RABiTS™/MOD Based YBCO Conductors

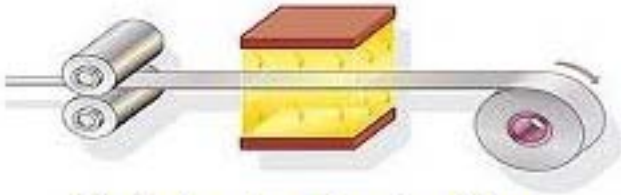
DoE Wire Workshop

January 21, 2003

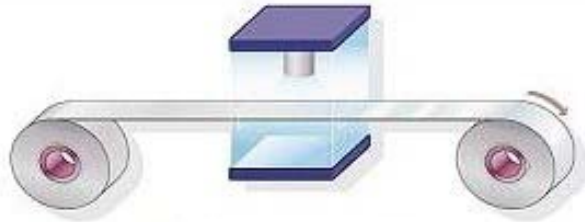
REVOLUTIONIZING THE WAY THE WORLD USES ELECTRICITY™

American Superconductor™

AMSC YBCO Manufacturing



Substrate Production

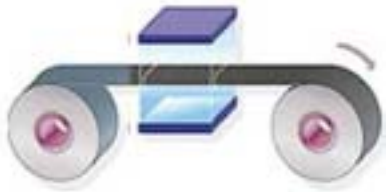


Buffer Deposition

YBCO Precursor Coating

Precursor Decomposition

YBCO Reaction



O_2 Anneal

Web Slitting

Process designed for 10 cm wide web tape which yields 25 individual 4mm wire conductors

Necessary Process Characteristics

- Viable manufacturing process must address both
  - Performance
    - Jc, texture, etc
    - Uniformity (length and width)
    - Reproducibility (run-to-run and within run)
  - Cost
    - Equipment (capital and maintenance)
    - Materials, energy
    - Throughput
    - Yield
    - Labor

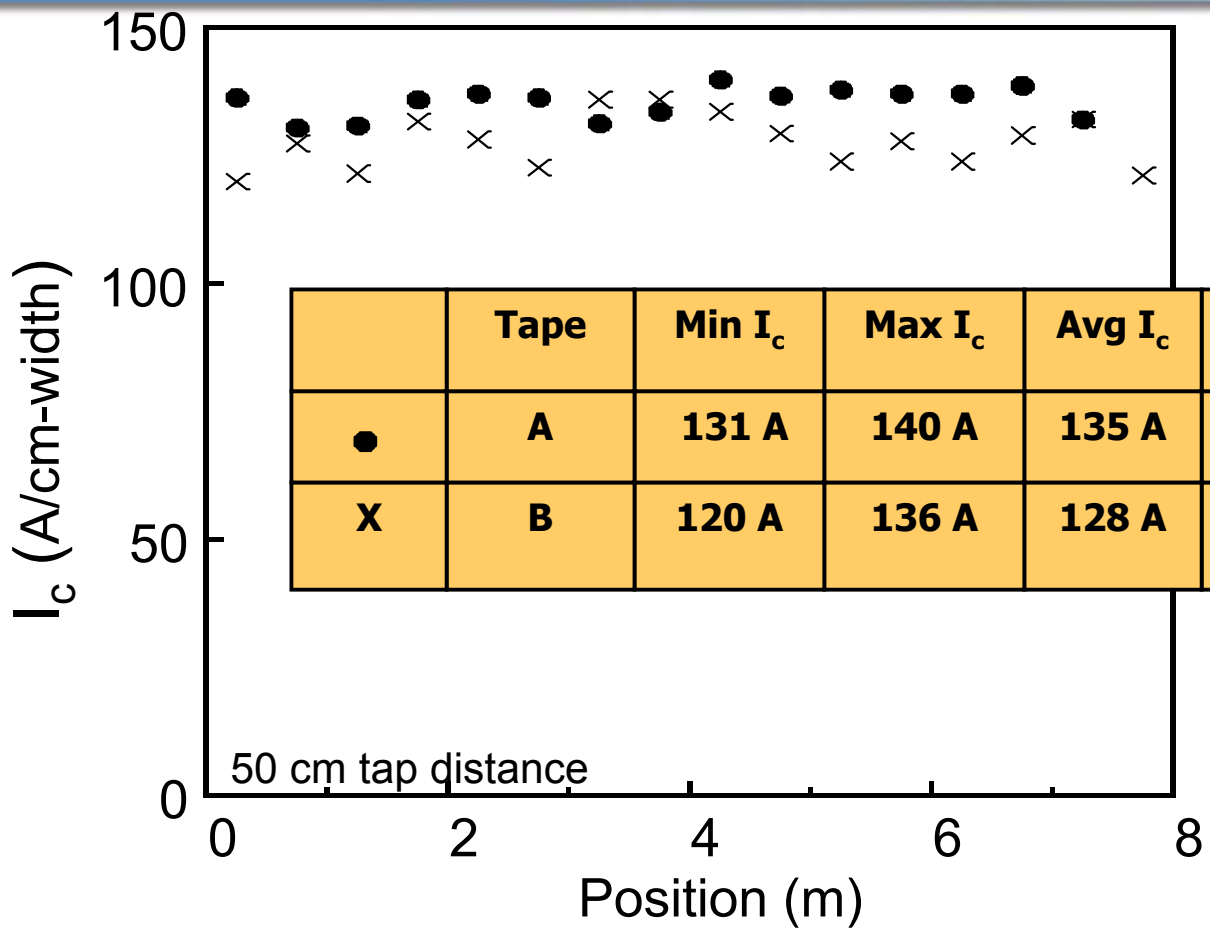
AMSC Manufacturing Process Targets Price/Performance of $10/kA-meter

