

Quality Control Initiatives in Manufacturing Scale-up of Coated Conductors at SuperPower

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HTS Solutions for a New Dimension in Power

18th International Symposium on Superconductivity 2005 - ISS 2005 – Tsukuba, Japan

October 24-26, 2005

Outline



- **Characterization of Ic non uniformity in long MOCVD tapes**
- **Development of new quality control tools**
 - Automated optical tape inspection tool
 - Ex-situ XRD measurements
 - In-situ Raman spectroscopy
 - Off-line non contact critical current profiles
- **Manufacturing of 100m+ coated conductor**
 - Performance
 - QA/QC procedures

Characterization of I_c non-uniformity in long MOCVD tapes

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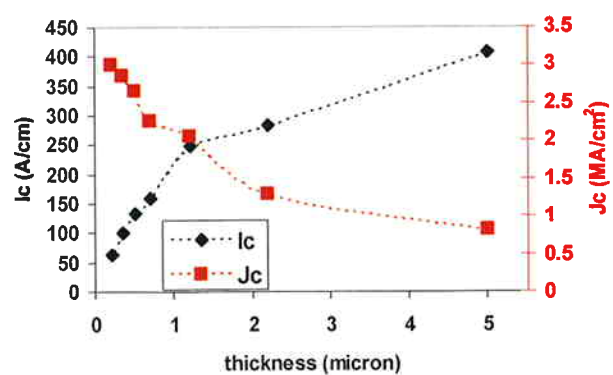
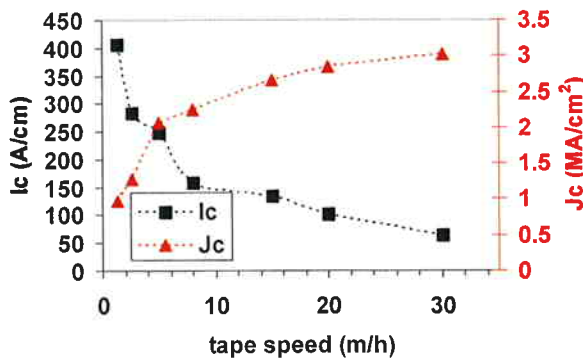
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MOCVD was chosen for its advantages of high throughput & high linear tape speed



High deposition rates (120 Å/s) in MOCVD enable very high linear tape speeds



Even at a high linear tape speed of **20 m/h** in our Research MOCVD system with a deposition zone of 20 cm, we achieved

I_c : 100 A/cm **$J_c \sim 2.8$ MA/cm²**

Pilot MOCVD system was installed for high throughput manufacturing of 100+ m tapes

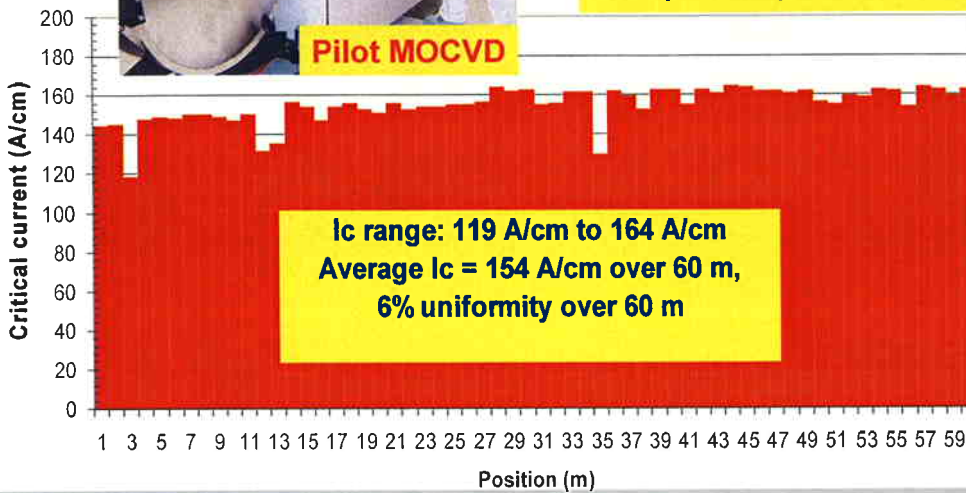
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Spool boxes fit 2 km single piece lengths

Up to 1 m long deposition zone

7 cm wide deposition zone (for multiple wraps in a helix)

