Brookhaven National Laboratory presentation
2007 Peer Review
August 7- 9, 2007, Arlington, VA

Enhancement of J_c in thick MOD and BaF_2 coatings through the structure improvement

DOE Peer Review, Arlington VA, August 7-9 2007

BROOKHAVEN NATIONAL LABORATORY

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Brookhaven National Laboratory, Upton, NY 11973

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Outline

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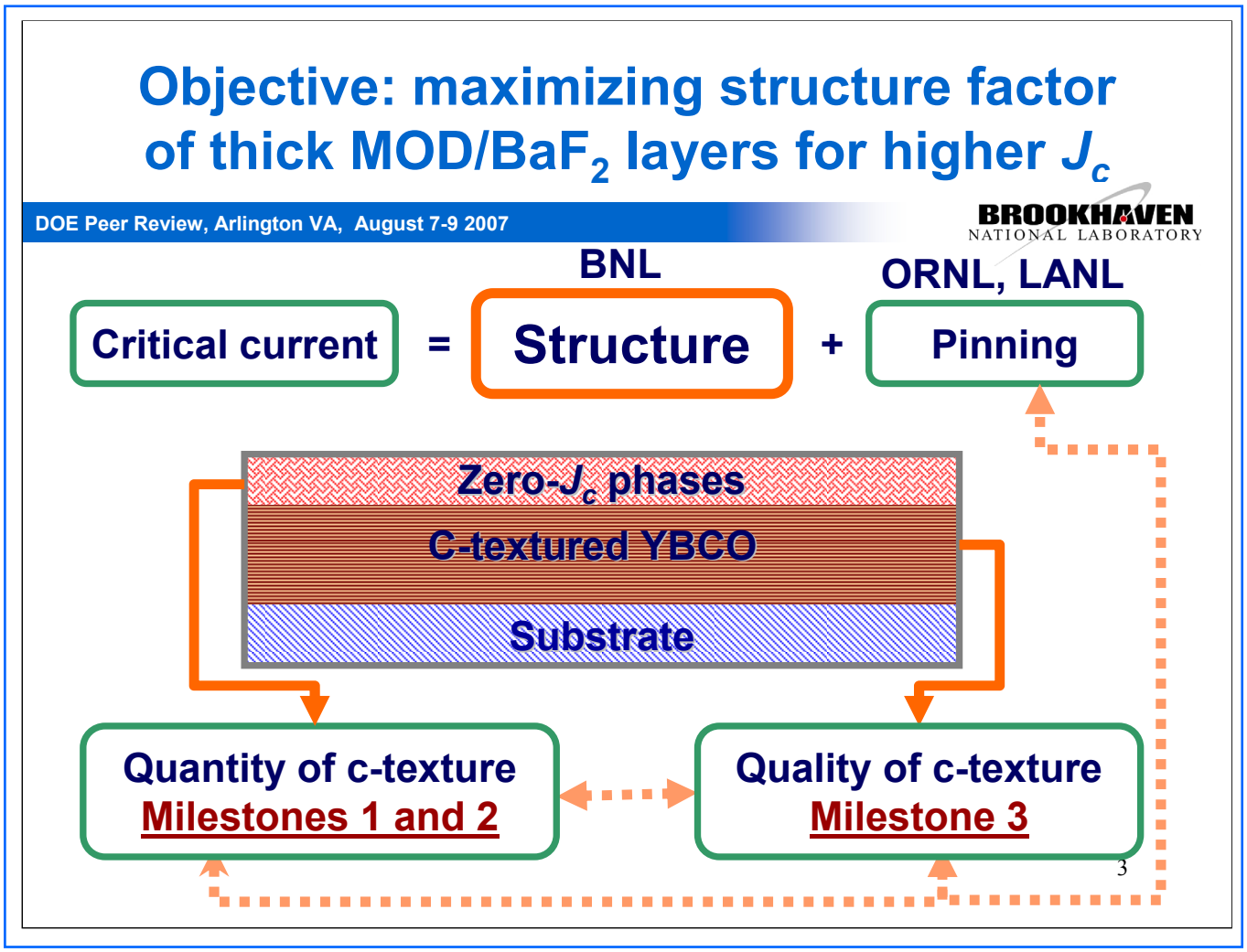
- Program objective and milestones
- FY2007 activities and progress (total $300K):
  - CRADA with AMSC: thick (>2 μm) MOD films ($100K)
  - Thermodynamics of structure formation ($200K)
- Project integration, publications
- Plans for FY2008

Staff:

Slowa Solovyov (PI) 100%, Harold Wiesmann (50%)


Objective: maximizing structure factor of thick MOD/BaF2 layers for higher Jc
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BNL
ORNL, LANL
Critical current
=
Structure
+
Pinning
Zero-Jc phases
C-textured YBCO
Substrate
Quantity of c-texture
Milestones 1 and 2
Quality of c-texture
Milestone 3
3

FY 2007 CPS milestones

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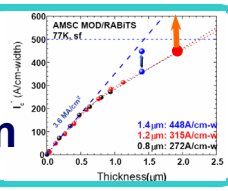
CRADA

1 . Make AMSC's 2 μm thick films with 400 A/cm (J_c = 2 MA/cm^2)

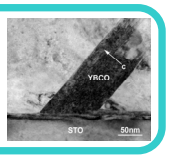
Goal: >600 A/cm



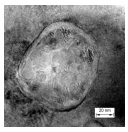
Core program

2 . Achieve 80% of effective cross-section in thick films.

