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powerful technology.

Recent Results in 2G HTS Wire Technology Development at SuperPower

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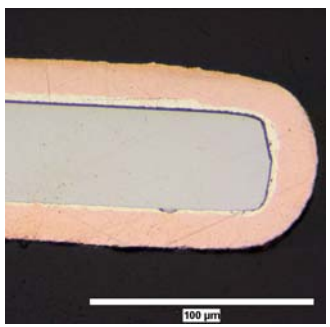
ICMC 2008 - Seoul, Korea - July 21-25, 2008

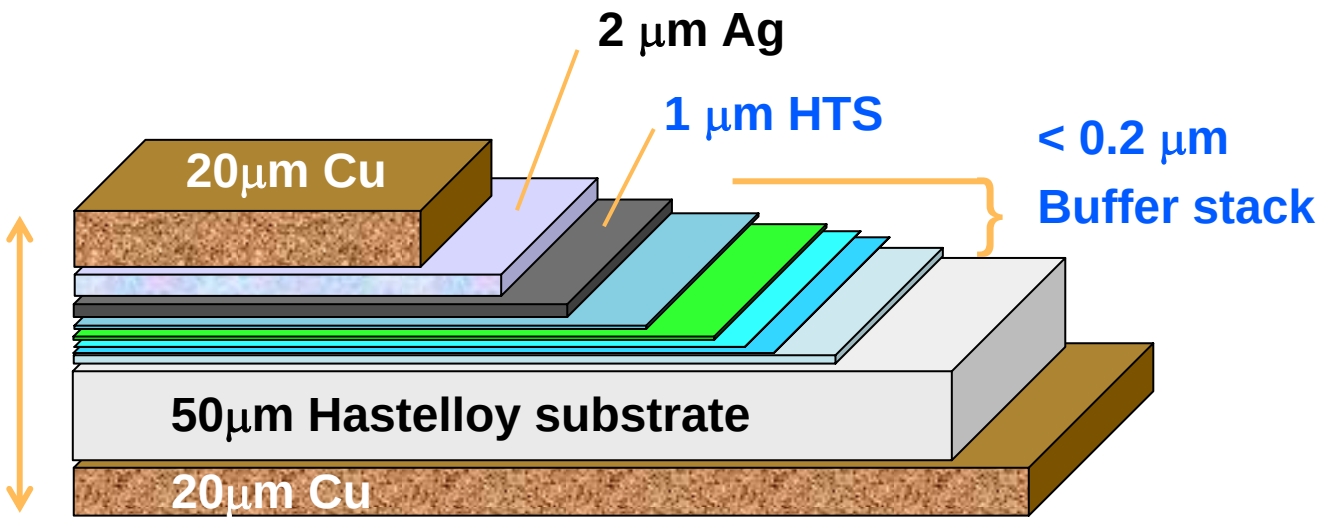
Program funding from Title III and DOE through UT-Battelle & AFRL. Supported by CRADAs with Oak Ridge, Los Alamos, and Argonne National Laboratories

SuperPower 2G HTS wire utilizes high strength substrates coupled with high throughput processing

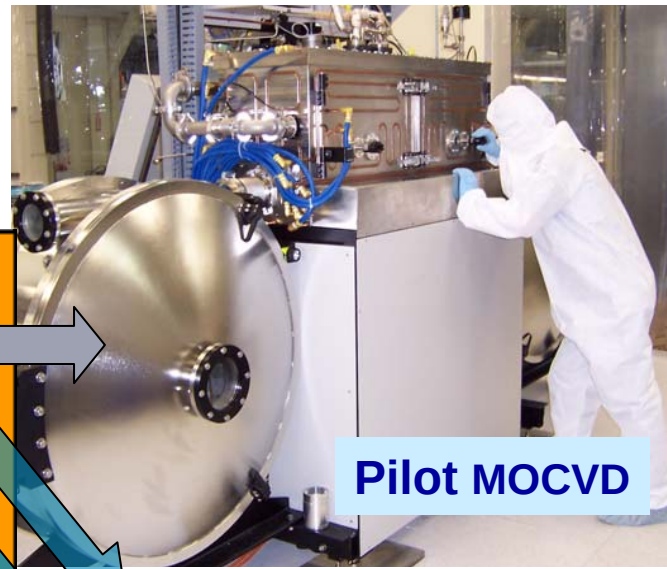
- SuperPower's 2G HTS wire is based on a high throughput thin film manufacturing approach permitting a wide choice of materials combinations
  - Advantages include high strength, low ac loss (non-magnetic, high resistivity substrates) and high engineering current density (ultra-thin substrates)
- High throughput is critical for low-cost 2G wire to enable early commercial adoption
  - IBAD-MgO based buffer technique
  - MOCVD for HTS layer: combination of high deposition rate and large deposition zone