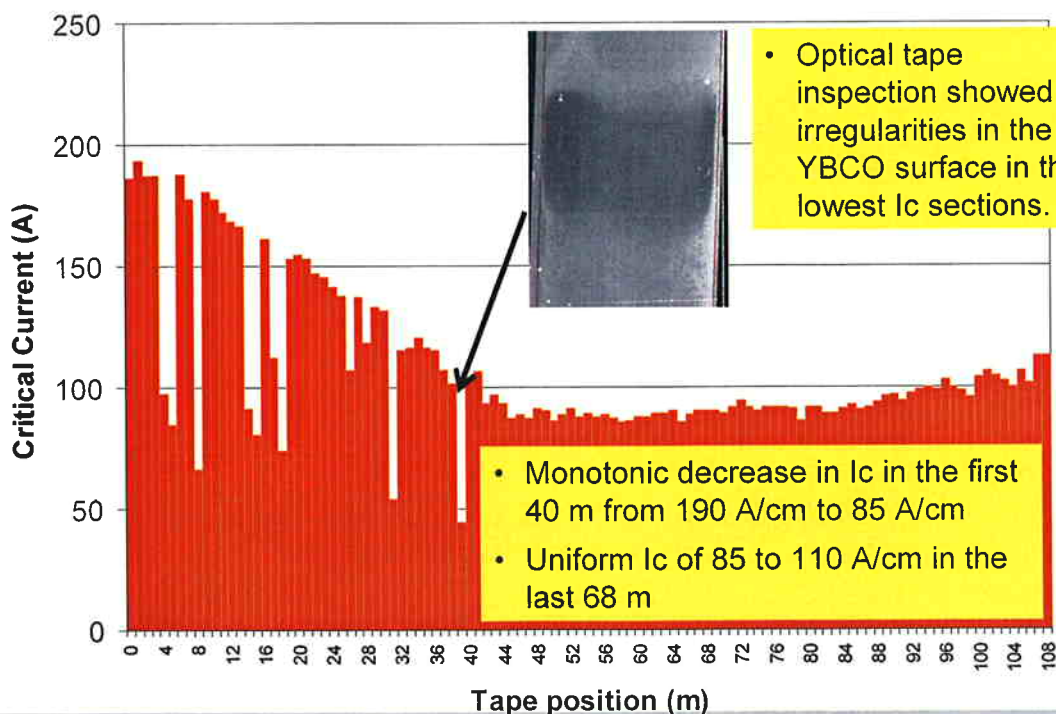


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An early 100 m tape in Pilot MOCVD showed variability in performance

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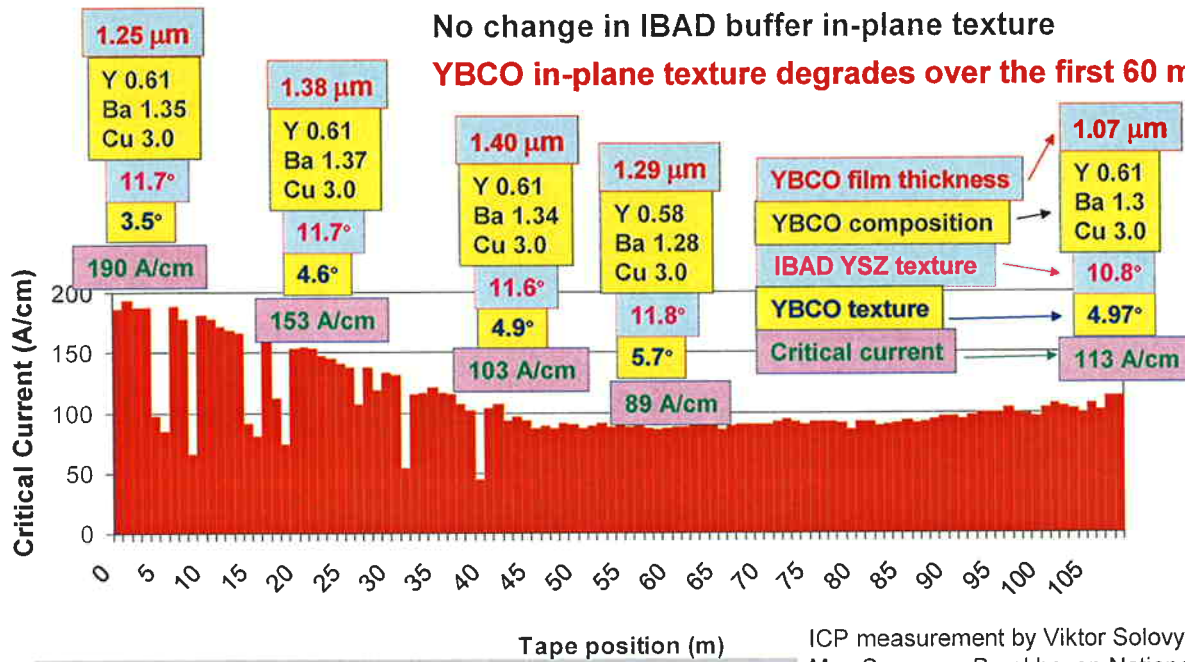
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A microstructural correlation to the I_c profile over 108 m was identified.

