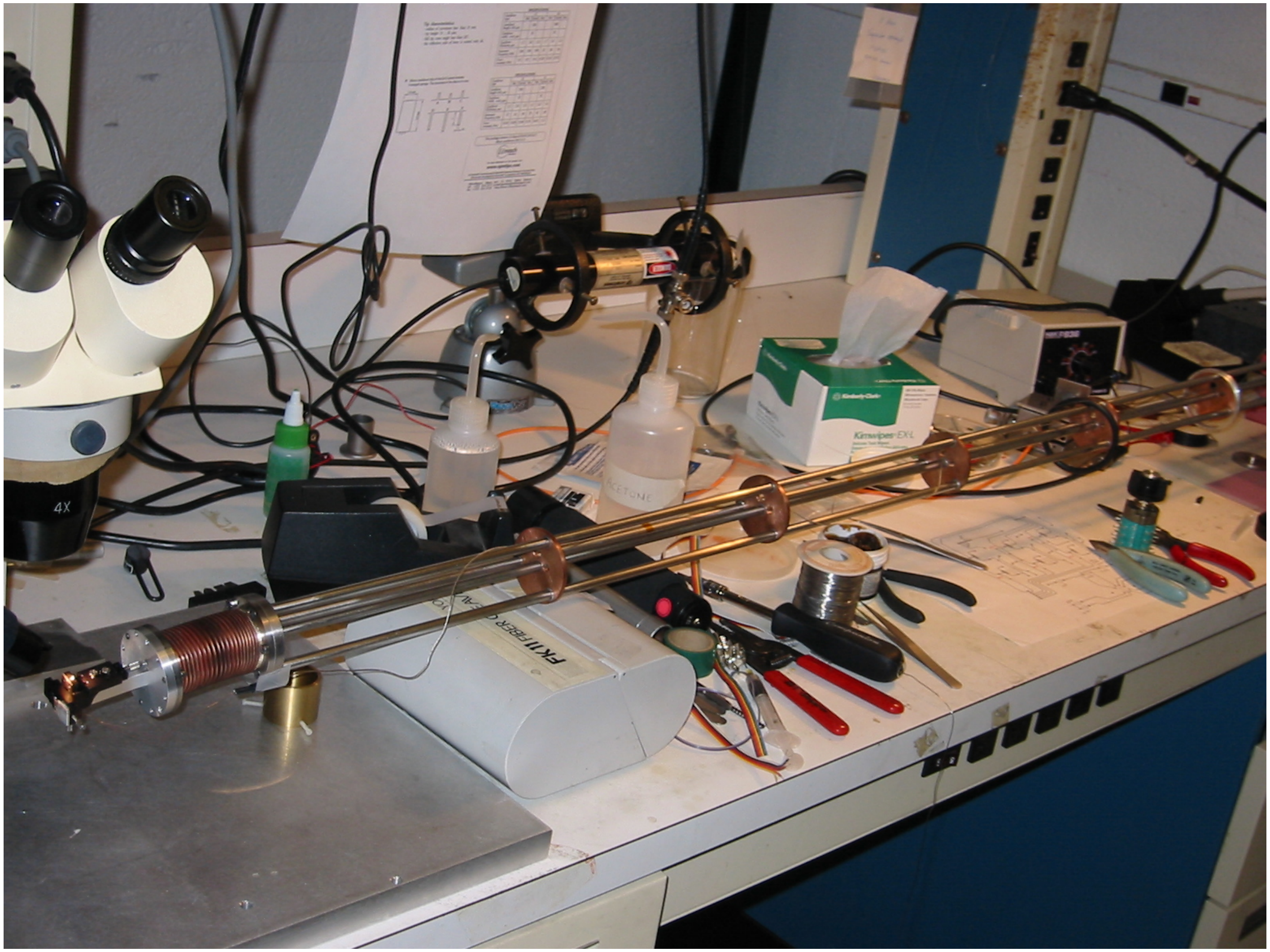
NRA Hydrogen depth profiles

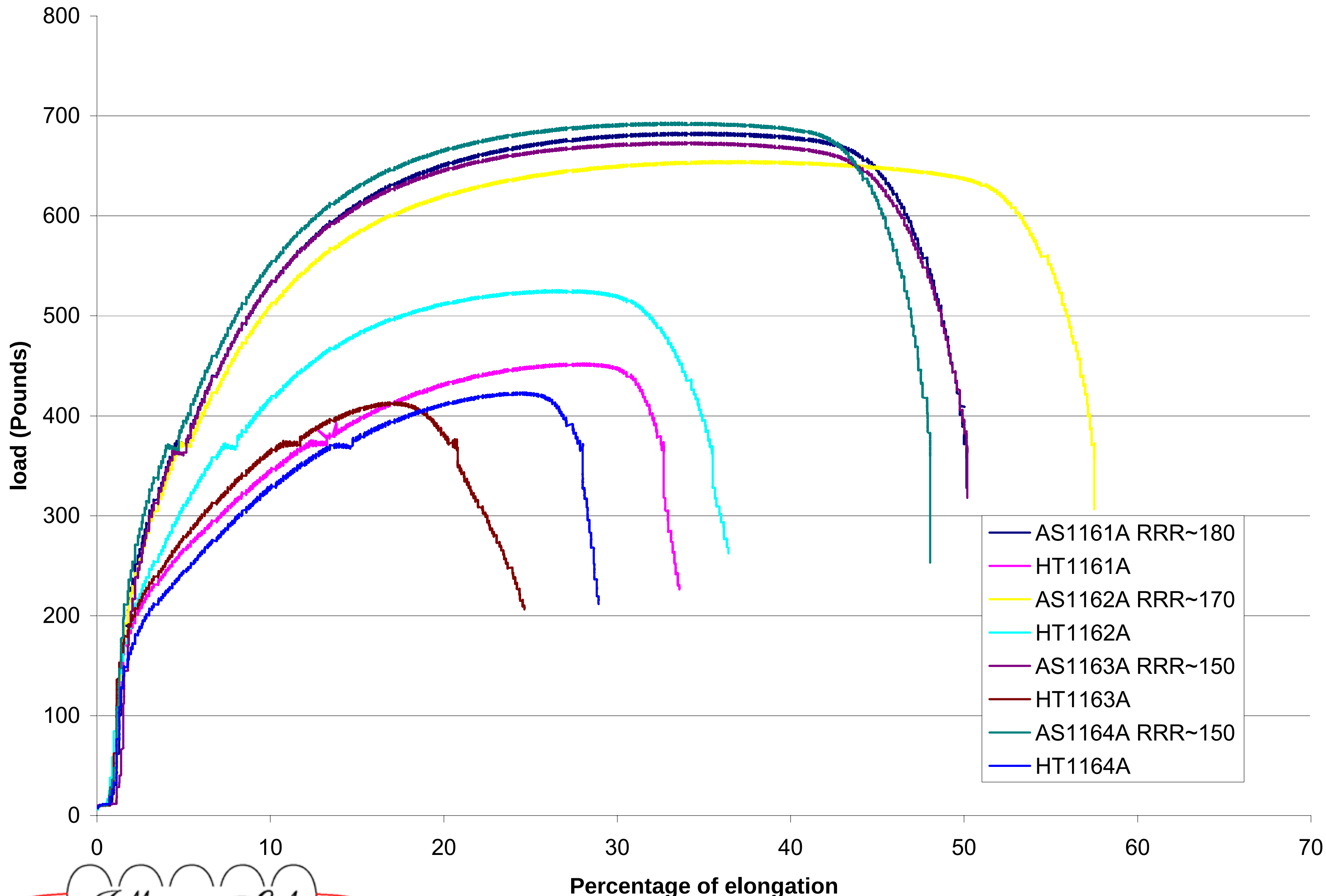


Schematic of MFM/SQUID Microscope