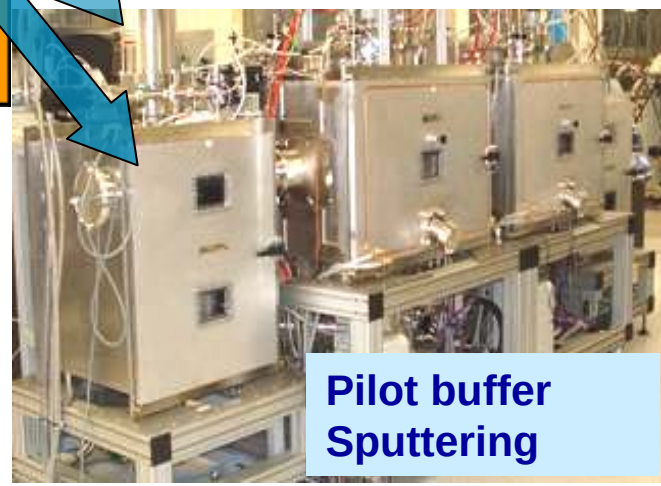


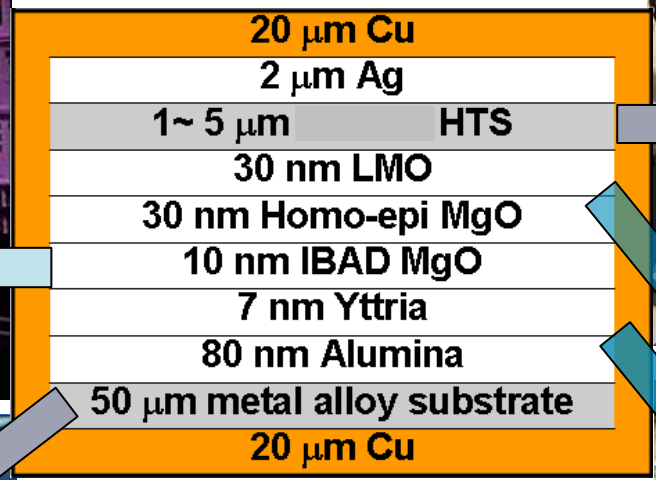
< 0.1 mm



SuperPower's 2G pilot manufacturing facility has been operational since 2006



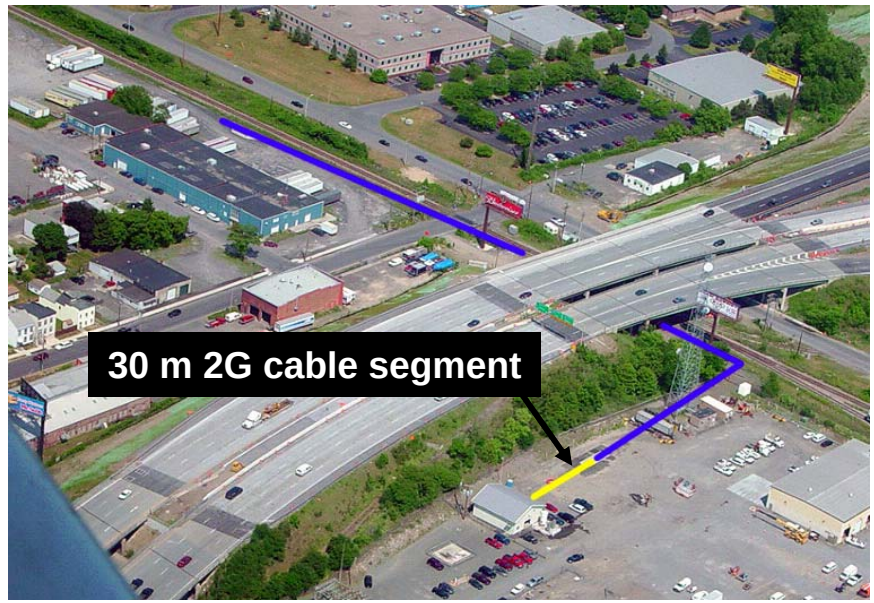




Majority of investment already made for 1000 km/year capability

SuperPower was the first and is still the only company to demonstrate pilot-scale 2G HTS wire manufacturing