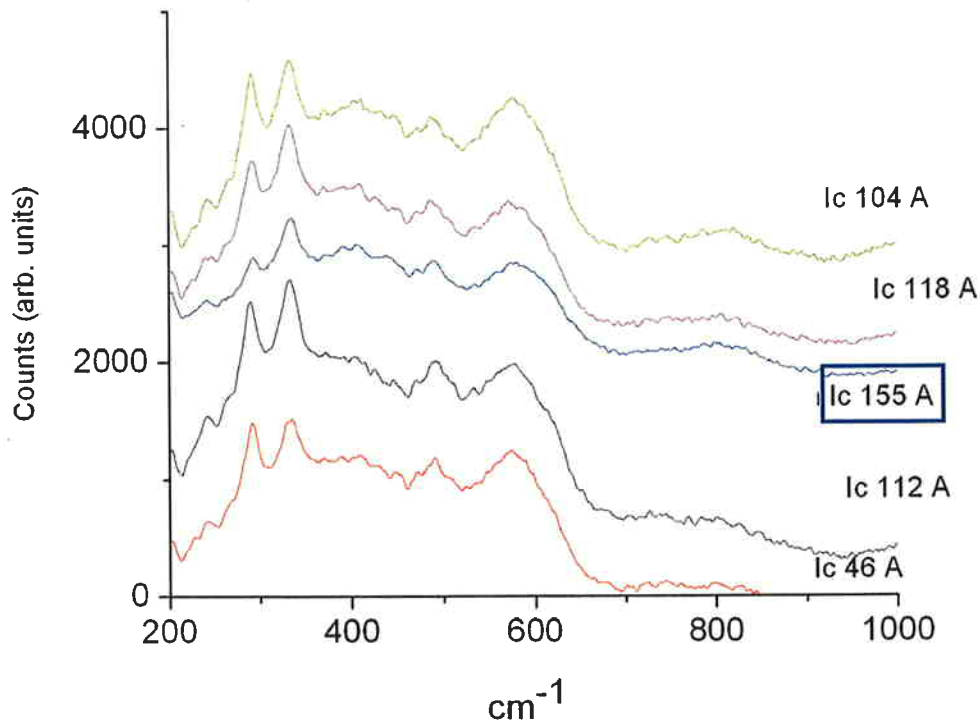
No change in YBCO film thickness
 No change in YBCO film composition
 No change in IBAD buffer in-plane texture

YBCO in-plane texture degrades over the first 60 m



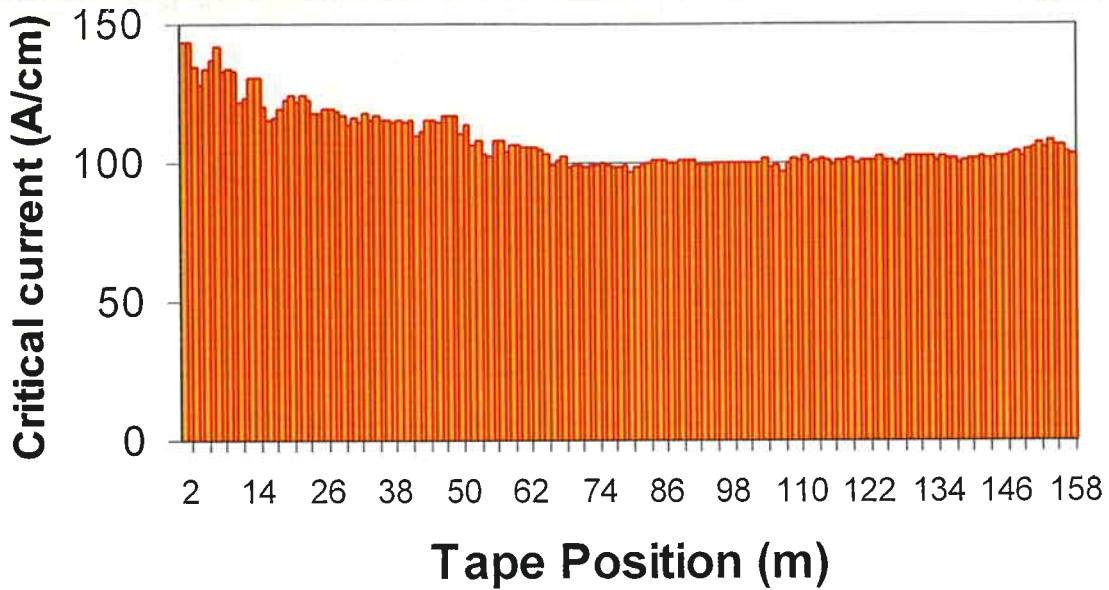
ICP measurement by Viktor Solovyov & Mas Suenaga, Brookhaven National Lab