MFM/SQUID Microscope



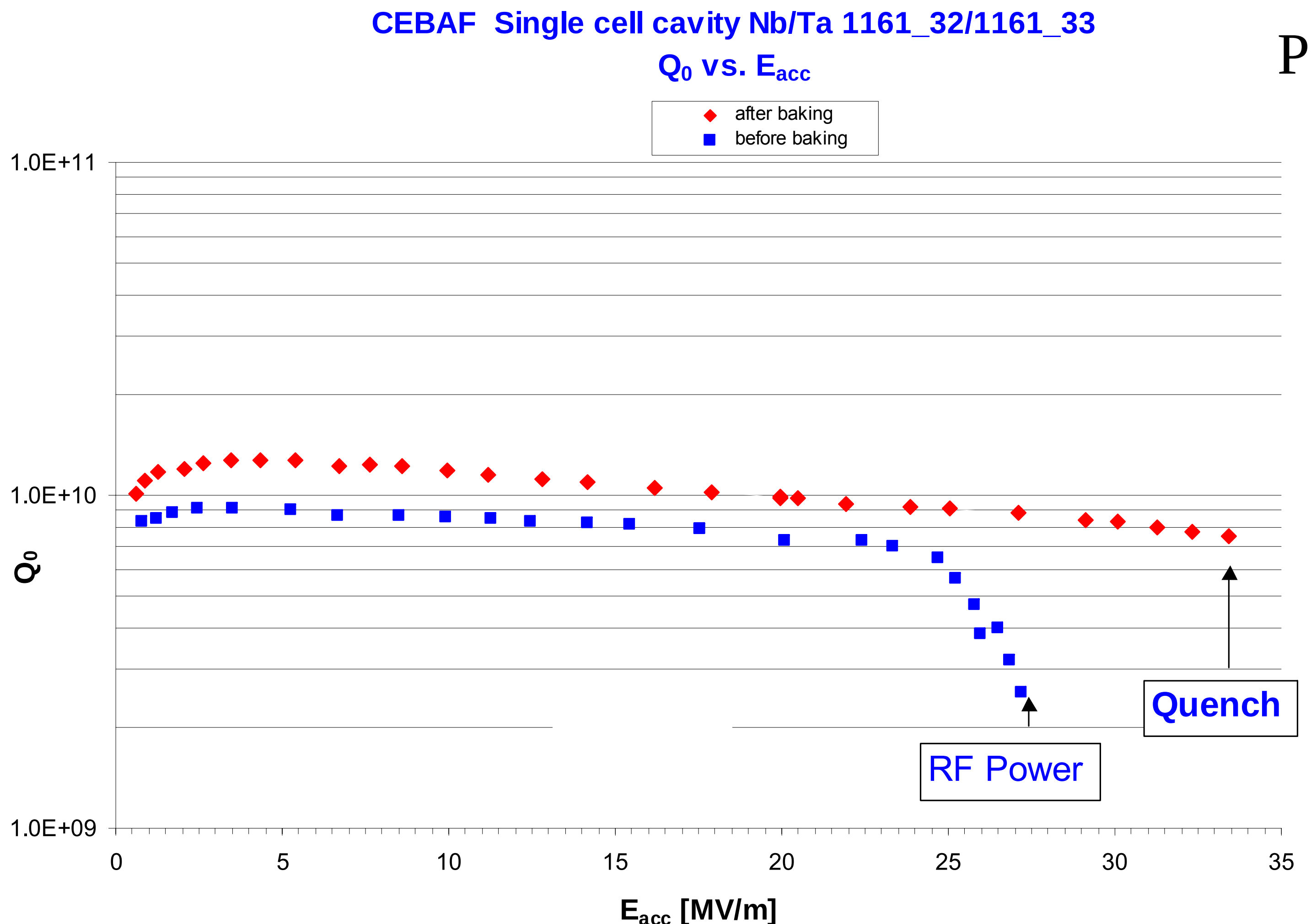


800
700
600
500
400
300
200
100
0
load (Pounds)
0
10
20
30
40
50
60
70
Percentage of elongation
AS1161A RRR~180
HT1161A
AS1162A RRR~170
HT1162A
AS1163A RRR~150
HT1163A
AS1164A RRR~150
HT1164A

NbTa(~160 ppm)

