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ILC SRF Materials R&D at FNAL

C. Antoine, P. Bauer, C. Boffo, C. Cooper

Universities:

Applied Superconductivity Center
University of Wisconsin

Michigan State University

Northwestern University

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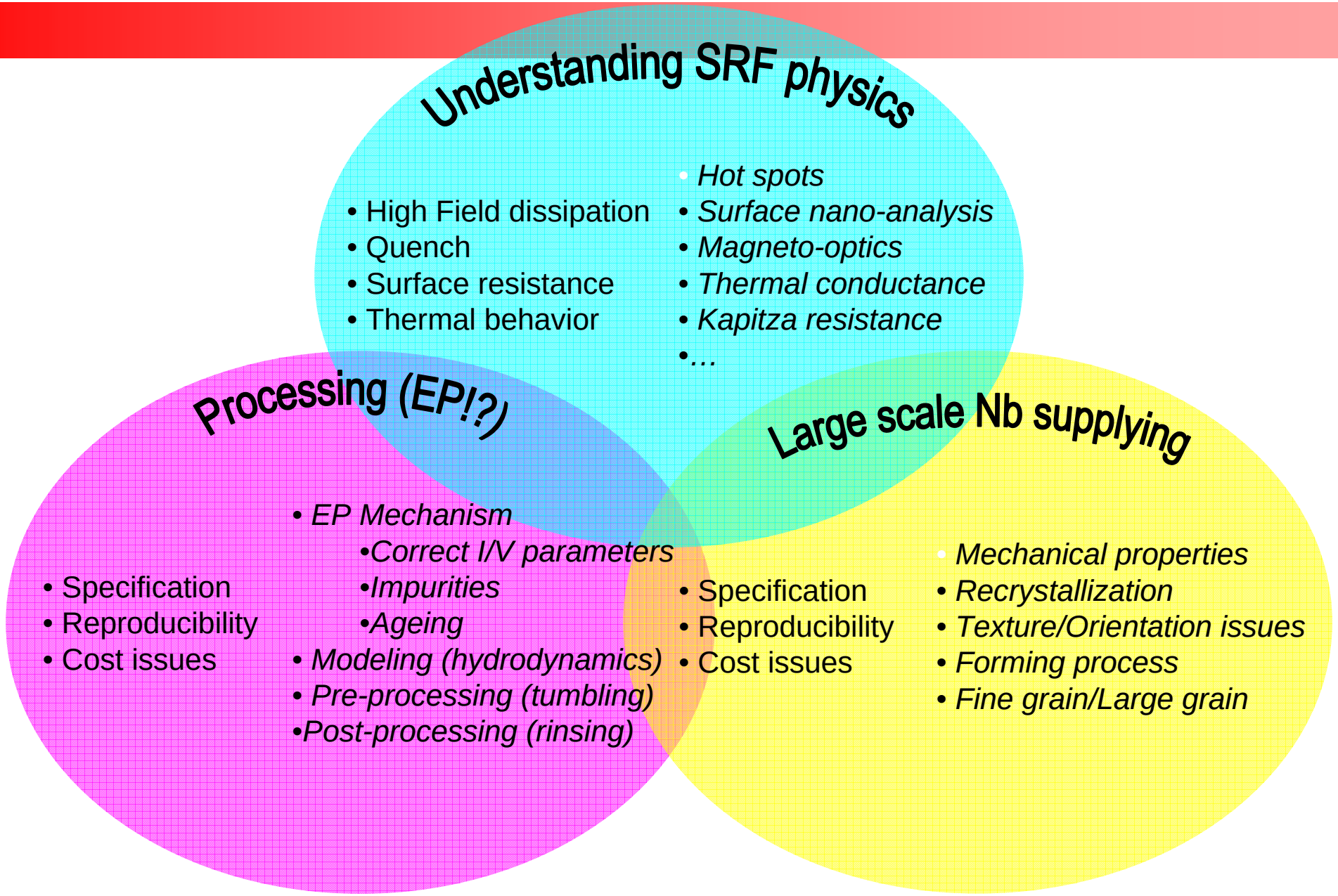
ILC Materials&Processing R&D



Materials R&D: SRF Physics

Fermilab & LCRD support a regional SRF Materials R&D program with regular meetings – last collaboration meeting in March 17th 2006

- **Applied Superconductivity Center**
  - **Magnetic and Transport Studies, Theory**
- **Michigan State University**
  - **Thermal and Mechanical Studies**
  - **TIG Welding**
- **Northwestern University**
  - **Nano-chemistry**

Collaboration Meetings

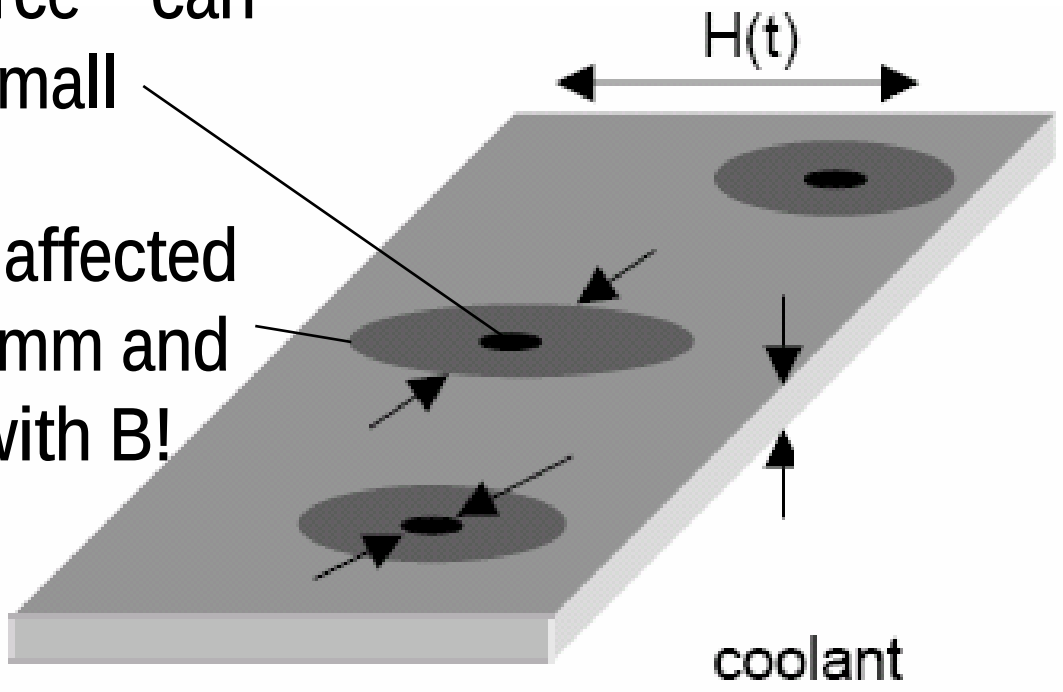
"Midwestern SRF Materials Group":
Initially: Fnal andASC/UW Kick-off meeting
April 11th 2003, NU and MSU joined later

- **Nov 21st 2003 – University of Wisconsin**
- **April 30th 2004 - Fermilab**
- **Nov 23rd 2004 – University of Wisconsin**
- **May 4th 2005 - Fermilab**
- **March 17th 2006 – Michigan State**
- **?? – Northwestern University?**

Hot Spot Model – A. Gurevich

Heat source ~ can be very small

thermally affected zone: ~ 5 mm and growing with B!



Growth of the thermally affected zone Rs→Rs(B)

$$L(B) \cong \frac{L_h}{\sqrt{1-\left(B/B_{rf,crit}\right)^2}} \qquad L_h = d\sqrt{1+\frac{\kappa}{d\alpha}} \qquad Q(B) \cong \frac{Q(0)e^{-\frac{(T_m-T_0)}{T_0}\frac{\Delta}{k_B T_0}}}{1+f_{HS}(B)}$$