Raman spectra show a less intense peak (Y211 phase) in the highest I_c section.



Multi-pass process successfully used to produce 158 m long tape by MOCVD with improved I_c uniformity

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$I_c \sim 100$ A/cm over 158 m

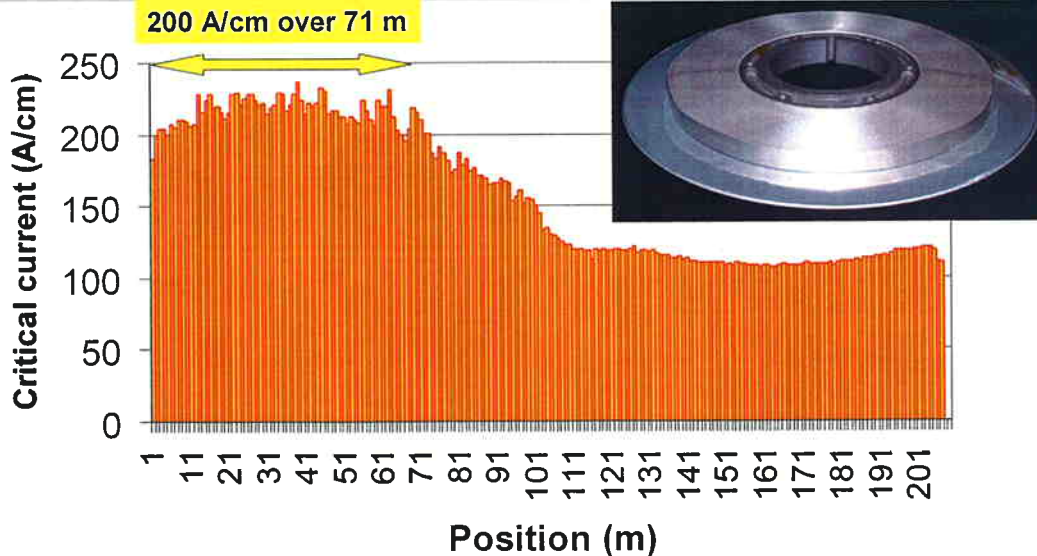
Standard deviation = 2% over last 100 m

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200 m long 2G conductor by MOCVD

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Minimum I_c of 106.7 A/cm over 206.7 m (22,030 A-m)

71 m with I_c of 200 A/cm with standard deviation of 4.3%

Standard deviation of 4.3% over the last 100 m

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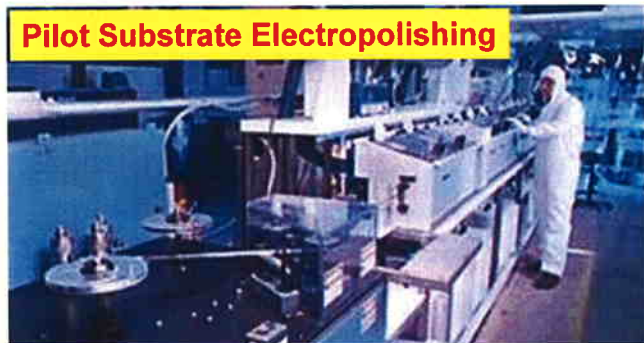
Quality Control Tools for Coated Conductor Manufacturing