Texture of RABiTS™ Process is Reproducible

In-plane ($\Delta\phi$) texture of buffer layers on NiW substrates is consistent run-to-run (texture derived from pole figures)

Wire A (7.5 m)	ΔΦ (degrees)	Wire B (8.0 m)	ΔΦ (degrees)
Ni-5atm%W	6.6	Ni-5atm%W	6.8
YSZ	6.2	YSZ	5.8
Y_2O_3 / CeO_2	6.0	Y_2O_3 / CeO_2	5.5
YBCO	6.1	YBCO	5.6

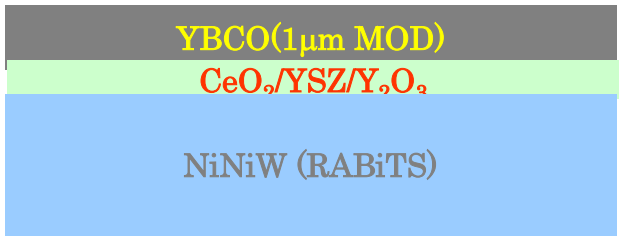
Critical Current is Consistent over Length



	Tape	Min I_c	Max I_c	Avg I_c	End-End I_c	σ
●	A	131 A	140 A	135 A	132 A	3.0 A
X	B	120 A	136 A	128 A	127 A	5.2 A

Within and run-to-run performance reflect reproducibility of entire process

200A/cm-width Performance with Improved YBCO Process on RABiTS™ (short sample)