Non-c texture



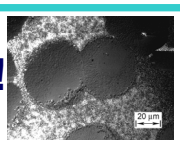
Other phases



Core program

3 . J_c vs. grains size in MOD layers Nucleation in thick MOD layers.

Granularity!



Material synthesis:
Two kinds of ex-situ precursors

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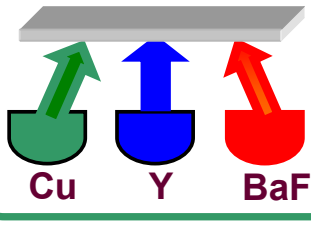
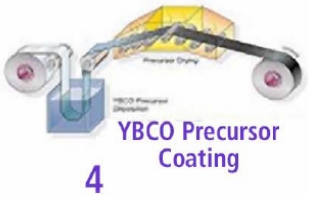
PVD precursor



RABITS tape

MOD precursor



- Lab-scale samples
- Dense, no shrinkage
- Uniformity at all thickness

- Industrial coatings
- Porous, high shrinkage
- Compositional variations

Conversion to YBCO at 735 – 780 °C

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Characterization:
Low-angle polishing for texture analysis

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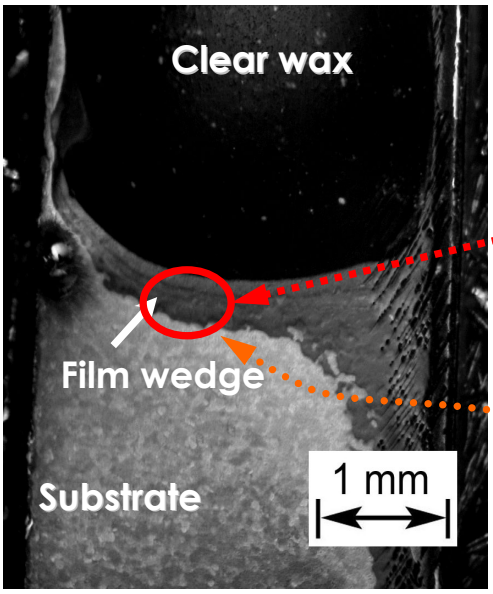

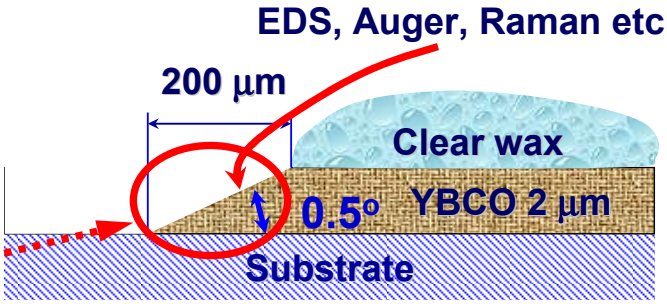

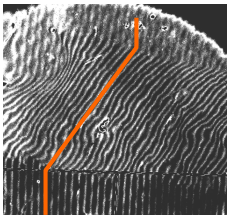

Interferometry: Linear thickness profile

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Quantity of c-textured material: Effective cross-section of thick-film YBCO

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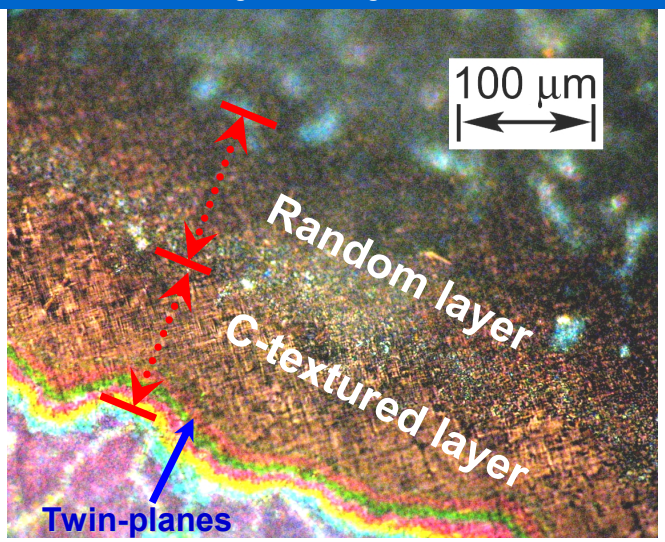