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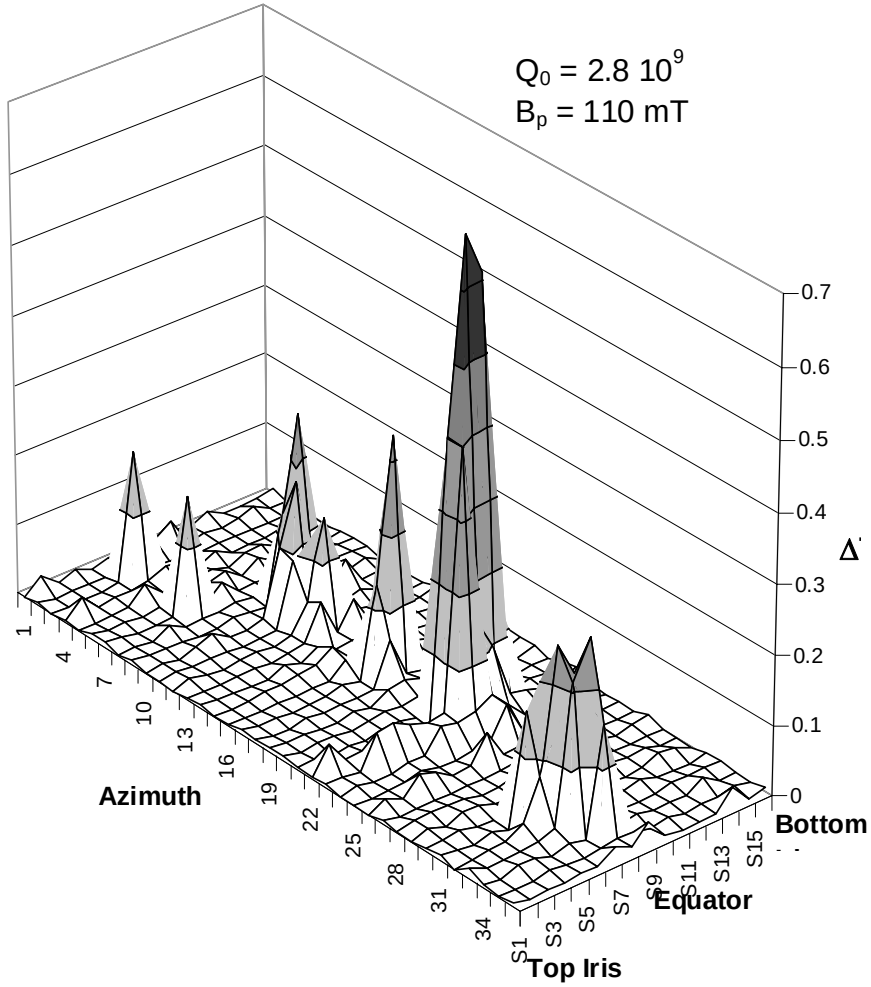
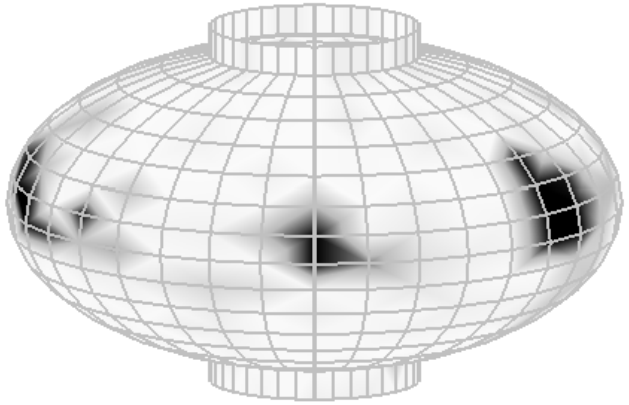
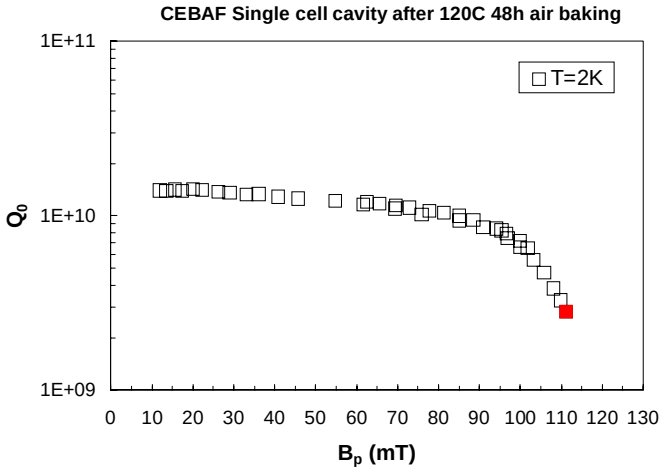
Hot Spots

Hot spots "ignite" in Q-drop regime!

What are those hot spots?







G. Ciovati - JLab

Chasing Hot Spots

Micro- & macro-scale

- **Local variations in SC properties?**

  Magneto-optics and Transport / ASC-UW

- **Defects, Impurities?**

  Local nano-chemistry – 3DAP / NU

- **Thermal Properties?**

  Kappa and Kapitza - MSU

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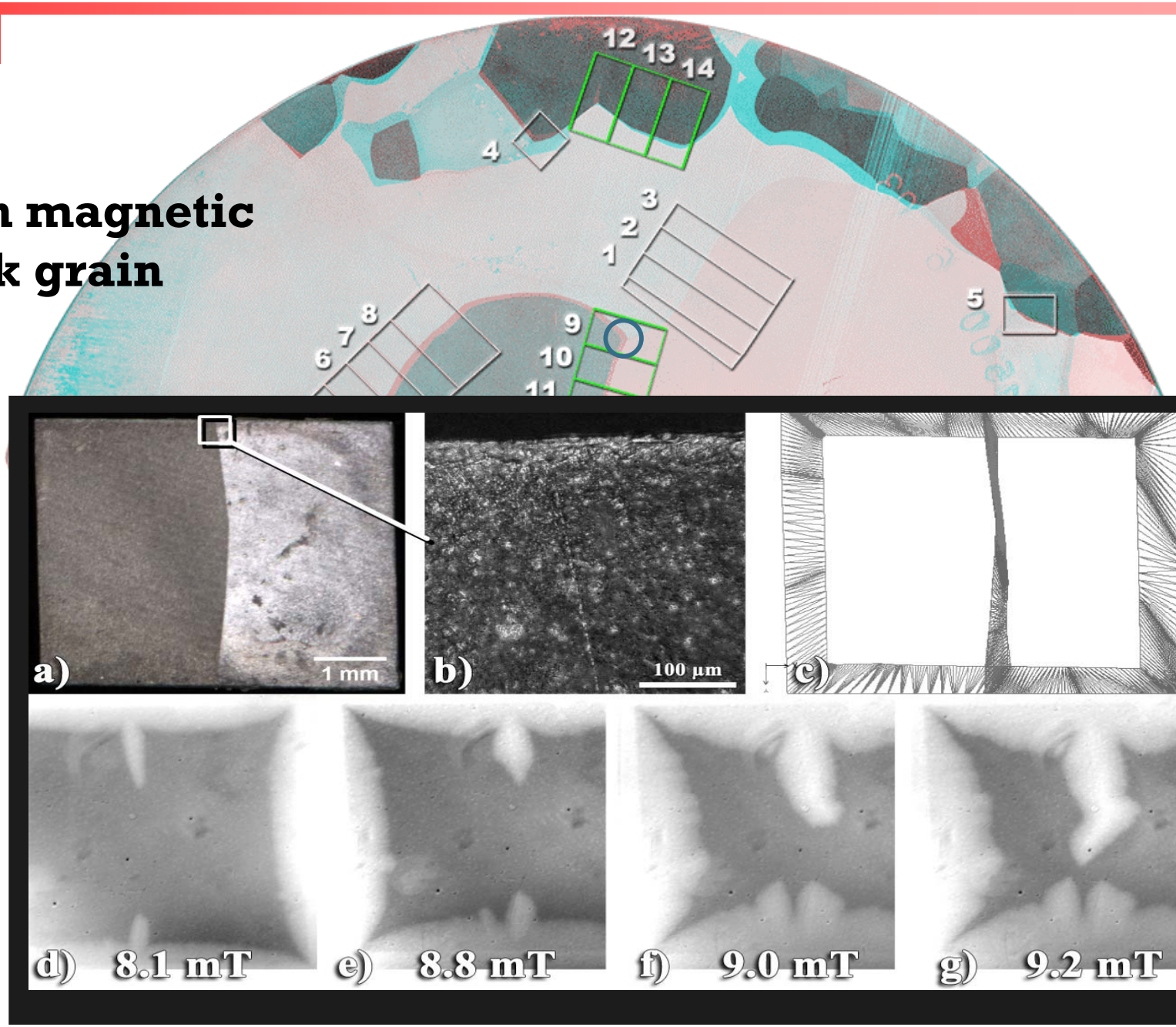
Magnetic investigation of Nb

Discovered in-homogeneities in magnetic properties – weak grain boundaries?

Non-uniformities and flux penetration gets worse along the cavity production route!