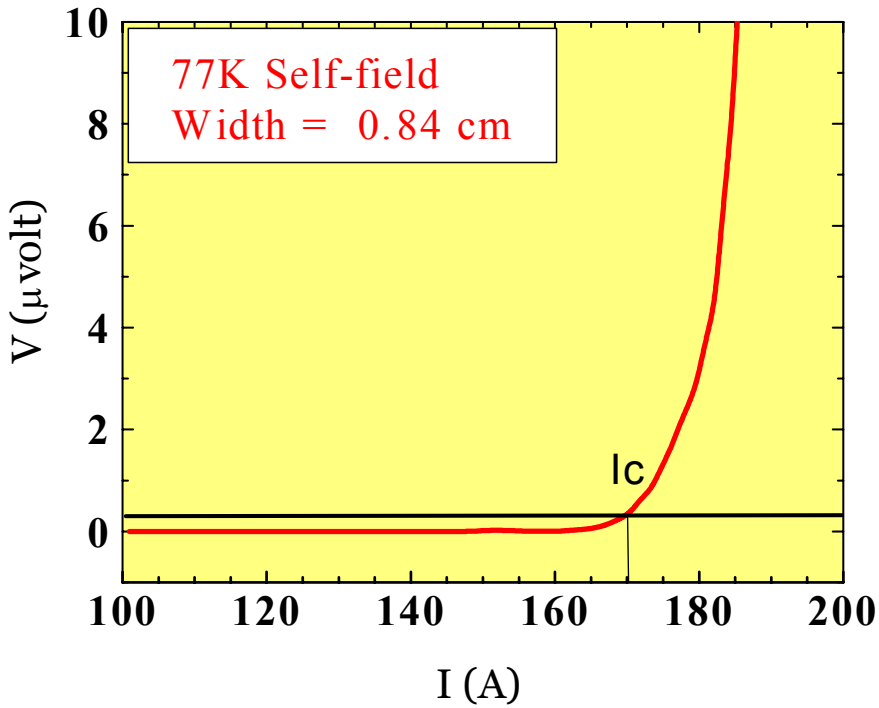


YBCO : $\Delta\phi_{103} = 4.6°$

CeO_2 : $\Delta\phi_{111} = 5.4°$

YSZ : $\Delta\phi_{111} = 5.5°$

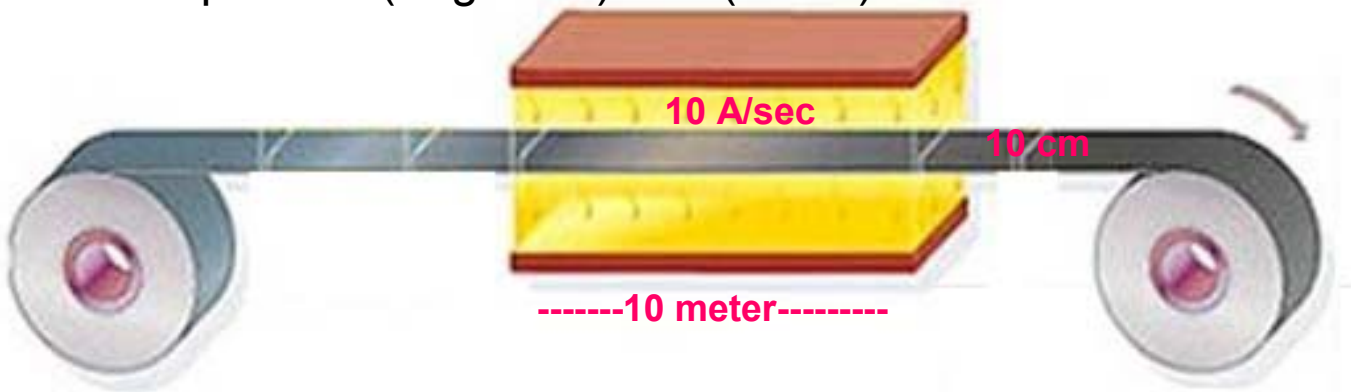
NiW : $\Delta\phi_{110} = 6.8°$



Jc(77K, sf) = 2.2 MA/cm², Ic=202A/cm-w, Tc=90.5K, ΔTc=0.8K

Process Rate Definition

- Manufacturing efficiency, cost and throughput are determined the volumetric deposition or growth rate – not simple the simple linear deposition or growth rates
- Volumetric Process Rate depends on
  - Deposition (or reaction) area (length x width)
  - Deposition (or growth) rate (A/sec)