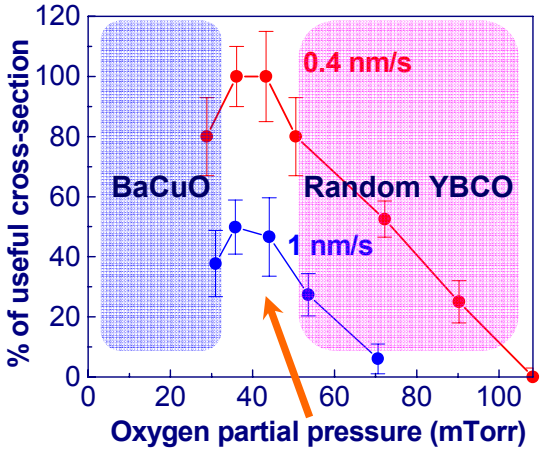

Optimum conditions
Solovyov, *JAP* (2006)

J_c = 1.2 MA/cm^2 because only 50% of film is used!

- There is a maximum growth rate which allows use of full cross-section

2 μm MOD layers: performance statistics

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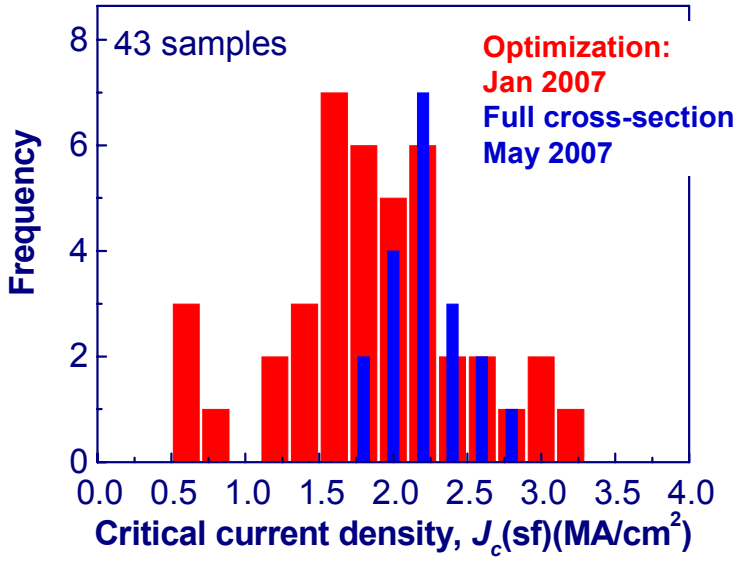
735 °C
0.4 nm/s



Milestone 1 (CRADA), completed:

- **2 MA/cm^2 level achieved for 2 μm triple coated films**

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Utilization of nearly full cross-section in 2 μm thick triple-coated MOD films

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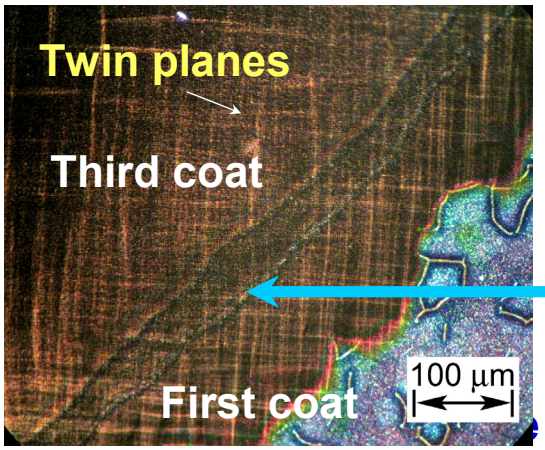

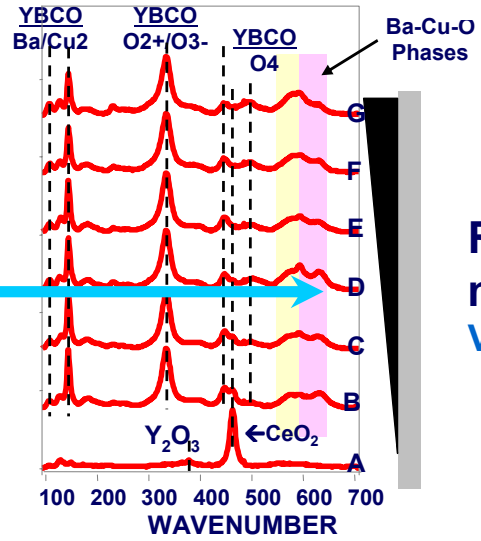

Raman microscopy
V. Maroni, ANL

Polarization contrast: Twin planes

Milestone 2, completed: 80% of the cross-section

- **Secondary phases and granularity limit J_c!**

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What is the initial precursor state?
EDX analysis of Cu-Ba ratio in 2 μm MOD film