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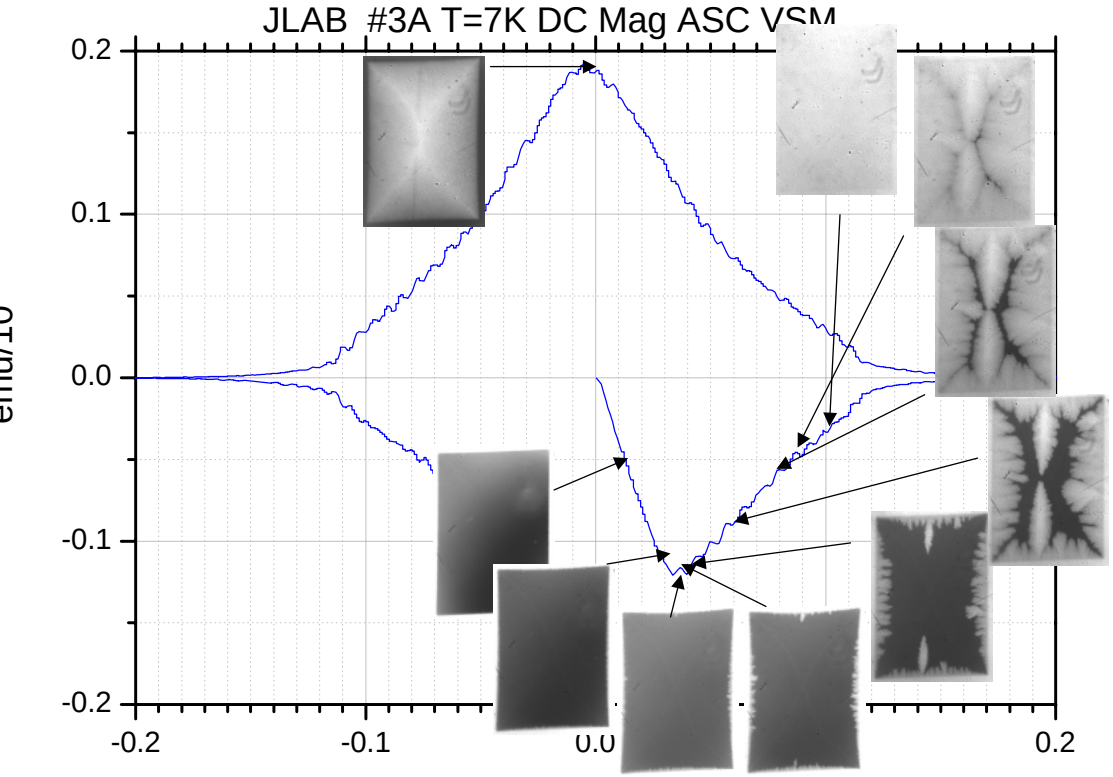
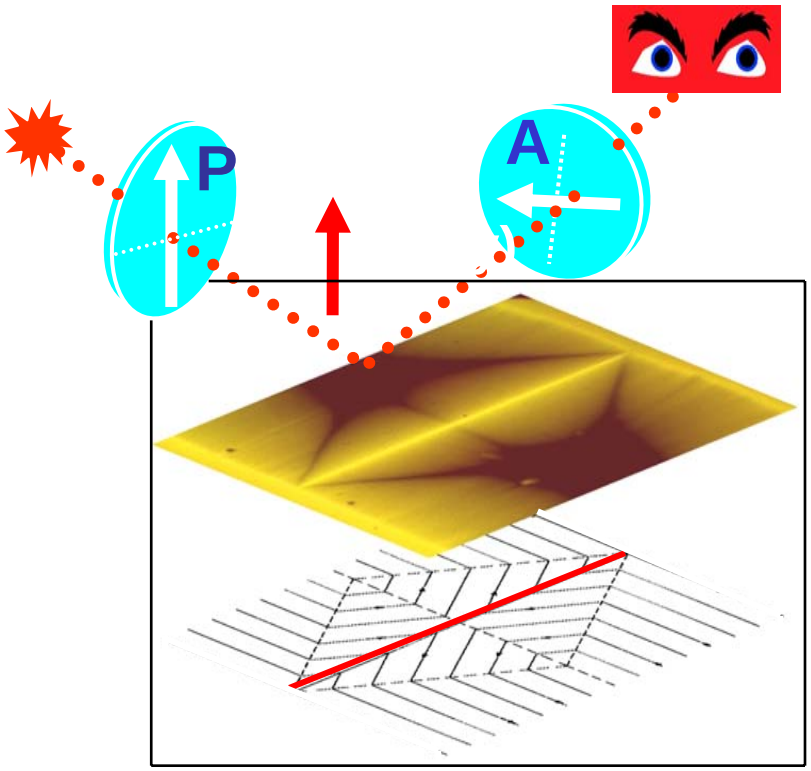
Weak Grain Boundaries?

Current blocking effect ?





Manifestation of reduced pinning?

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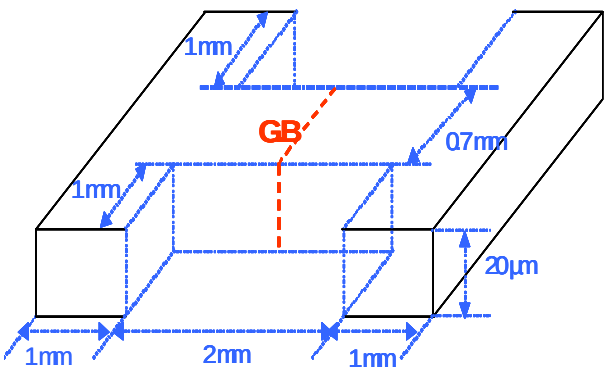
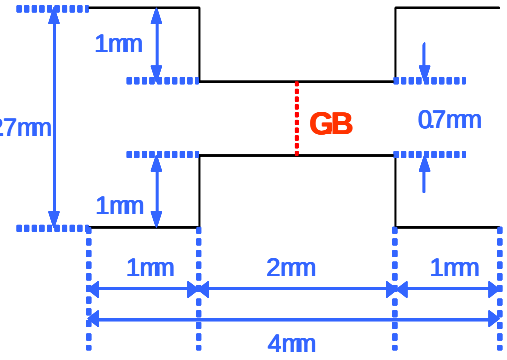
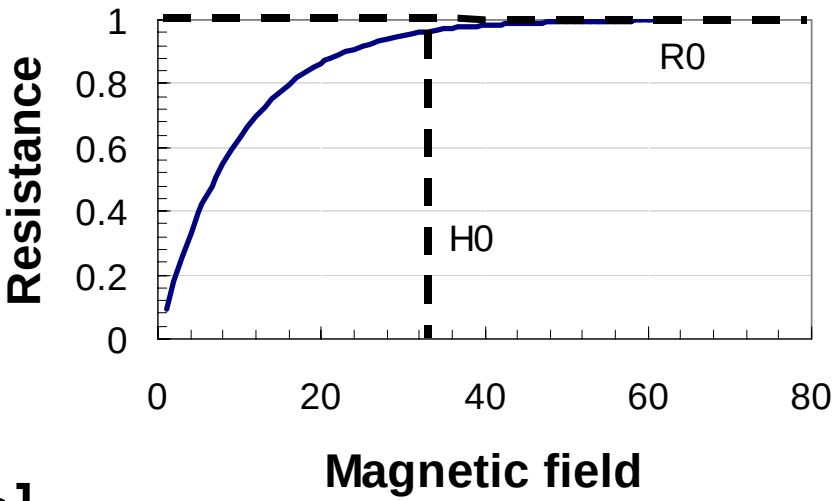
Transport Experiment



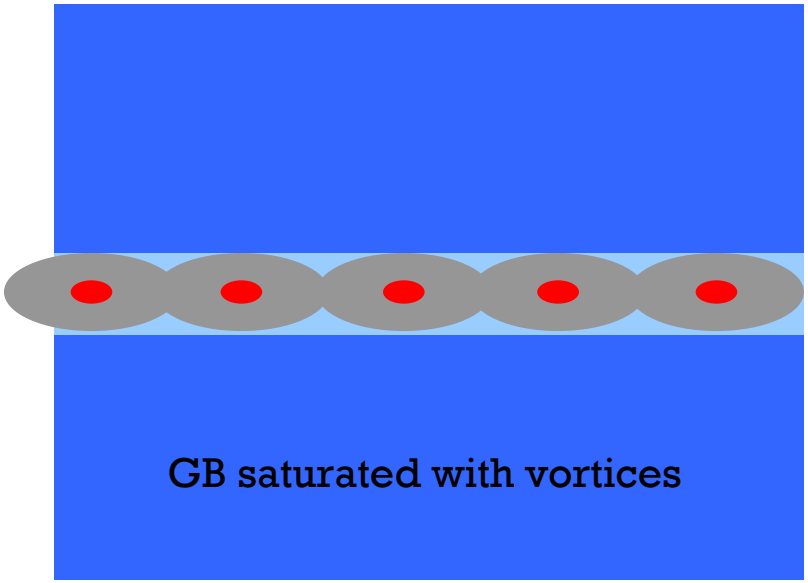




Measure flux flow resistance through GB as function of external field; Saturation-field H_0 gives information on de-pairing J_d of sc GB!