10 A/sec growth (deposition) rate over a 10 meter x 10 cm area results in a volumetric rate of 10,000 nm*cm^2/sec

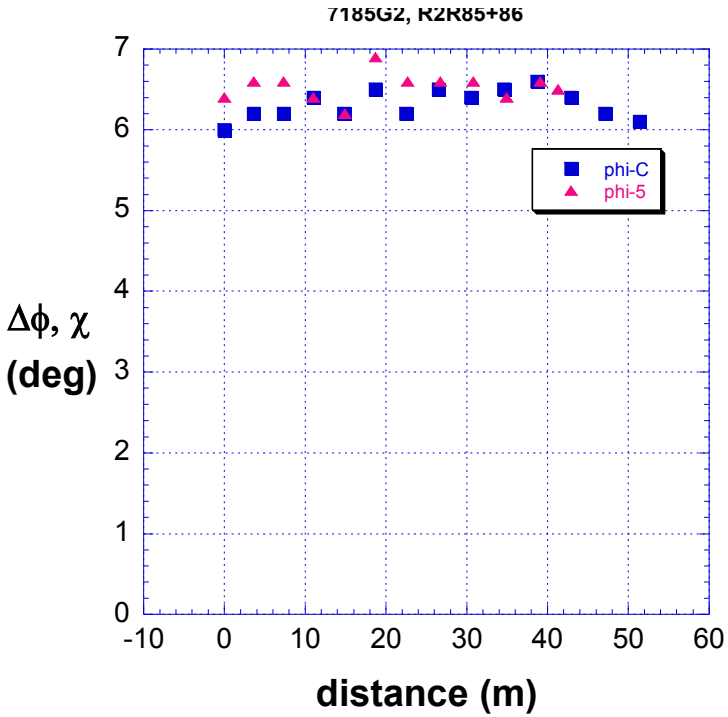
Scalable, Wide Web Processes Required for Manufacturing

- Substrate deformation/texture anneal
  - Substrate dimension (length x width) determined by rolling equipment and texture annealing furnace
    - No polishing required for RABiTS substrates
- Buffer Layer Deposition
  - Vacuum deposition (reactive sputtering)
    - Rates of 5 – 10 A/sec
    - Volumetric rates scale with area of target (length x width)
- HTS Deposition
  - MOD/ex-situ YBCO processing
    - Volumetric rate is function of growth rate and area of furnace
    - Growth rates of 10 A/sec

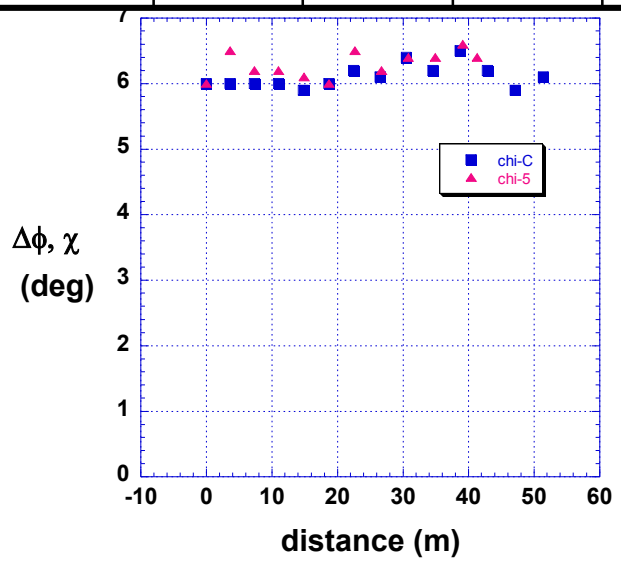
Increasing width of process oven or sputter deposition zone multiples throughput with minimal equipment or operating cost