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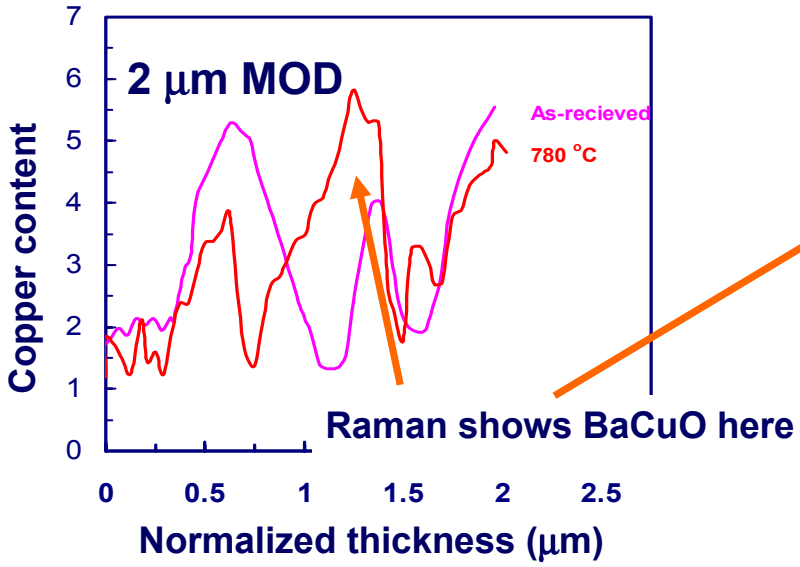

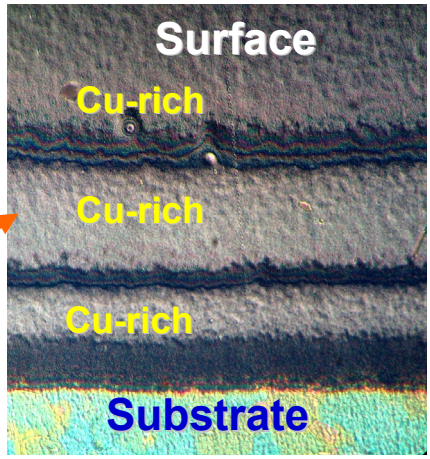

Profile of 2μm MOD film
Quenched from 780 °C

- Low-T (400 °C) Cu separation at the decomposition stage
- High-T (>700 °C) Cu separation at the growth stage

PVD films: precursors with no Low-T effect
EDX analysis of Cu-Ba ratio in 2 μm PVD film

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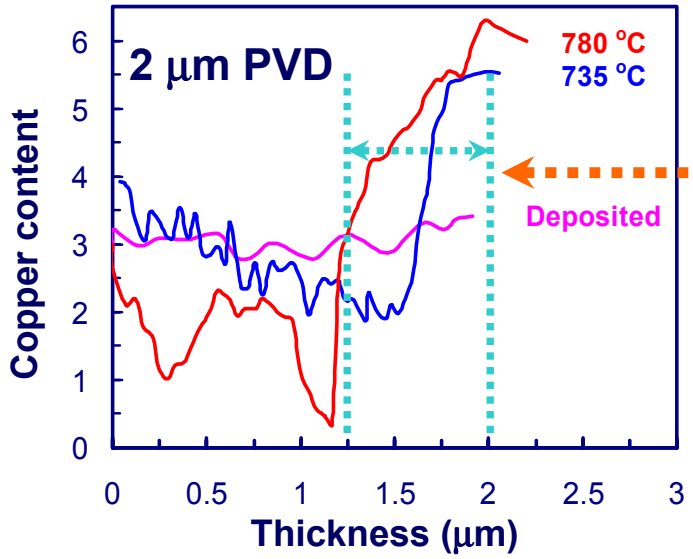