$$H_0 = \frac{\phi_0}{4\pi^2 l^2} \qquad l = \frac{c\phi_0}{16\pi^2\lambda^2 J_d}$$

saturation field — vortex size



S.Hawn, A. Gurevich

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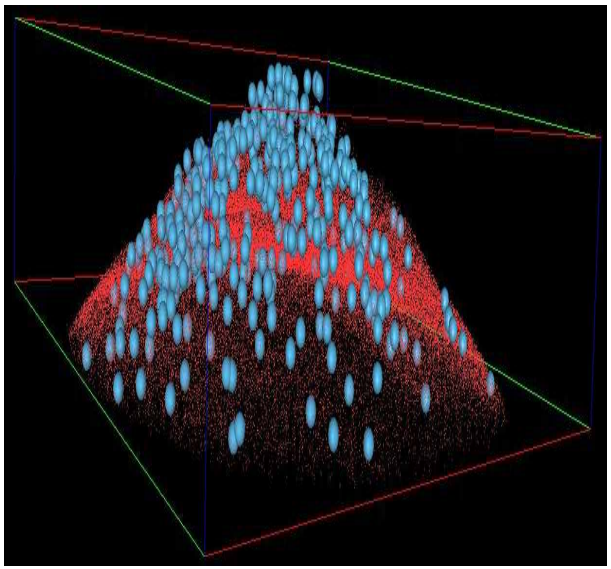
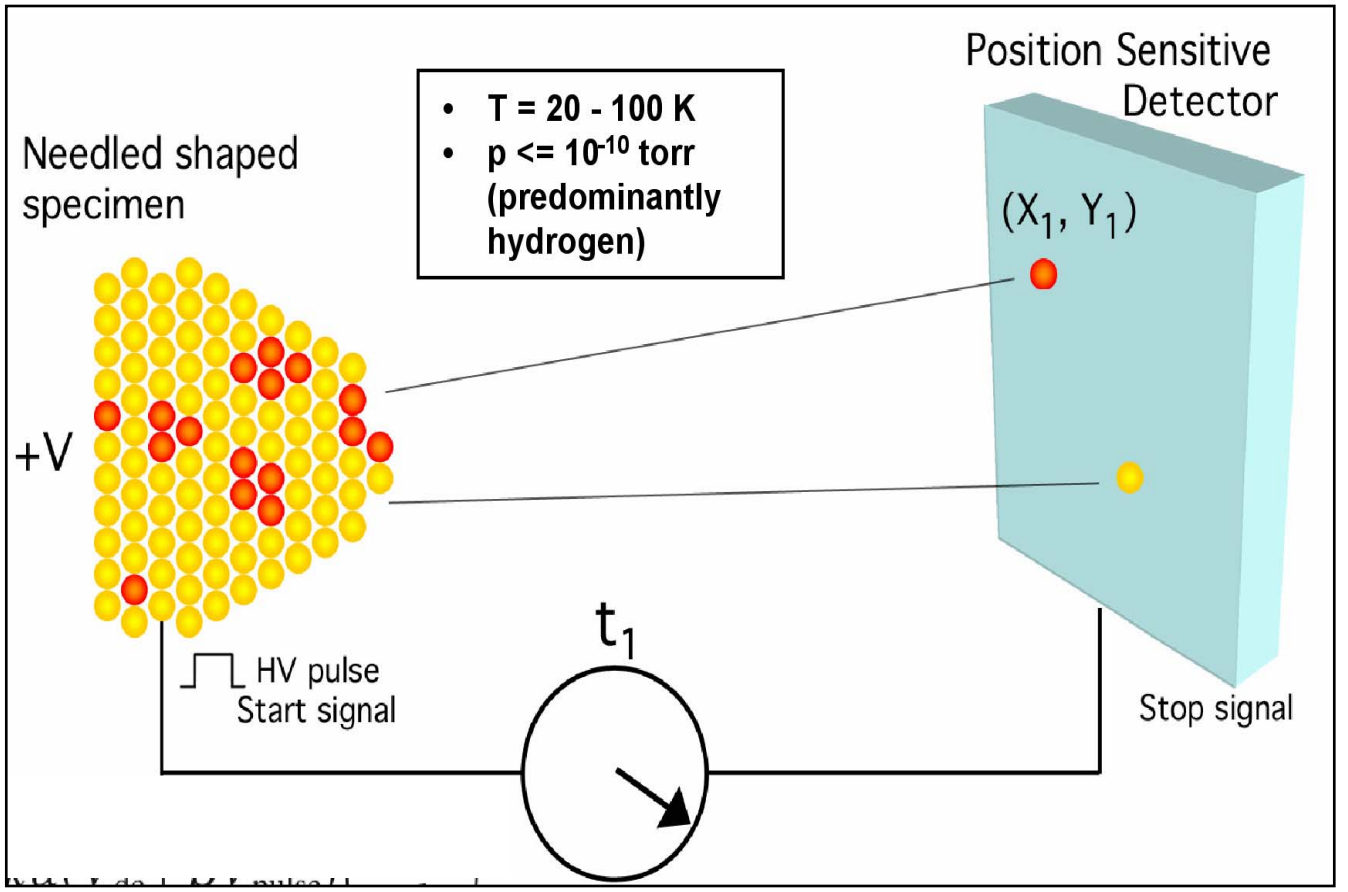
NUCAPT Northwestern University Center for Atom-Probe Tomography

Nb Nanochemistry w. 3DAP

D. Seidman,
K. Yoon
Northwestern University





Atomic resolution!

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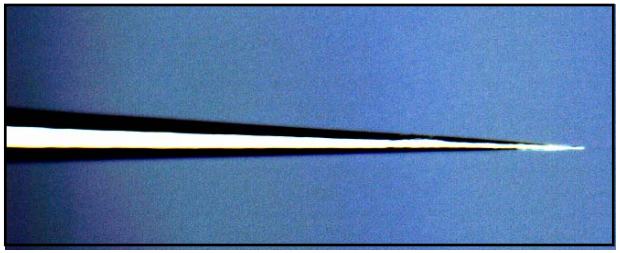
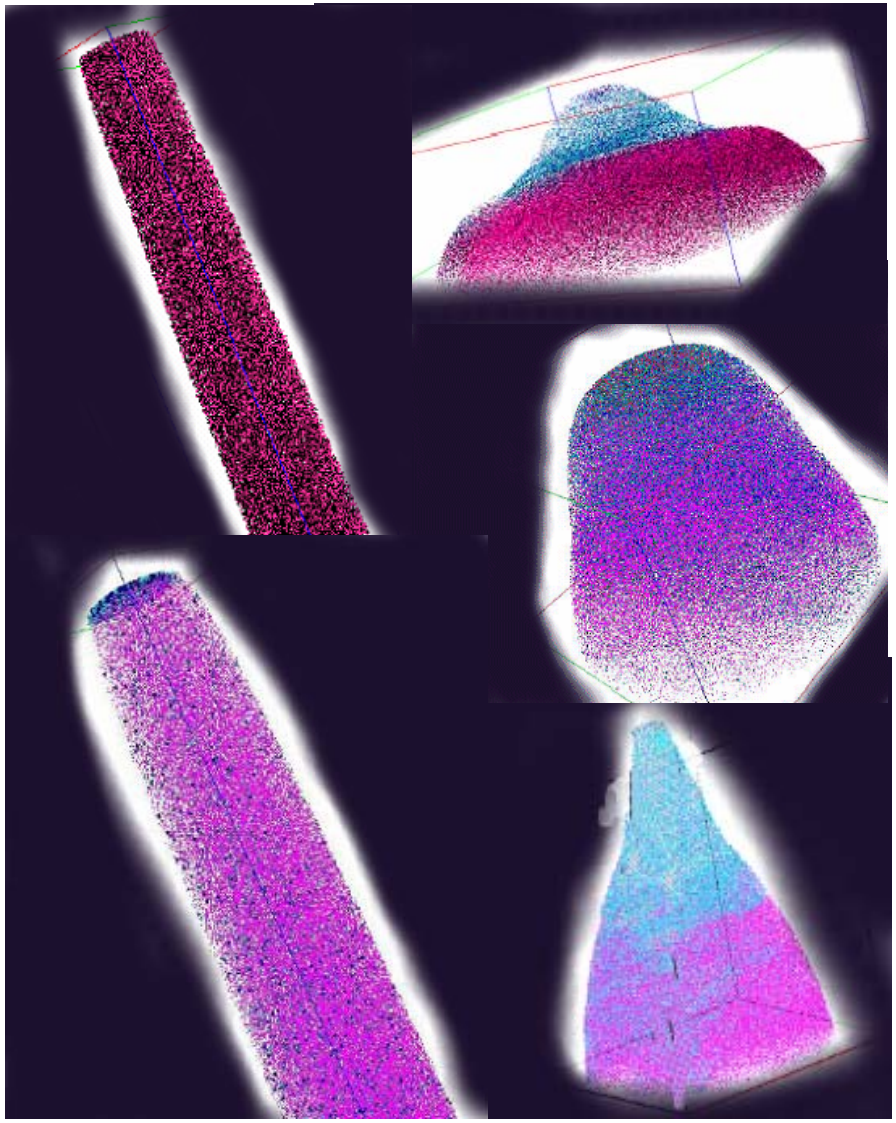
Nb Nanochemistry w. 3DAP