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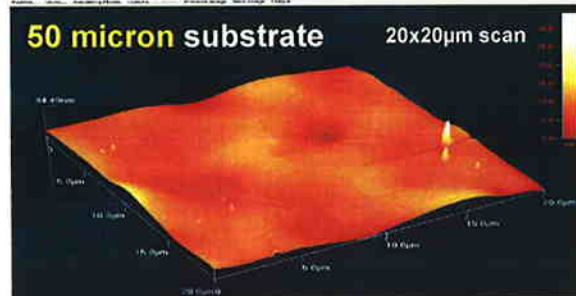
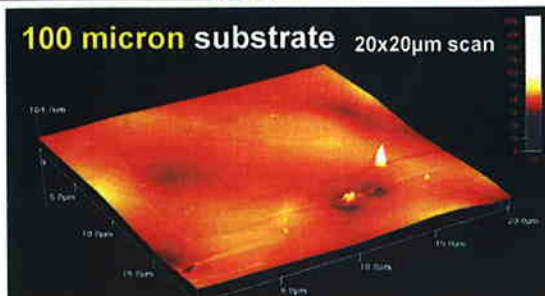
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On-line roughness monitoring and off-line AFM measurements used as QA/QC for substrate polishing



	100 micron substrate	50 micron substrate
Lengths	150 m	300 m
Roughness	2.8 nm	1.9 nm
Slope	~ 3.3°	~ 7°
G.B. slope	< 1°	< 1°



Quality of electropolished 50 micron substrates meets even the stringent requirements of IBAD MgO

Reel-to-reel Nomarski microscopy & optical profilometry are used for substrate characterization

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Electropolished tape – with grain boundaries



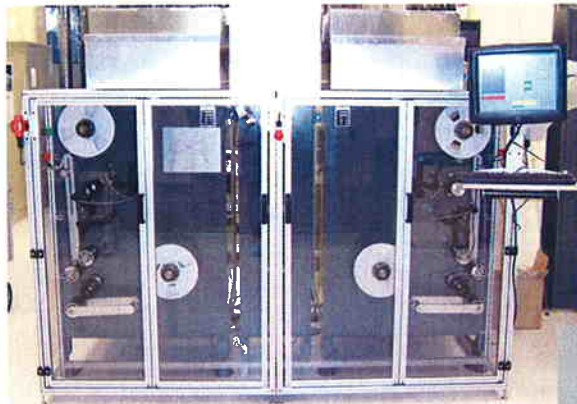
Electropolished tape – no grain boundaries

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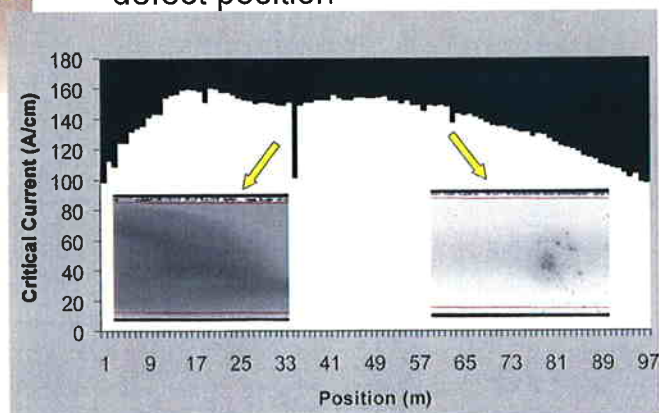
An automated optical tape inspection system is used for QC/QA between every process step.

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- Reel-to-reel tape drives for edge guided, tension control for over 2 km long tapes at a maximum speed of 450 m/h
- Camera system inspects tape at 90m/hr and correlates defect type to defect position

- 100 - 300 m long tapes inspected - as polished substrate, buffer, MOCVD YBCO
- Tape Inspection system was used to locate weak spots in the first 100 m MOCVD tape *before* I_c testing

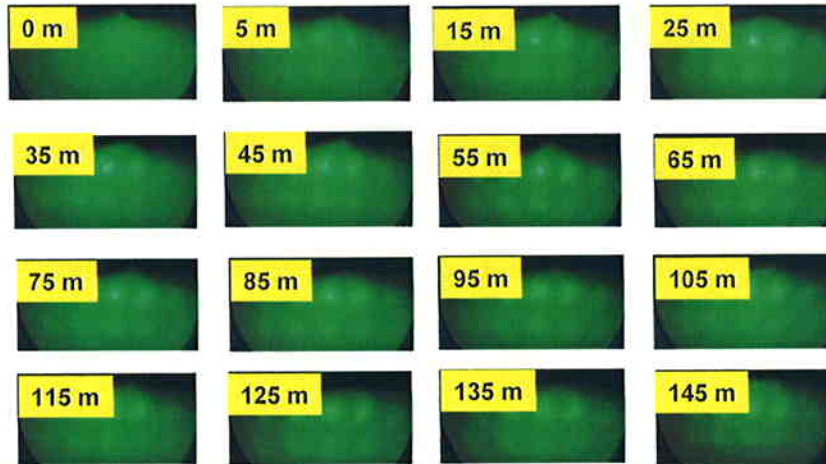
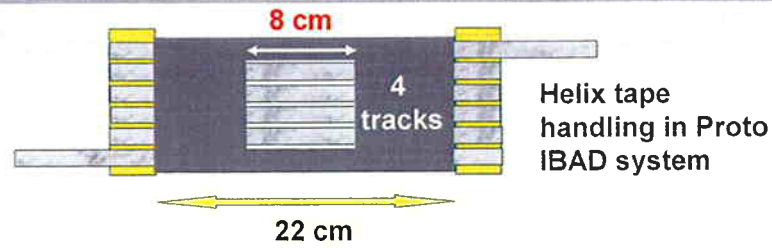