Cavity was heat treated with Ti at 1250 C for 3hrs, then 24 hrs at 1000C

P. Kneisel



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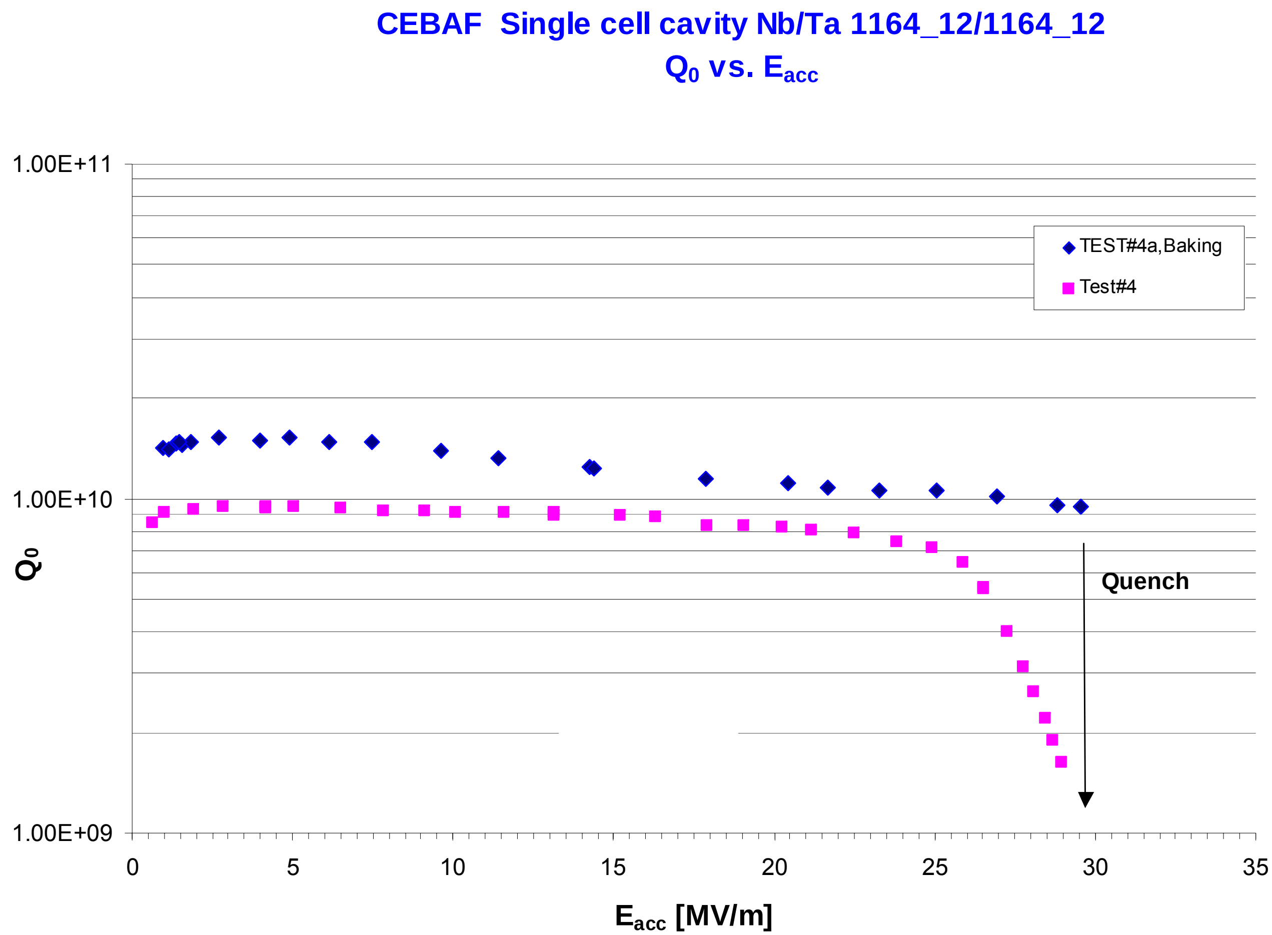
NbTa (1300 ppm)