D. Seidman,K. Yoon
Northwestern University
C. Antoine, Fermilab



Tip prepared by D. Hicks and C. Antoine at Fermilab



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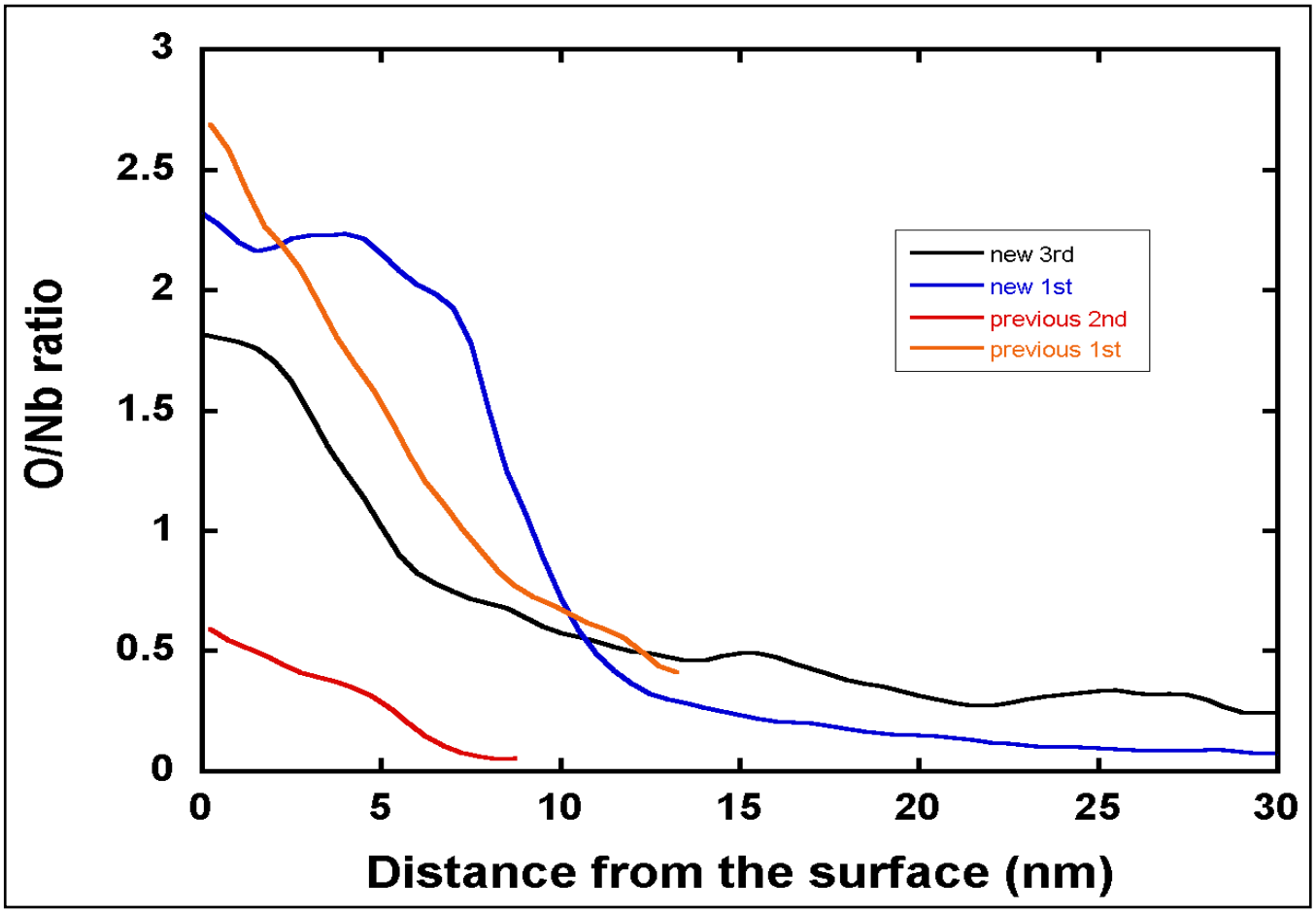
NUCAPT Northwestern University Center for Atom-Probe Tomography

3DAP Results

O levels in surface and bulk:

Oxygen concentration doesn't drop sharply – 10at% levels in first 20-30 nm of bulk!



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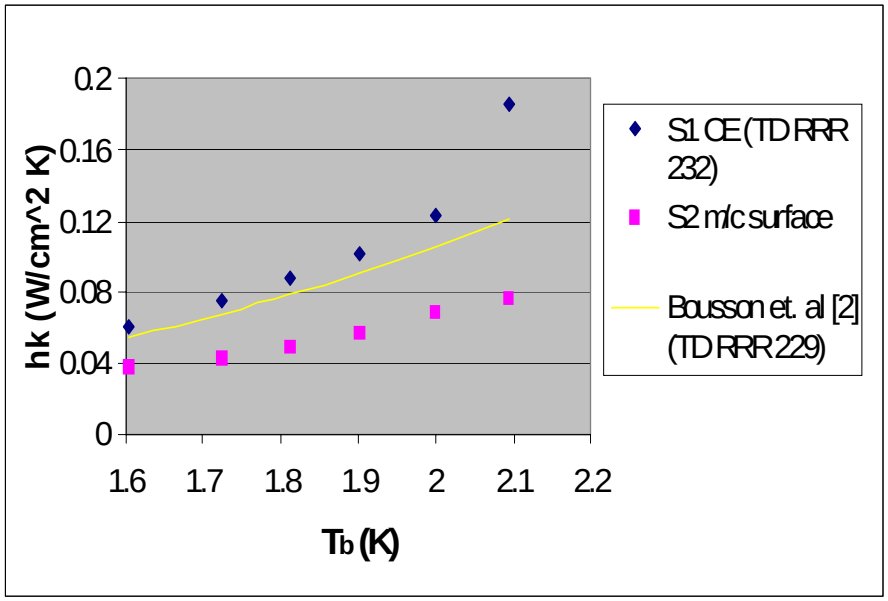
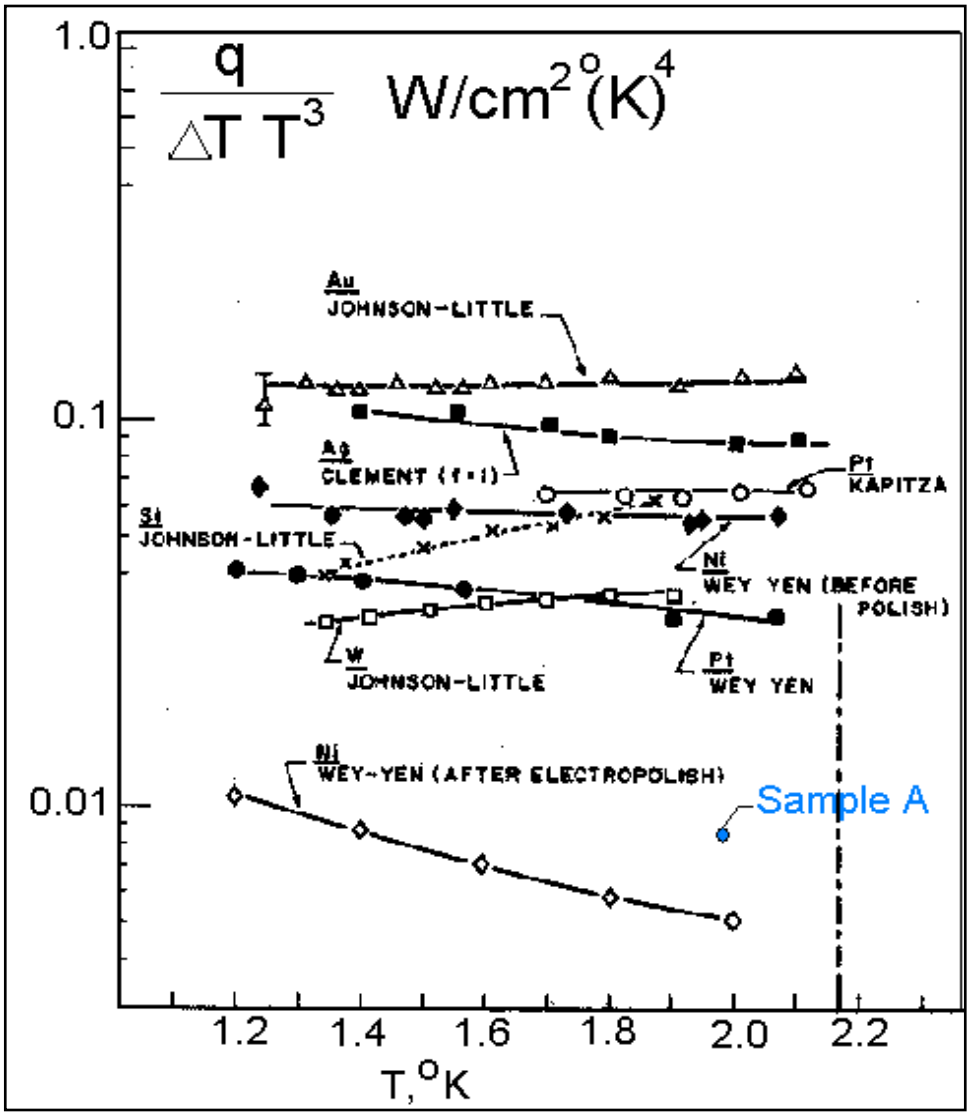
MSU Kapitza Conductance Study

Potential for a 10-fold improvement in Kapitza conductance!