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On-line RHEED qualifies the buffer surface texture during IBAD MgO processing

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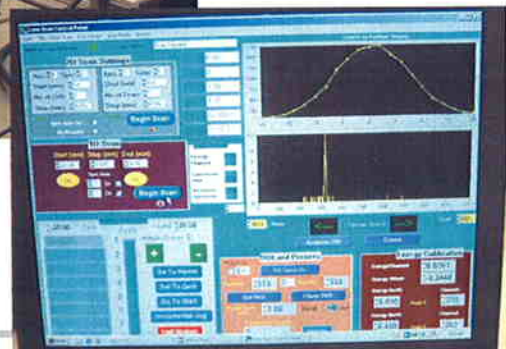
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High-speed, novel in-plane texture measurement system used for texture measurements on long IBAD tapes

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- ⊕ Acquisition time: 1 sec per point with detector averaging 5000cps
- ⊕ Cycle time for complete pole figure = 35 seconds !

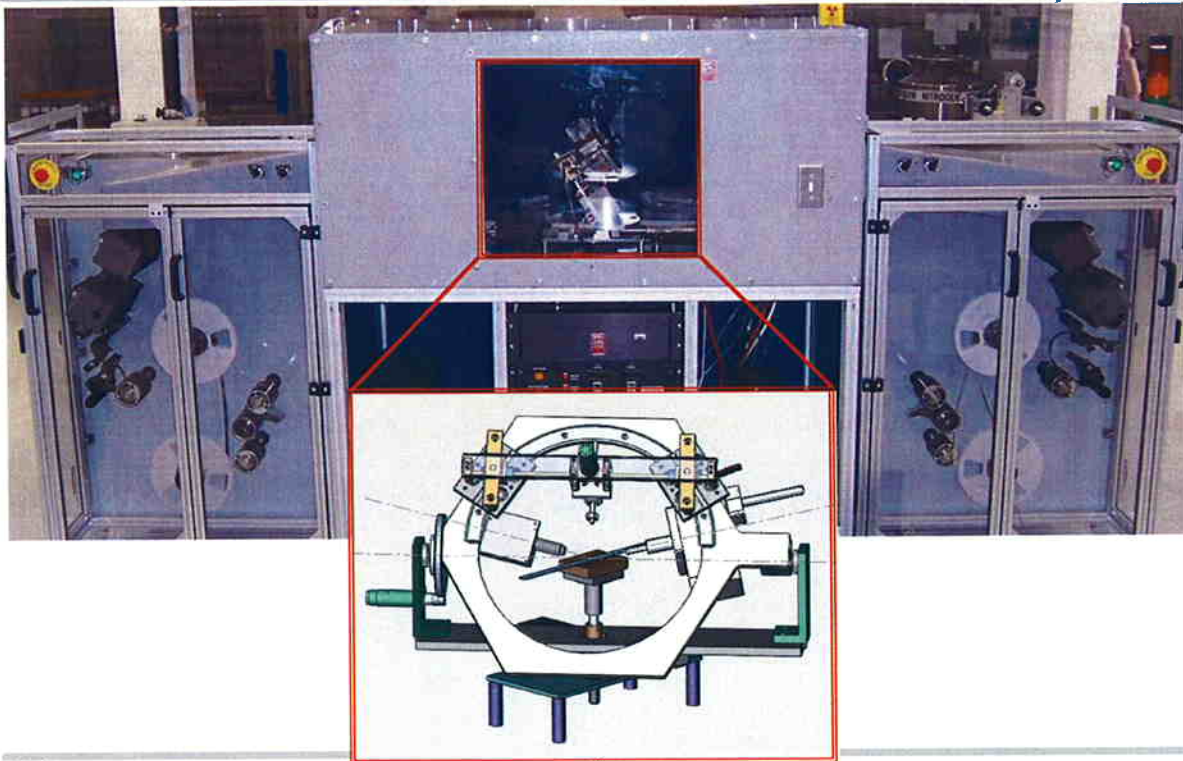


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Upgrade to XRD system will allow rapid texture measurements of up to 1km of any material