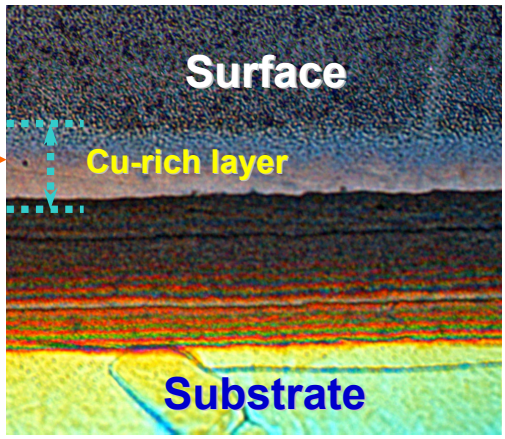

Profile of 2μm PVD film quenched from 780 °C

- In PVD precursors there is only High-T Cu separation

What can we do about Cu separation? Effect of processing temperature

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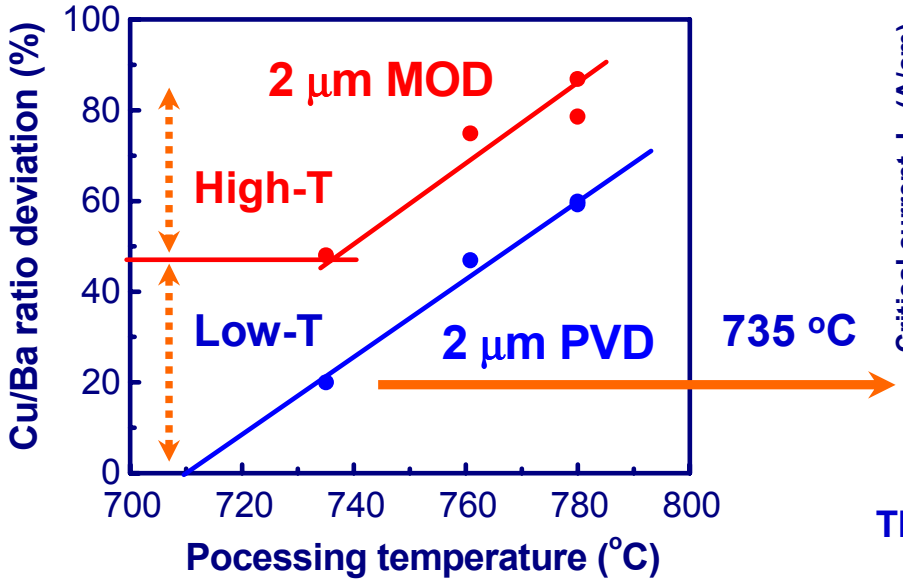
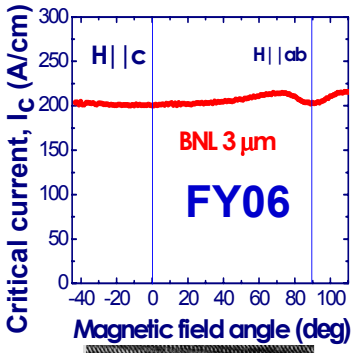
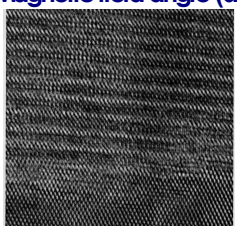




TEM



- **Processing at <740 °C suppresses high-T effect but growth rate is slow, thus not practical**

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High-T separation and secondary phases: Precursor structure in 0.8 and 2 μm MOD films

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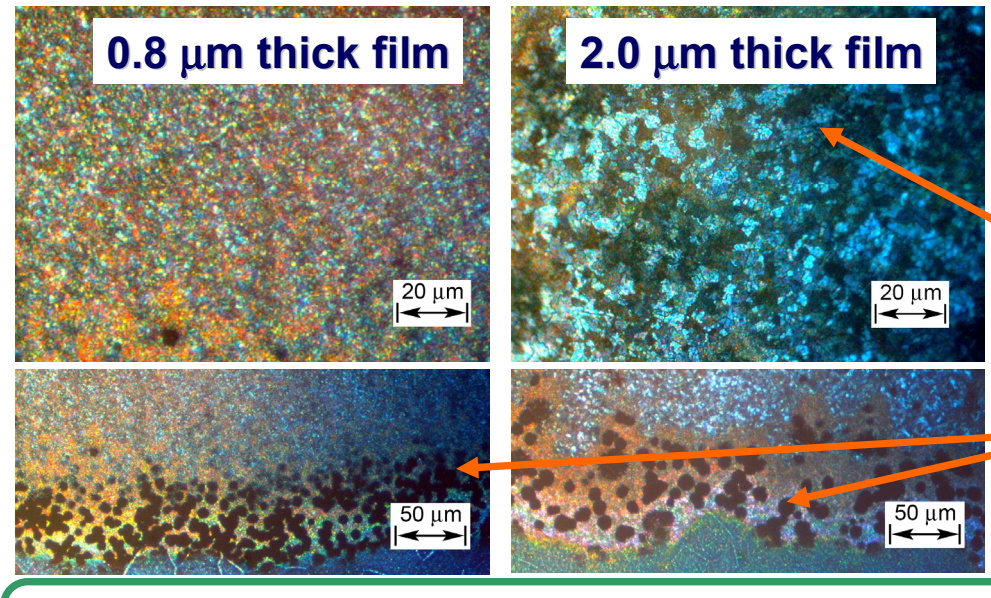

Quench 780 °C

First coat $BaCuO_2$ already here

YBCO nuclei

- High-T effects are related to the nucleation and HF loss
- Better thick films = better oxide buffers (work for FY08)