Wide Substrate Fabrication

- **In-plane Texture Characterization**
  - Rolled 6 cm wide NiW slit to five tapes, each 10mm wide.
  - Center and edge tapes were annealed and analysed every 4 meters



tape	Δϕ–av	Δϕ–σ	Δχ–av	Δχ–σ
center **C**	6.3	0.18	6.1	0.18
edge **5**	6.6	0.17	6.3	0.20



Uniform texture obtained over length and width of wide deformation textured NiW substrate

J_c Modeling of RABiTS™ Templates

Distribution of grain orientation in RABiTS™

- FWHM Pole Figures
- EBKP patterns – locally resolved

J_c models to predict *limiting current path* for a given GB distribution

→ ratio of I_{GLOBAL} / I_{GRAIN} [Specht, Holzapfel, Rutter]

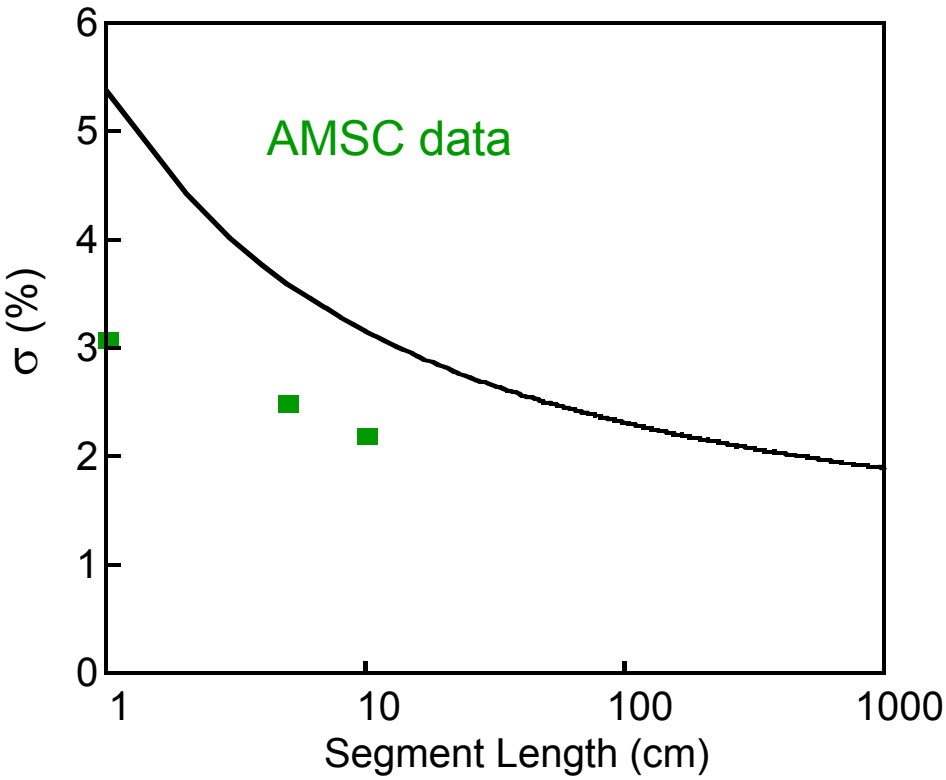
→ use models to simulate local J_c along a length

- $J_c(x)$ distribution
- Std deviation

Models predict a characteristic Jc distribution for RABiTS™ template while actual Ic variation holds valuable information on template and processing data

I_C variations in wire

- ORNL model
- Segment Length ↔ Voltage Tap Distance
- Sigma on small length scales
- end-to-end IV-curves (n-value)
- Refine models to develop an important research and process tool:
  1. $J_C(\alpha)$
  2. GB-distribution (EBKP)
  3. IV curve – μV/cm criteria
  4. GB microstructure



Actual data shows less Ic variation than predicted by initial models

Required Advances in RABiTS™ Processing

- Substrate development and characterization
  - Improved texture
  - Improved characterization over length
  - Correlation of texture with performance
- Buffer development and characterization
  - Characterization of oxygen and metal diffusion
  - Thinner buffer layers/ elimination of buffer layers