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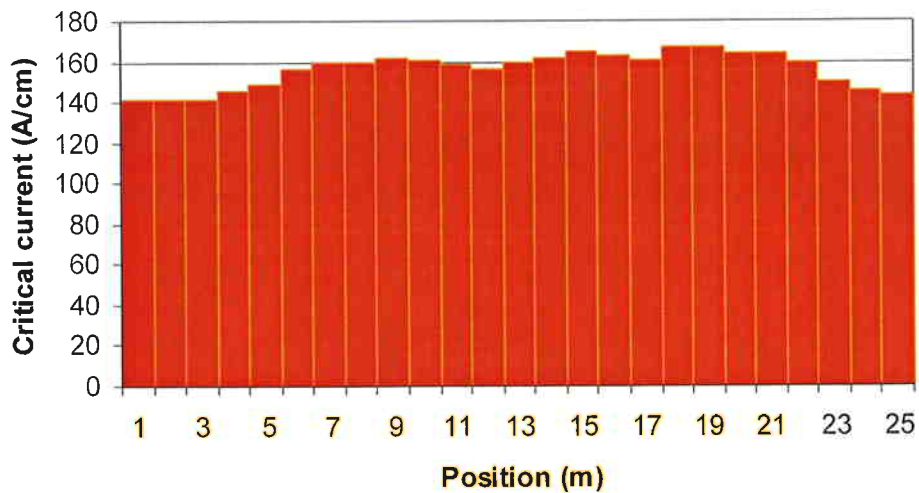


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25 m MOCVD tape demonstrated with LMO buffered IBAD MgO: all buffers @ 10 m/h

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Long length performance: 142 A/cm over 25 m

Short length performance:

220 A/cm, 1.1 micron YBCO, $J_e = 40 \text{ kA/cm}^2$

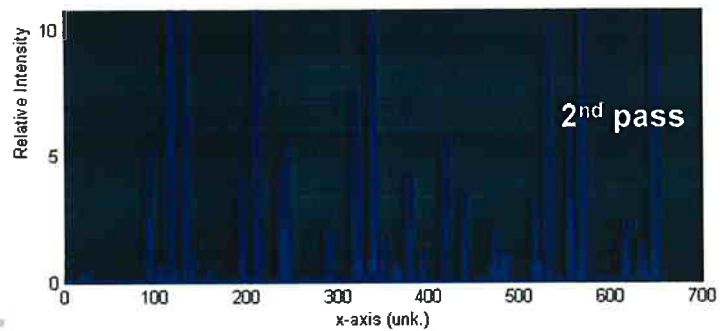
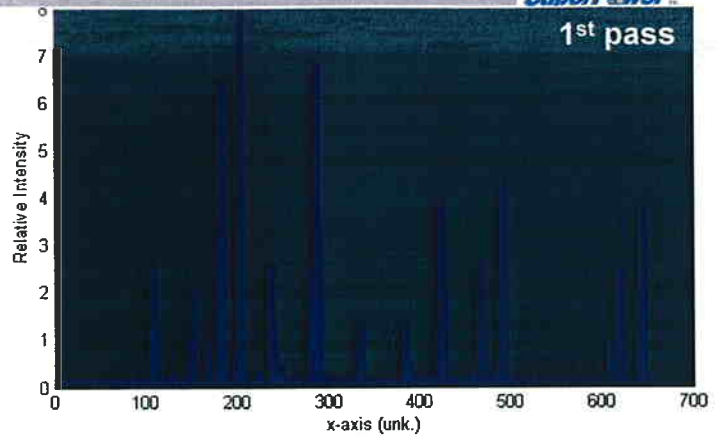
400 A/cm, 3.0 micron YBCO, $J_e = 71.4 \text{ kA/cm}^2$

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On-line Raman spectroscopy data can be acquired during each pass of 100-200m long MOCVD deposition

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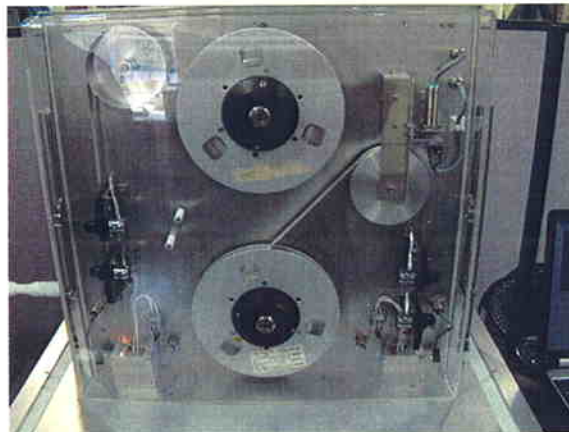