P.Kneisel

Cavity was heat treated with Ti at 1250 C for 3hrs, then 24 hrs at 1000C



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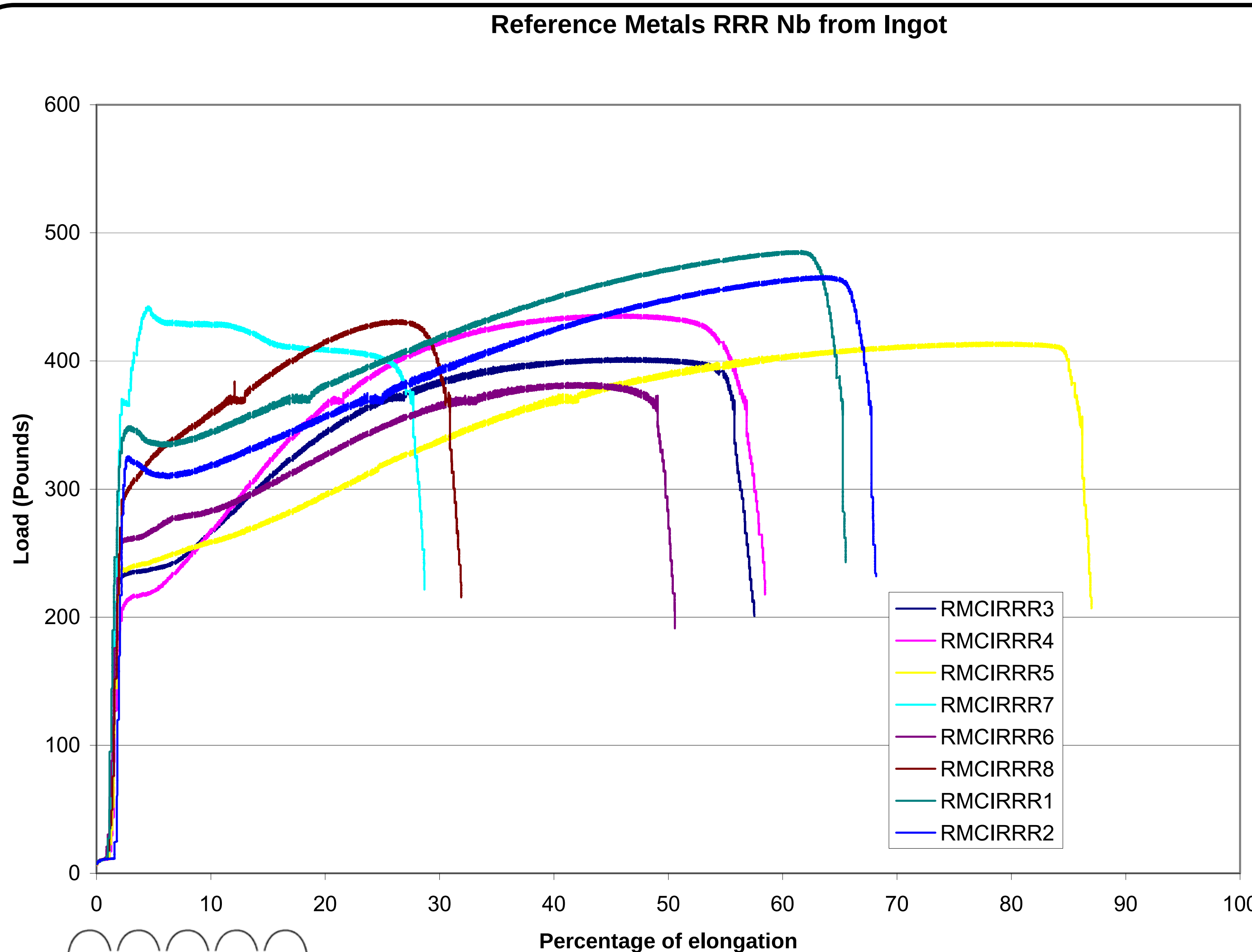
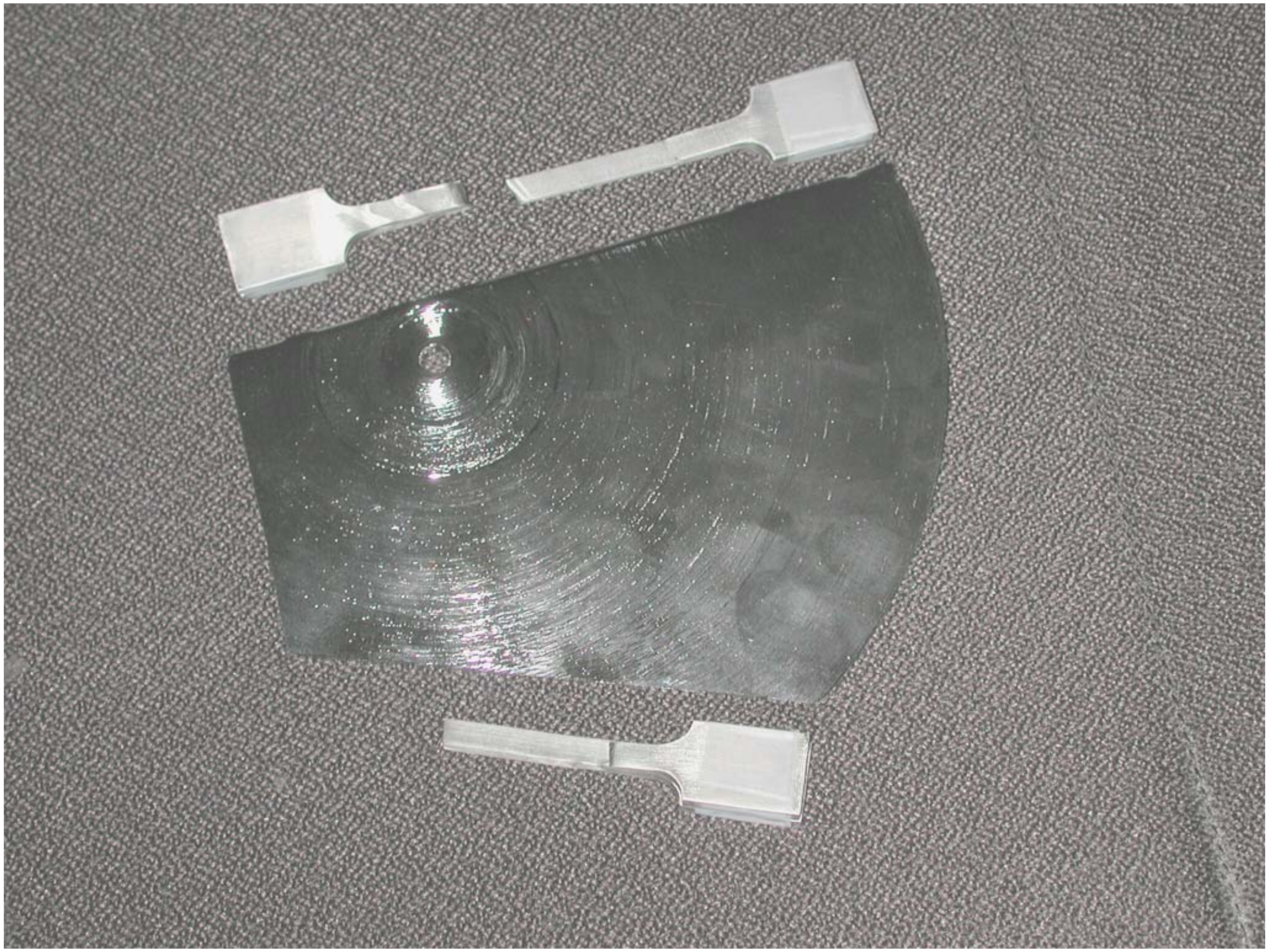
