

THERMAL DESIGN STUDIES OF NIOBIUM SRF CAVITIES

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Oct 17, 2007

This research is funded by the Fermi National Accelerator Laboratory









Heat Transfer Problem

$T_{s} \qquad T_{i} \qquad T_{b}$ $\downarrow e \rightarrow \downarrow$ $R^{"} \qquad N^{b} \qquad He II$ $T_{s} \qquad \frac{e}{k} \qquad T_{i} \qquad \frac{h_{k}}{h_{k}} \qquad f_{b}$ $\downarrow T_{b}$

 $q'' = \frac{\Delta I}{R_T}$

 $\Delta T = (T_s - T_h)$ $R_T = \left(\frac{e}{k} + \frac{1}{h_{\mu}}\right)$

Assumptions:

- Steady state
- No internal heat generation (surface penetration of B is in the order of nanometers)



Motivation

• Improved k & h leads to

- Higher B and thus greater accelerating gradients, and
- Smaller T_s and thus low R_s providing reduced cryogenic load

Thermal-magnetic interactions in defect free cavities







Outline of Experiments

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- Two cylindrical (RRR 232) Tokyo Denkai
- Two rectangular flat plates (RRR 390) FermiLab/Wah Chang
- One single crystal and one bi crystal sample (RRR 280) JLab/CBMM

Treatments:

- Cylindrical sample 1
 - 3% strain
 - Titanification
- Cylindrical sample 2
 - Surface deformation (SI >3)
 - 750 ° C heat treatment
 - Titanification

- •Flat plate samples
 - 750 $^{\circ}$ C heat treatment
 - Titanification
 - RRR measurement
- Single/bi crystal samples (EDM cut)
 - Baseline measurements

For all samples,

- 750 ° C heat treatment for 2 hrs Fermi Lab
- Titanification at 1300 ° C for 2 hrs and then at 1200 ° C for 4 hrs Cornell University



Experimental Apparatus

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Results

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Cylindrical sample 1



	As received (M. polish + light BCP etch)	After 3% strain	Post-titanification1300 ° C (2 hrs), 1200 ° C (4 hrs)
h _k	_	No change	Increased (~125% at 2.1 K)
k	Phonon peak	No phonon peak	Phonon peak recovered; No improvement above 3 K





Results (cont.)

Flat plate samples



Avg. Temp. (K)

	As received	Post-heat treatment 750 ° C (2 hrs)	Post-titanification 1300 ° C (2 hrs), 1200 ° C (4 hrs)
k	No phonon peak	Slight increase @ < 2.5 K	Phonon peak recovered; significant decrease > 2.5 K

- Post-titanification thermal conductivity measurements suggest RRR ~ 80
- Post-titanification expectation of RRR ~ 600
- •Twice repeated RRR measurements in samples cut from same plate indicate RRR 67 \pm 20% confirming above measurements



Results (cont.)

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Single/Bi crystal samples (RRR 280)



- Reduced phonon contribution observed in either sample
- Both samples to be annealed and re-tested



Discussion

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- Plastic deformation caused the phonon peak to disappear
 - Thermal conductivity of Nb decreased by ~80% at 2 K
- Annealing at ~750 ° C for 2 hrs insufficient to recover the phonon peak
- Annealing at ~1200 1300 ° C for 6 hrs during titanification recovers the phonon peak
- Kapitza conductance persistently increased after each heat treatment
 - Total increase is ~300% at 2.1 K due to annealing and titanification
- Post titanification RRR of flat plate sample 67 \pm 20 %



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- Numerical simulations demonstrate the importance of k and h in the performance improvement of defect free SRF cavities
- Titanification found to the single most important step to improve both k and h of the SRF cavities
- Re-purification of flat plate samples
- Low and moderate temperature annealing of single and bicrystal samples



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Questions ?