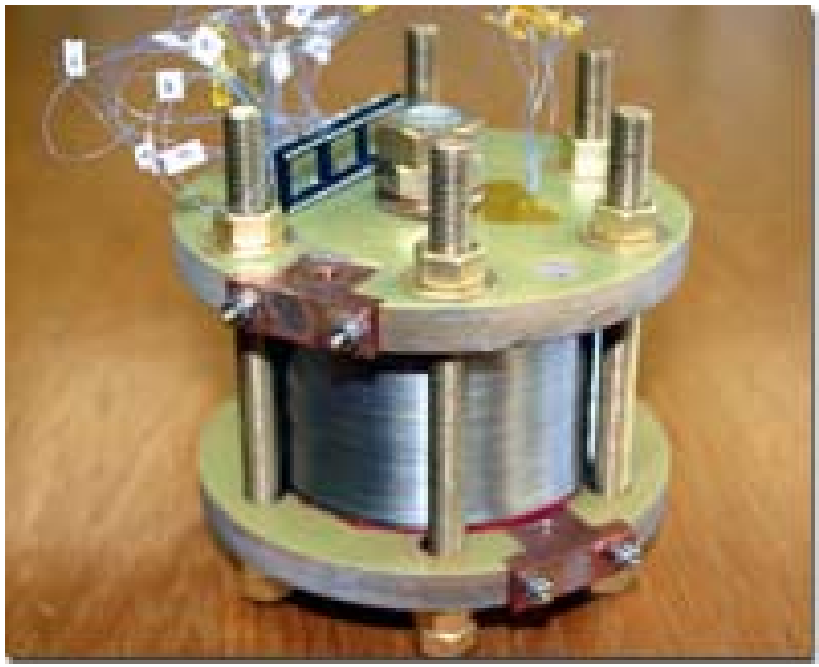
- In Dec. 2006, SuperPower delivered nearly *10 km* of 2G HTS conductor in 2006 to build a 30 m long cable for the Albany Cable project, *which is now the world's first & only 2G device energized in the power grid.*
- *Largest single quantity of 2G delivery*
- 225 segments delivered each with a piece length of 43 m – *not a delivery of tapes from laboratory runs !*



Albany Cable project: National Grid, 350 m long cable. World's first in-grid cable, first underground cable, first cable-to-cable joint.

Excellent demonstration of reproducibility & manufacturing viability of our processes