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New non-contact Ic measurement system used for high speed location of weak spots

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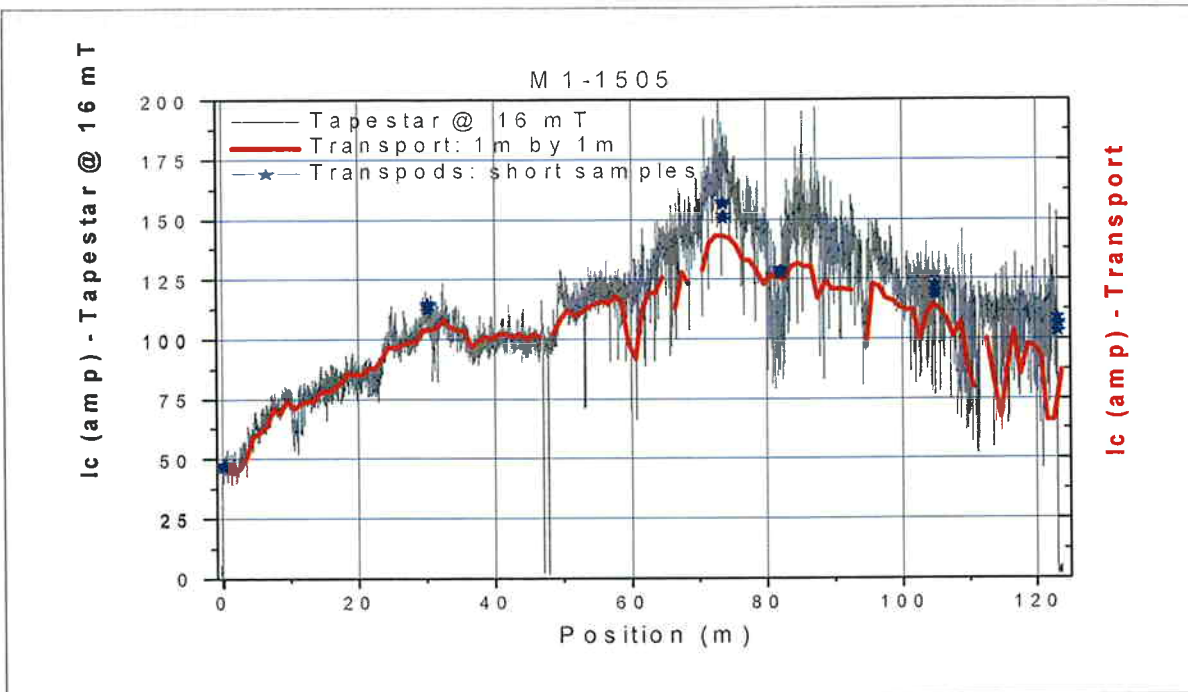
	FY04 Transport current system	FY05 Non-contact Ic (Hall probe) system
Tape speed	0.5 m/h	54 m/h
Resolution	1 cm	0.5 mm

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Non-contact Ic measurements are similar to transport Ic measurements

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Establishing robust support operation for manufacturing

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Standard Operating Procedures

- ☒ Process
- ☒ Equipment
- ☒ Personnel

Material Procurement & Equipment Specifications

Data Management

- ☒ Data collection, retrieval, archiving

Production Control

- ☒ Product traceability through tape traveler system

ISO training is in progress for entire 2G group

- ☒ SPC, DOE, FMEA, GR&R
- ☒ Over 3000 person-hours of training is being implemented in a 9-month time frame using a \$ 90 k grant from the State of NY

New York State Workforce Development Initiative grant

- ☒ \$2.7 M of \$5 M to support CapEx purchases for QA/QC at SuperPower
- ☒ Manufacturing workforce training at Union College, Schenectady County Comm. College

In-process & On-line QA/QC tools

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Summary

- Characterization of I_c non uniformity in long MOCVD tapes
- Development of new quality control tools
 - Automated optical tape inspection tool
 - Ex-situ XRD measurements
 - In-situ Raman spectroscopy
 - Non contact critical current profiles
- Manufacturing of 100m+ coated conductor
 - Performance
 - 206 meters with $I_c = 107$ A/cm
 - 71 m with $I_c = 200$ A/cm with 4.3% uniformity
 - QA/QC procedures & documentation