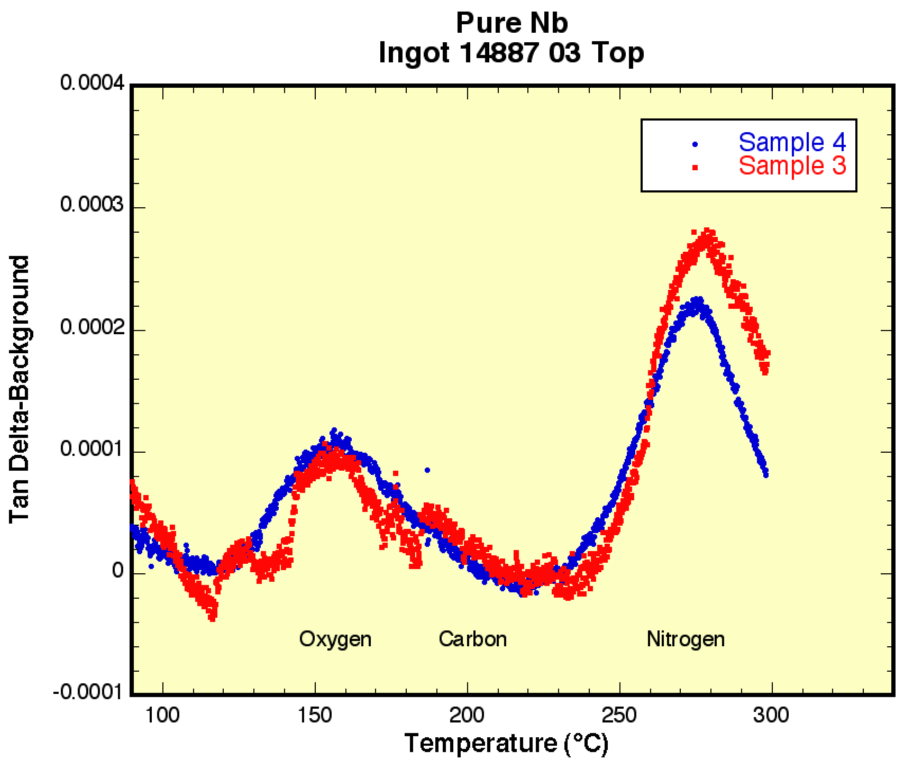
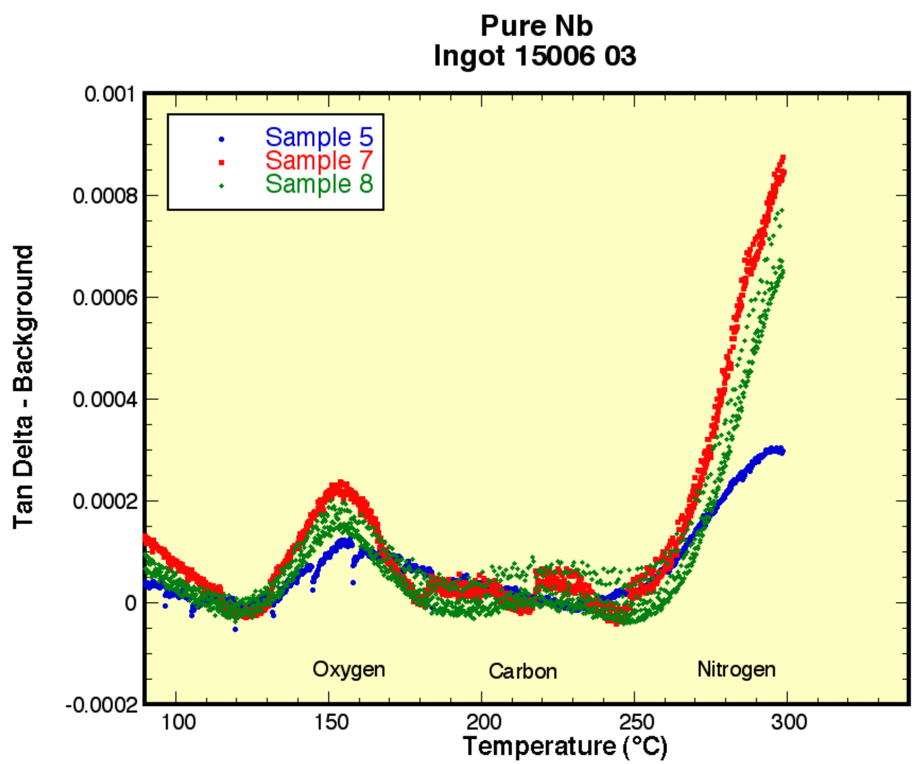