Sub-grain formation in ex-situ films

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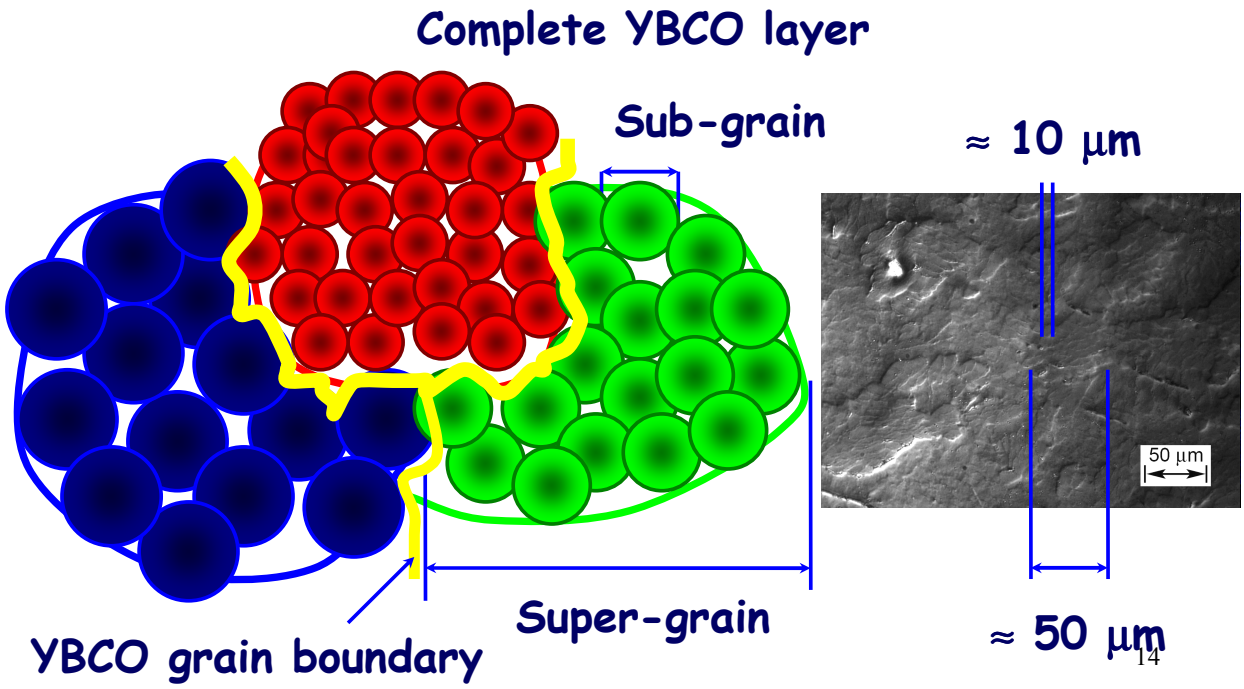

Sub-grain size: the critical quality factor in both PVD and MOD YBCO layers

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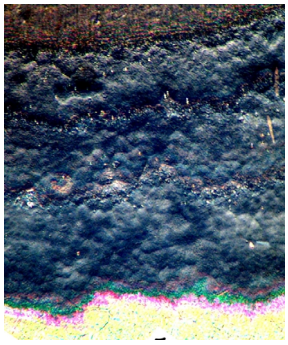
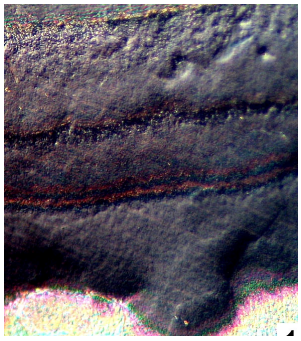
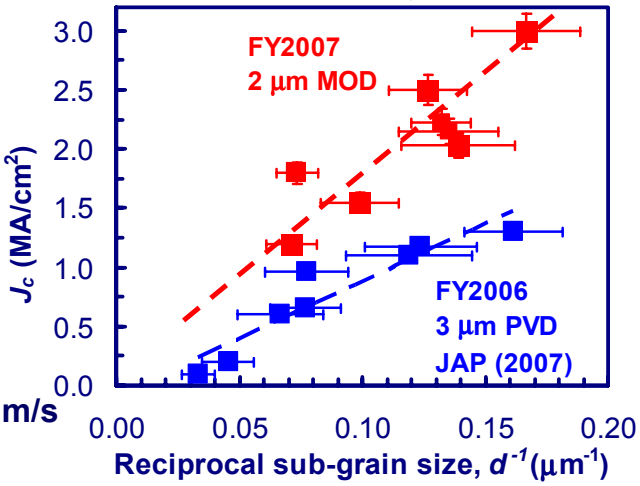
2 μm triple-coated MOD films



13 μm grain, 0.2 nm/s
J_c = 1.2 MA/cm²



≈6 μm grain, 0.4 nm/s
J_c = 2.8 MA/cm²



Milestone 3, completed:

- J_c is inversely proportional to the sub-grain size
- High J_c = Full cross-section + pure YBCO + small grains!