A. Aizaz, T. Grimm

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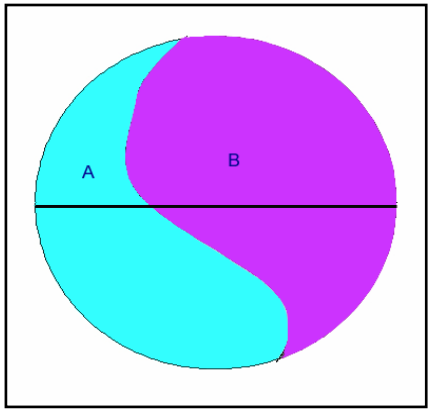
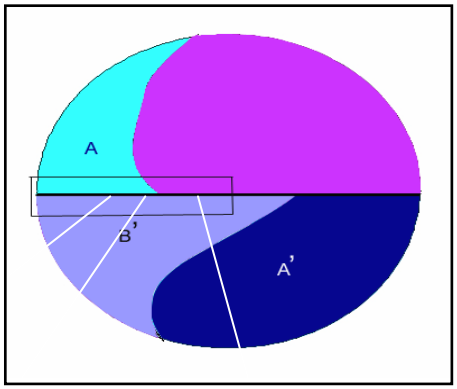
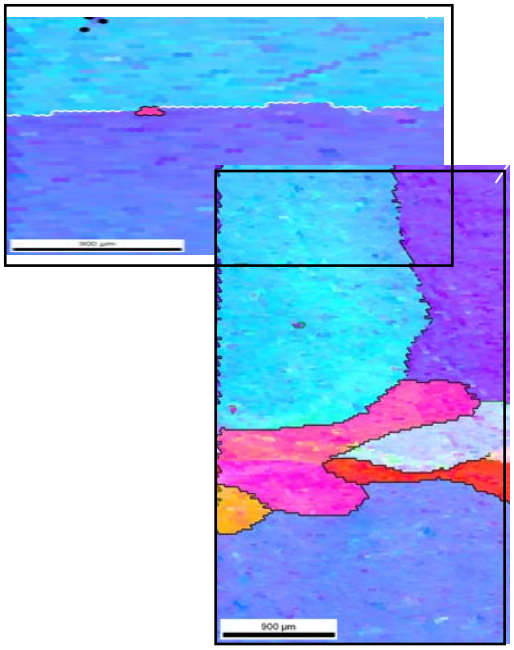
Nb Mechanical Property Studies

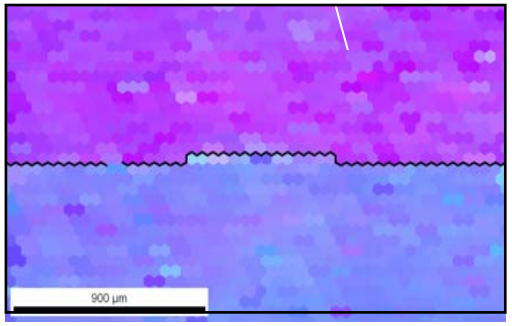
A. Aizas, D. Baars, T. Bieler, T. Grimm, H. Jiang





Re-crystallization of large grain Nb welds:





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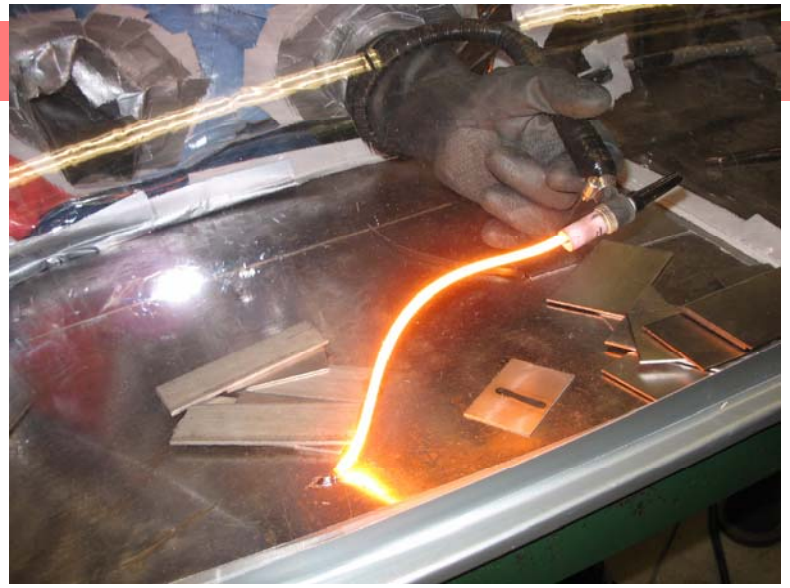
TIG Welding Study

High purity TIG Welding of Nb TIG process (tip, current,..etc) was defined; First samples were welded in "glovebox" flooded with commercial Ar and an improvised hot Ti filament; New Weldchamber in preparation



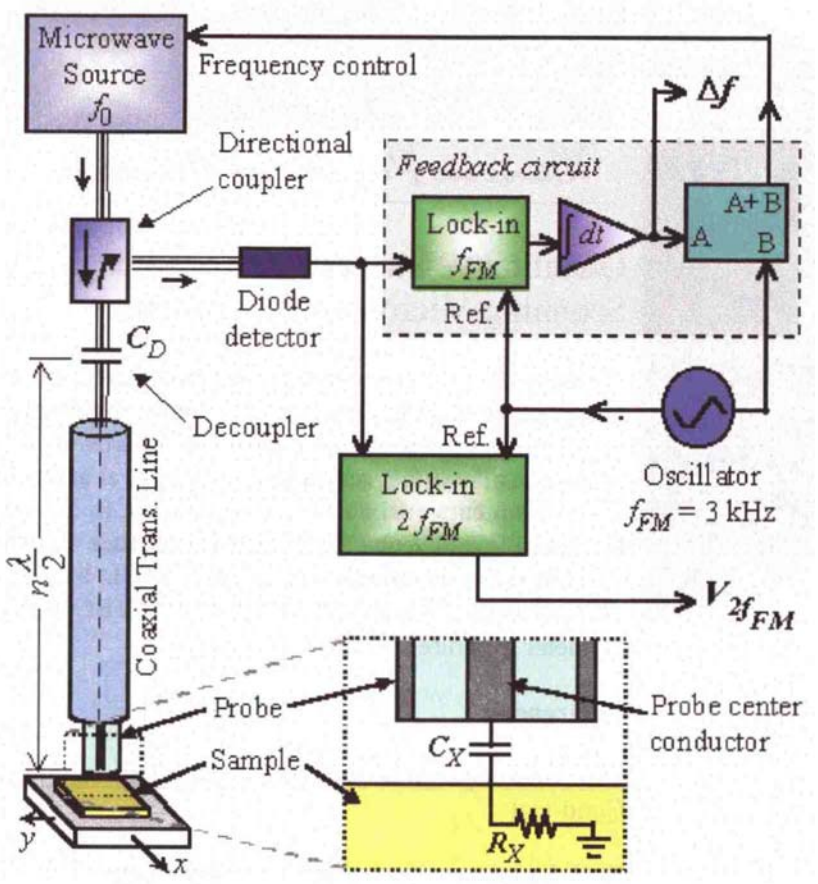
S. Bricker / D. Pendell – MSU

Achievements - University Programs

- UW discovery of in-homogeneities in superconducting properties in high purity Nb for SRF
- Advances in SRF theory – "Hot Spot Model", Non-Linear BCS Resistance, Thin Film Idea
- Nb nano-chemistry at unprecedented resolution – promising big results very soon!
- Investigation of welded large and single crystals

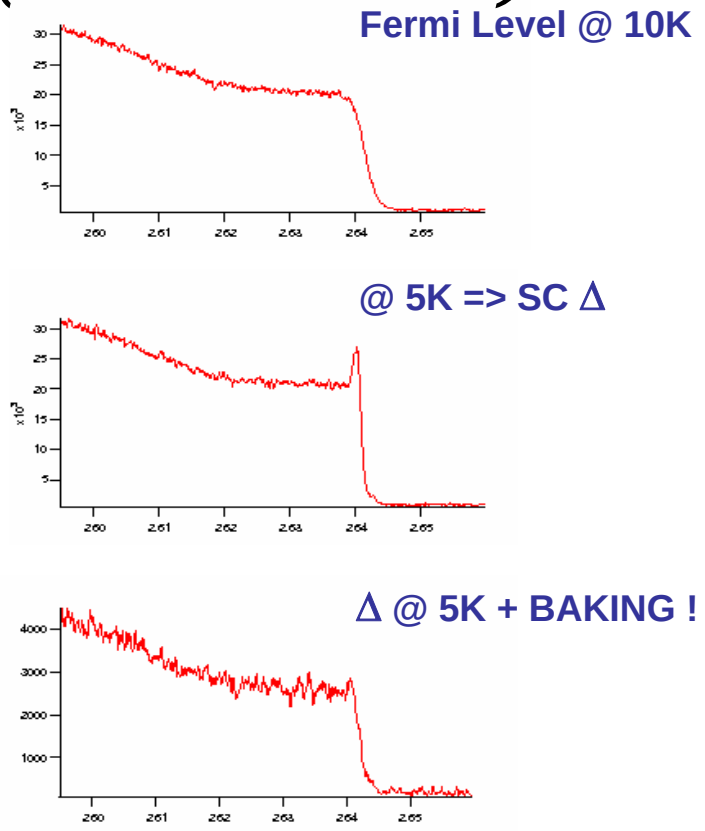
Others ideas ...?