Reference Metals RRR Nb from Ingot
Load (Pounds)
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
80
90
100
Percentage of elongation
RMCIRRR3
RMCIRRR4
RMCIRRR5
RMCIRRR7
RMCIRRR6
RMCIRRR8
RMCIRRR1
RMCIRRR2







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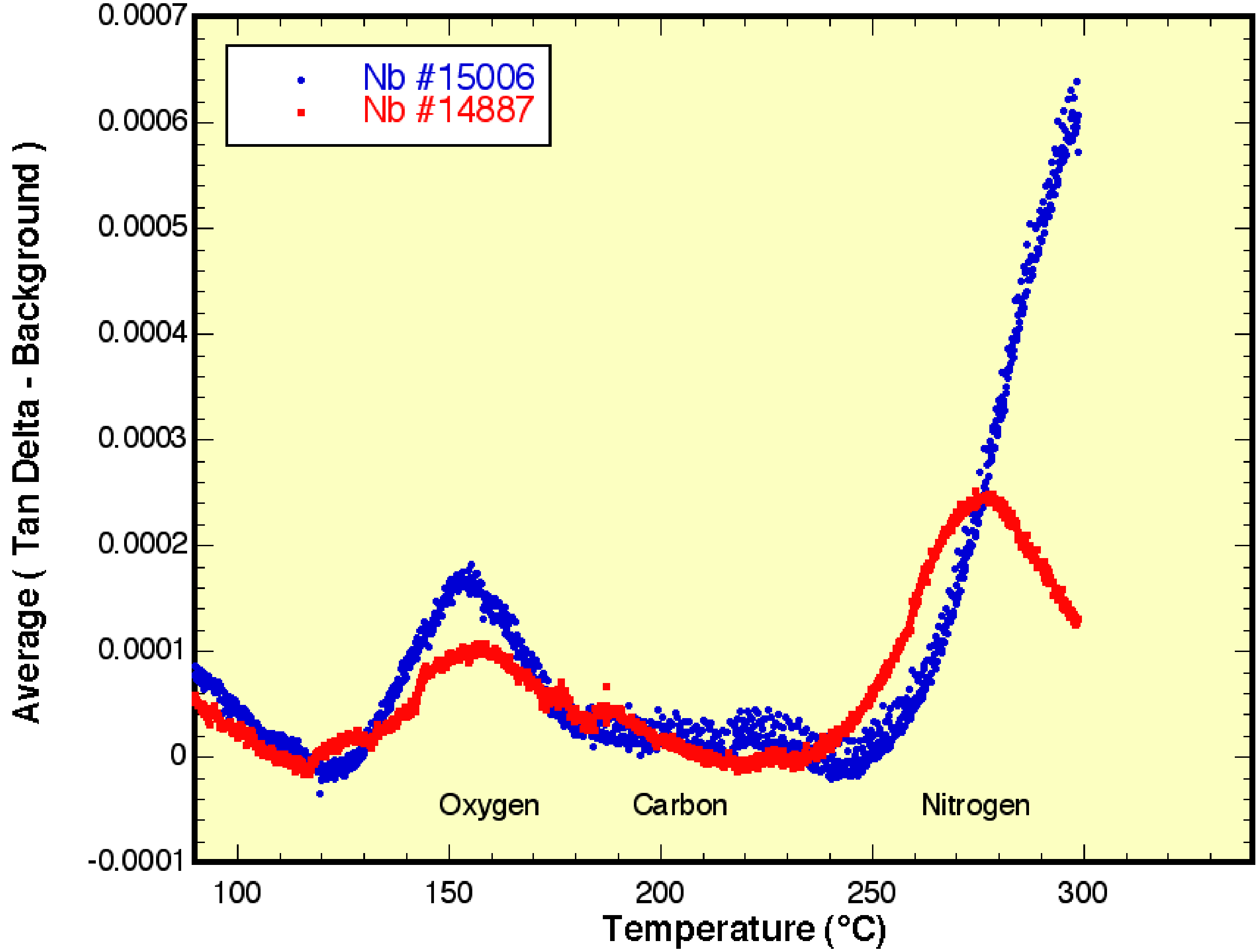

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Conclusions

- The presently used high RRR niobium properties appear to be not consistent from batch to batch and/or even from sheet to 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 sheets sliced directly from the ingots can be expected to have consistent properties from batch to batch, less expensive and may provide high performance!!!!