Why films with large grains have low J_c? TEM study of the granularity

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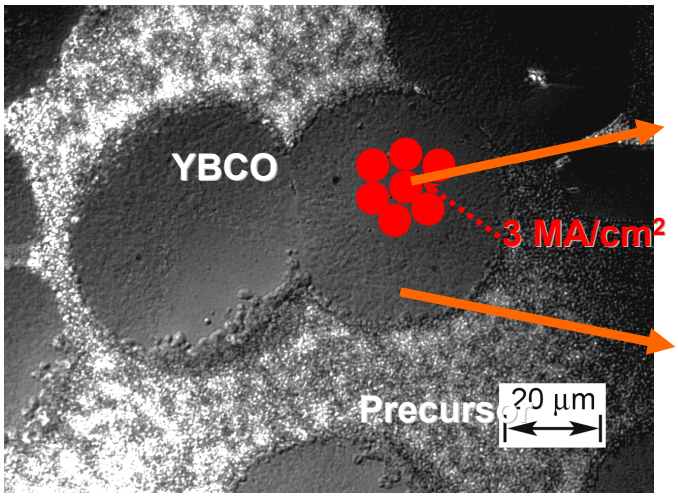
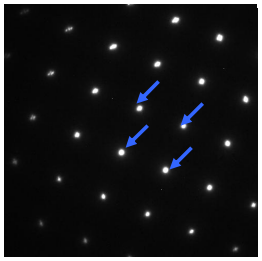
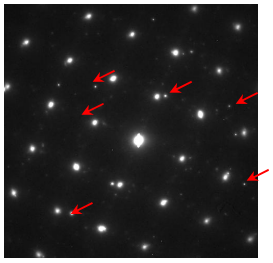




YBCO



non-YBCO

SAED by P. Oleynikov CFN, BNL

- Granularity does not degrade the YBCO alignment
- Big grains contain a lot of secondary phases

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Connection between structure and pinning: $J_c(H)$ vs. grain size in 2 μm MOD films

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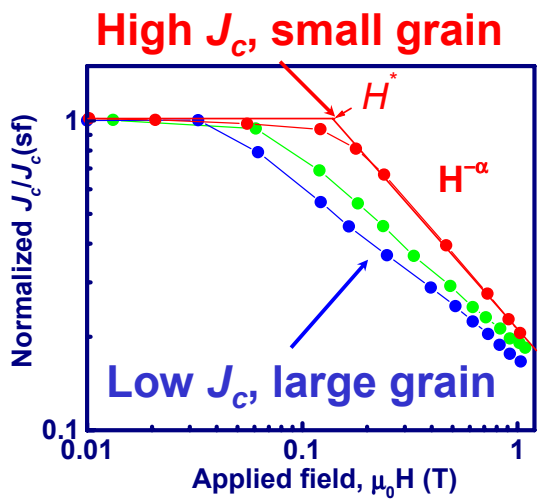

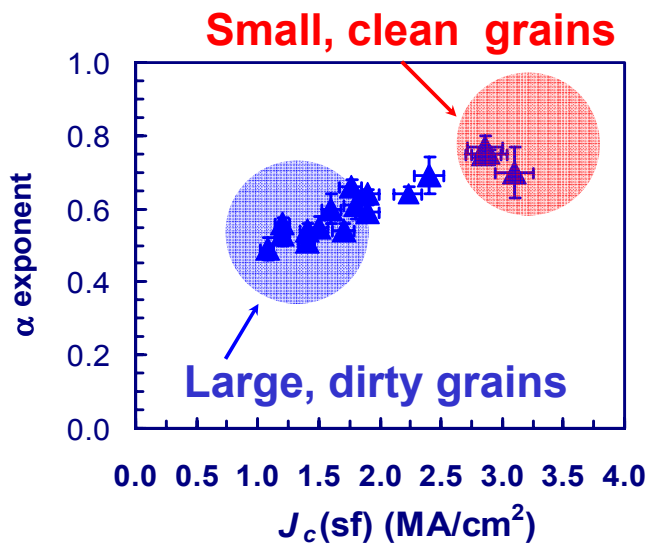

- Smaller grains = higher self-field J_c
- Smaller grains = weaker high field pinning (higher α)

Summary of FY07 activity: Milestones completed

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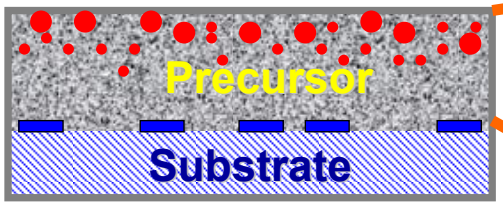
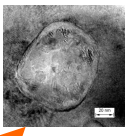
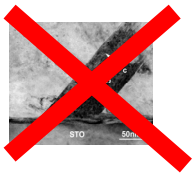
Parasitic reactions: Precursor+ H_2O = zeroJ_cPhases + 2HF
Assisted by surface proximity!







FY2008

Useful reaction: Precursor+ H_2O = epiYBCO + 2HF
Assisted by the substrate!