RF microscopy



S. Anlage - UM

Superconducting gap measurement *(Photoemission)*



C. Antoine - CEA

Nb Production

- Specification
- Reproducibility
- Cost issues

- *Mechanical properties*
- *Recrystallization*
- *Texture/Orientation issues*
- *Forming process*
- *Fine grain/Large grain*

❑ *Specifications: tend to converge*

Improvements to gain in reproducibility ?

❑ Reproducibility: not yet achieved from batch to batch

*Need to study recrystallization vs deformation, time, temp, **&** RRR !*

Suppliers: QA/ instrumentation of the furnaces

❑ What is the favorable texture ?

(forming/mechanical resistance)

❑ Same work with large grain/monocrystals

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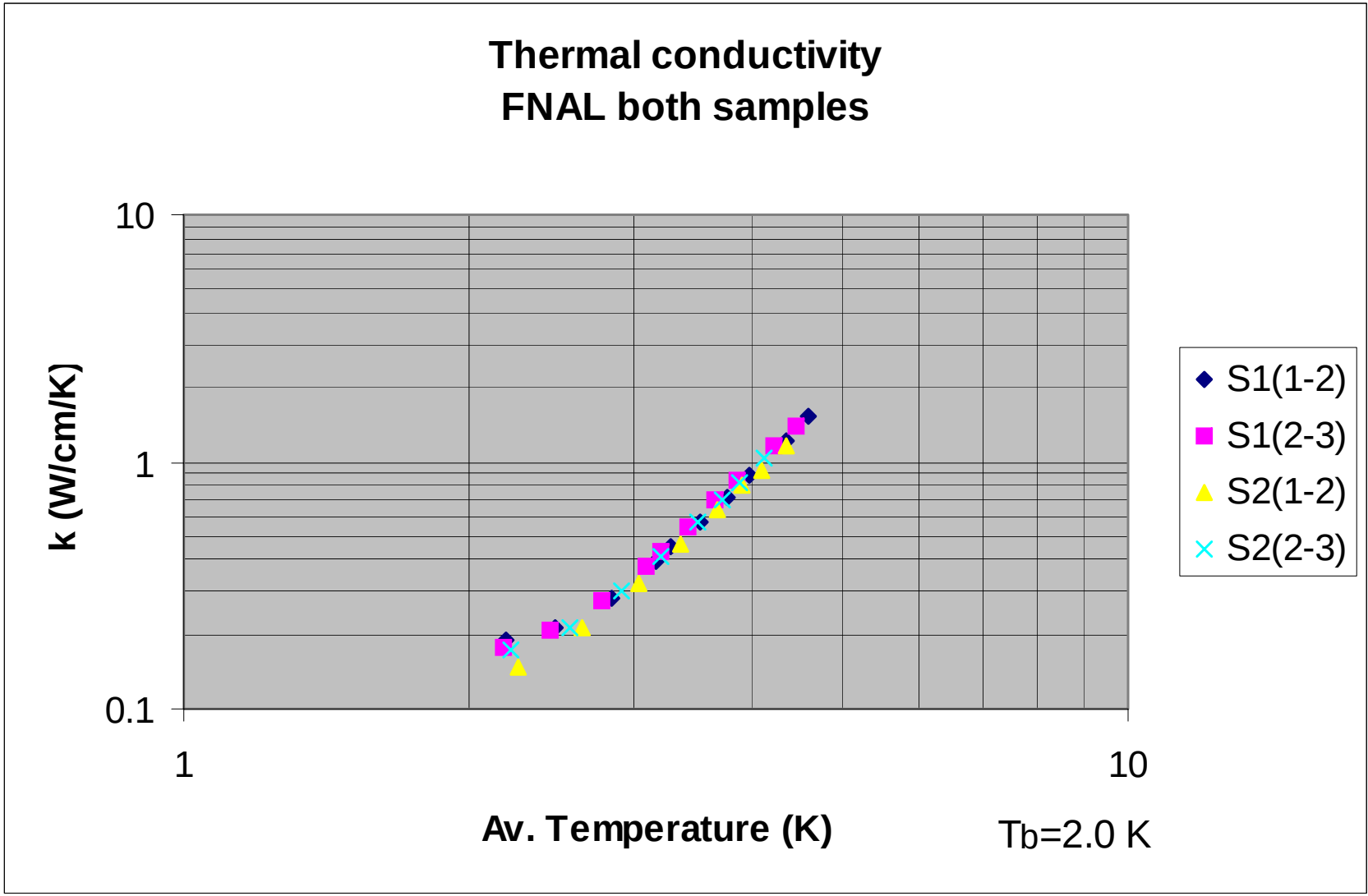
Thermal conductivity

Data on ILC Nb

Ahmad Aizaz & Terry Grimm MSU



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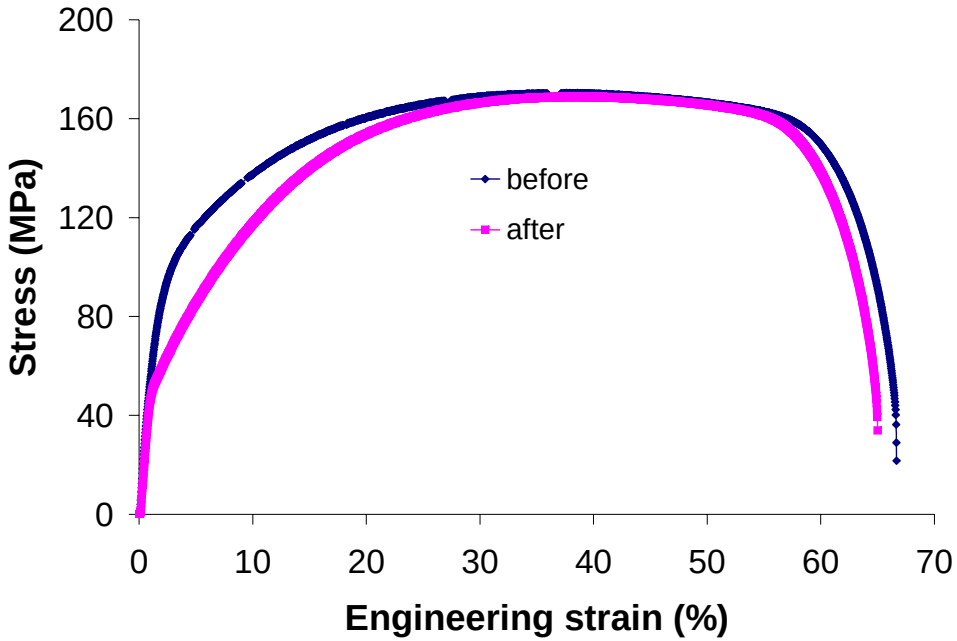
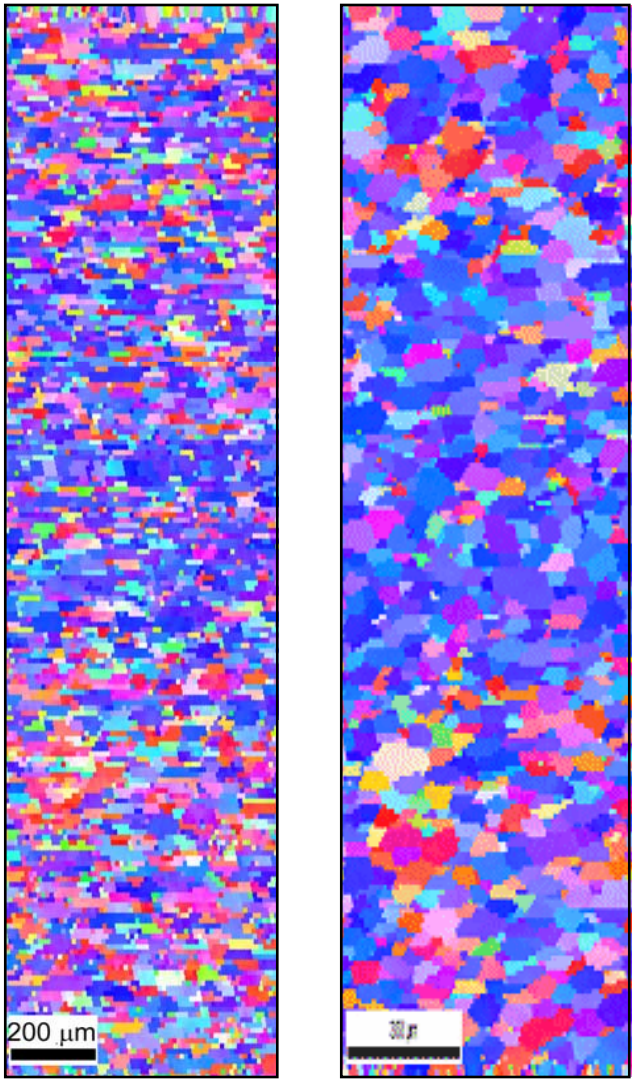
Microstructure & Mechanical Propert.