- Achieved 2 MA/cm^2 in 2 μm MOD layers
- Utilization of over 80% of the cross-section
- Established J_c vs. granularity relation in MOD layers

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Summary of FY07 activity: Project integration

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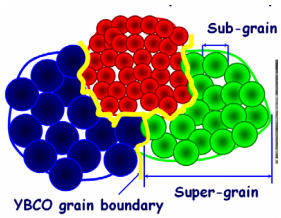
- Industry: CRADA with AMSC:
  - Over 100 MOD samples processed
  - Weekly teleconferences, 4 visits/year
- Argonne: Vic Maroni, Raman microscopy:
  - Low angle polishing and Raman Spectroscopy
  - Analysis of secondary phases
- Florida State: Dmytro Abraimov, EBSD:
  - Meandering, sub-grains, super-grains



Summary of FY07 activity: Scientific publications and presentations

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Presentations

1. ***Applied Superconductivity Conference*** *2006,* Seattle, WA*,* Solovyov V.F *"*Evolution of texture during ex-situ processing of 3-4 micron thick YBCO films."
2. ***MRS Meeting 2007***, San Francisco, CA, Solovyov V.F*, "*Texture Development in 2-3 μm Thick YBCO Films Synthesized by BaF_2 and MOD Processes on Metal RABiTS™ "

Publications

1. ***Journal of Applied Physics*** 99(1): 013902-013908, (2006). Solovyov, V. F., H. J. Wiesmann, et al. "Three- and four-μm-thick $YBa_2Cu_3O_7$ layers with high critical-current densities on flexible metallic substrates by the BaF_2 process."
2. ***Superconductor Science and Technology*** 20: L20-L23, (2007). Solovyov, V. F., H. J. Wiesmann, et al. "High critical currents by isotropic magnetic-flux-pinning centres in a 3 μm-thick $YBa_2Cu_3O_7$ superconducting coated conductor."
3. ***Journal of Applied Physics****,* 102(5): 2007 V.F. Solovyov, H. J. Wiesmann, and M. Suenaga "Critical current densities and the structural quality of 3- and 4-μm-thick superconducting $YBa_2Cu_3O_7$ layers synthesized using the ex-situ process"
4. ***Physica C***, submitted for publication, Solovyov, V. F., H. J. Wiesmann, "Application of low-angle polishing for rapid assessment of texture and morphology of thick film $Y_1Ba_2Cu_3O_7$ tapes"

Plans for FY08 I:
Better structure through better substrates

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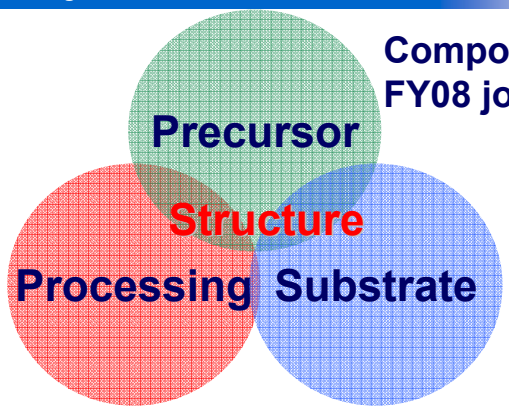
Composition uniformity (Low-T)
FY08 joint with WDG

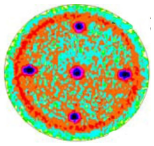


Optimized
(FY06-07)

FY08: substrate factor
High-T separation
granularity, other phases

FY08: What is a good substrate?

Traditional: XRD, not enough!



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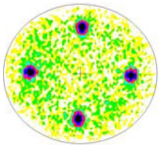
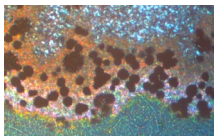


Good

FY08: The nucleation efficiency!



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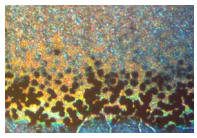

Good

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Plans for FY08 II: Growth defects vs. J_c(H) in MOD films

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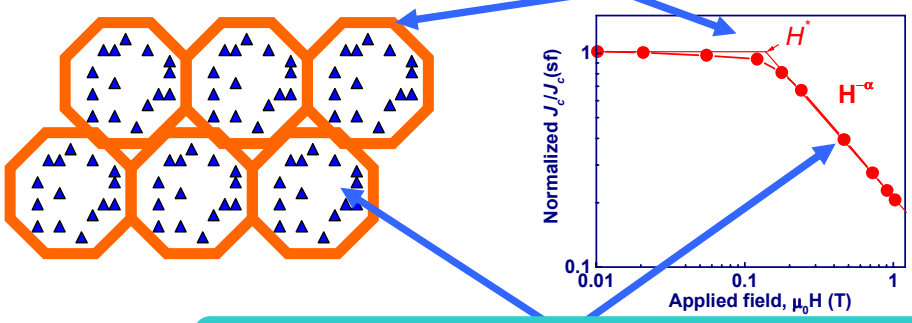
Two types of growth-induced defects

Grain boundaries, responsible for H*?



Defects within the grains, responsible for α

- How H* and α change when we change the grain size?
- What are the defects within the grains (TEM)?