Recent Forming Problems: Improved Microstructure through Heat Treatment

T. Bieler, H. Jiang – MSU





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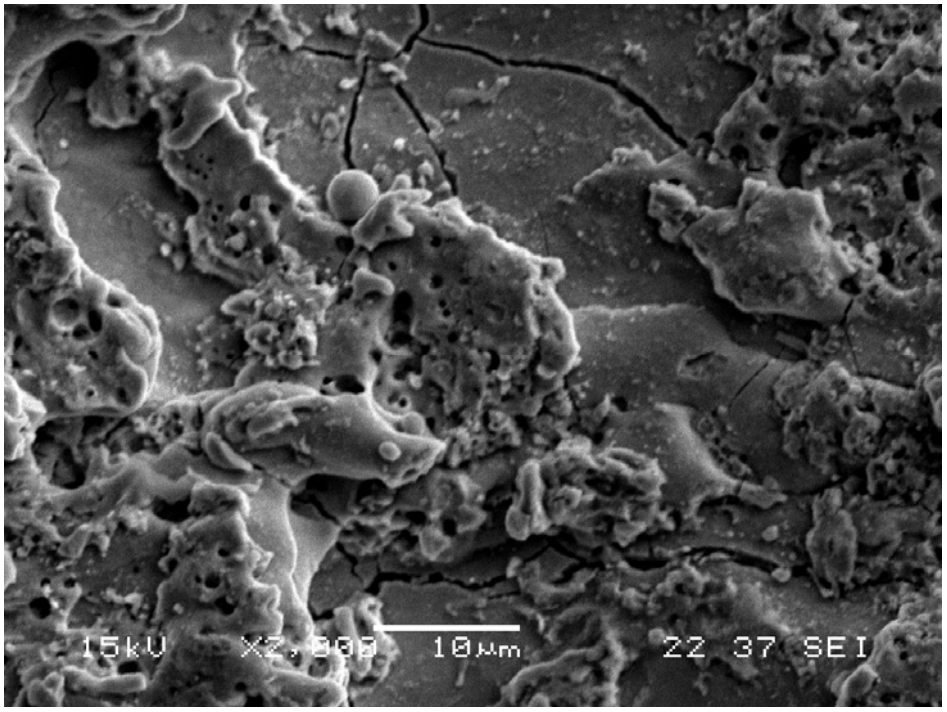
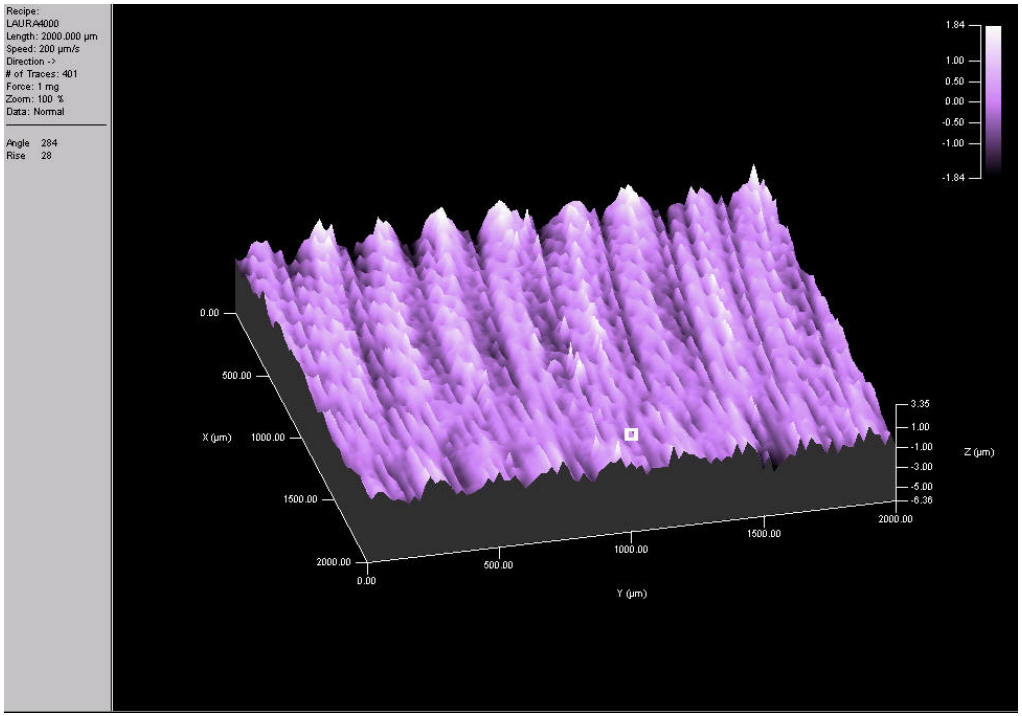
Surface Topology

Surface Roughness and Chemistry: Example: Study of different cutting techniques by C. Cooper / Fnal

EDM Cut Surface SEM



Milled Surface Topology



Vision for the near-to-mid term

- Continue w. Midwestern Group Activity;
- Possibly expand with DOE AARD Funds;

- Chasing Hot Spots
- Chemistry of the first 40 nm
- Macro-properties (Kappa, Kapitza,..)
- Microstructure – small & large grain

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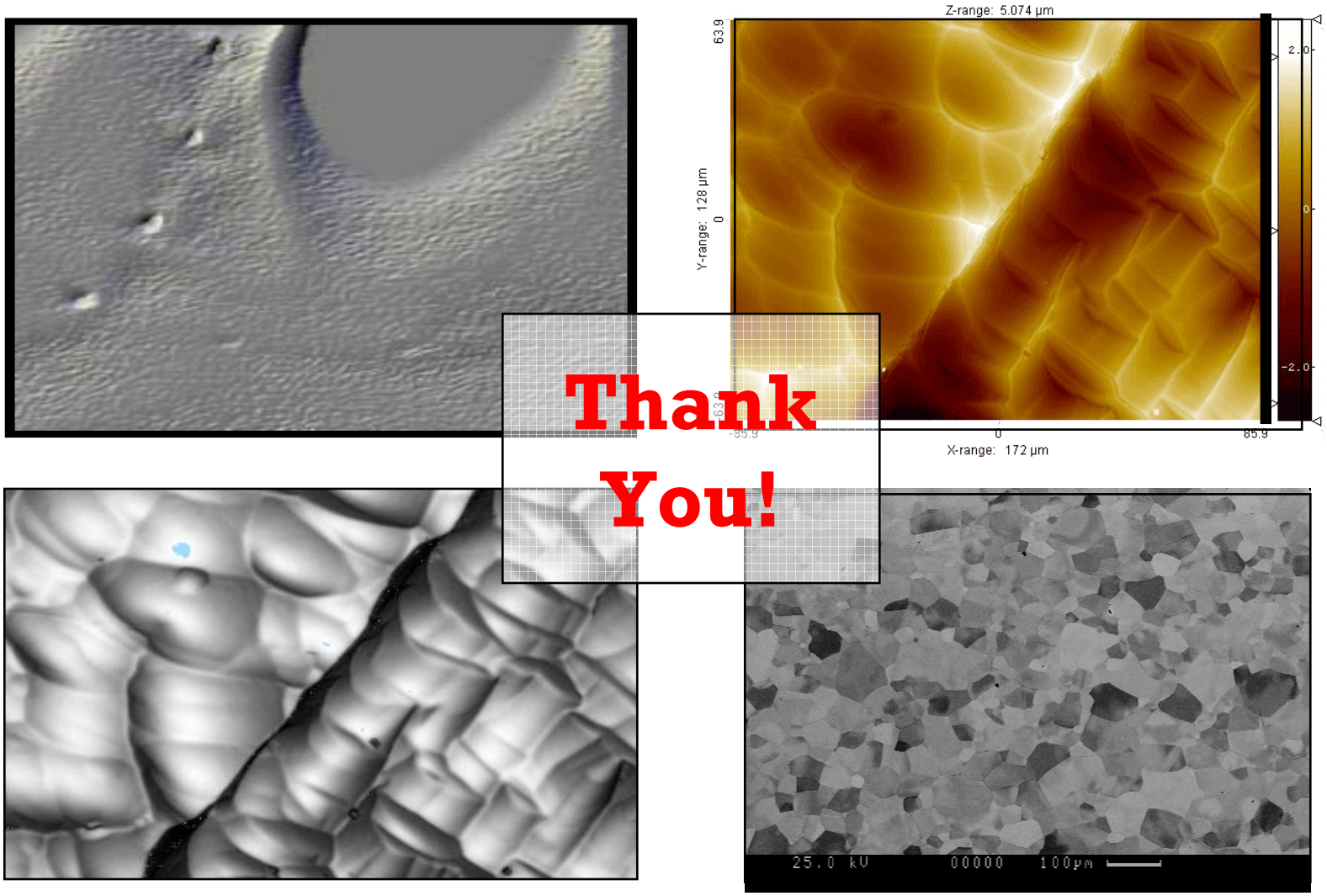

Thank You!