World record performance achieved with 2G coil

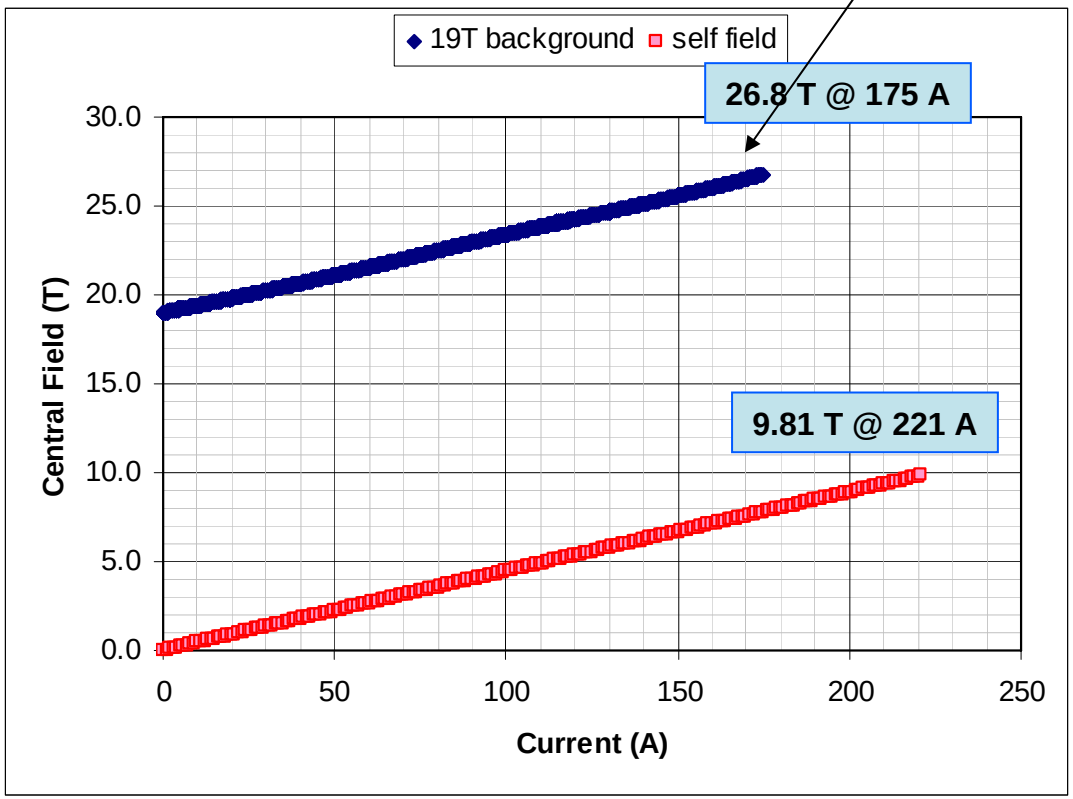


Coil ID	**9.5 mm (clear)**
Winding ID	**19.1 mm**
Winding OD	**~ 87 mm**
Coil Height	**~ 51.6 mm**
# of Pancakes	**12 (6 x double)**
2G tape used	**~ 462 m**
Average Ic of tapes in coil	**78 A in 4 mm width (77 K, self field)**
# of turns	**~ 2772**
Coil Je	**~1.569 A/mm^2 per A**
Coil constant	**~ 44.46 mT/A**

Coil tested by H. Weijers, D. Markewicz, & D. Larbalestier, NHMFL, FSU

High field insert coil achieves world records for highest HTS field, highest magnetic field by a SC magnet

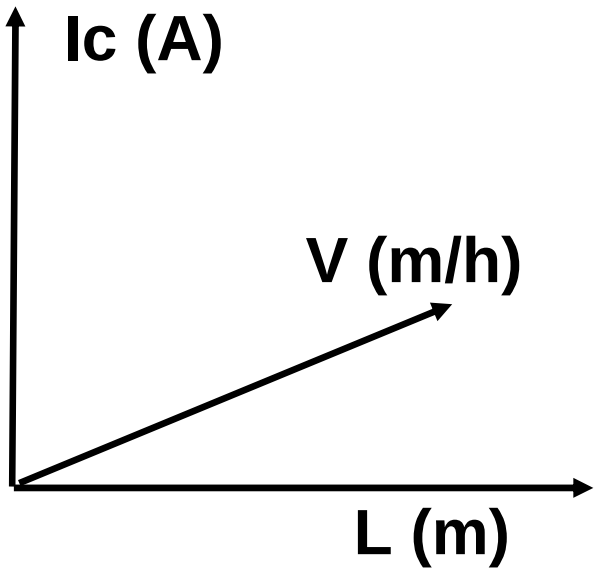
Peak hoop stress ~ 215 MPa, well below tape limit



Ic of Tapes in Coil	72 A – 82 A (77K, sf)
4.2 K Coil Ic - self field	221 A
4.2 K Amp Turns @ Ic-self field	612,612
4.2 K Je @ Ic, self field	346.7 A/mm^2
4.2K Peak Radial Field @ Ic, self field	3.2 T
4.2 K Central field – self field	9.81 T
4.2 K Coil Ic – 19 T background (axial)	175 A
4.2 K Amp Turns @ Ic – 19 T background (axial)	485,100
4.2 K Je @ Ic, 19 T background (axial)	274.6 A/mm^2
4.2 K Peak Radial Field @ Ic, 19 T bkgd (axial)	2.7 T
4.2K Central Field – 19 T background (axial)	26.8 T

Key metrics of 2G wire for broad market penetration

- Key metrics determining the price-performance characteristics of 2G HTS wire and qualifying for applications:
  - Ic 500 A/cm at 0T & 77K
  - Ic(B) 100 A/cm at 1.5T &77K
  - L 1 km
  - V 1000 km/year

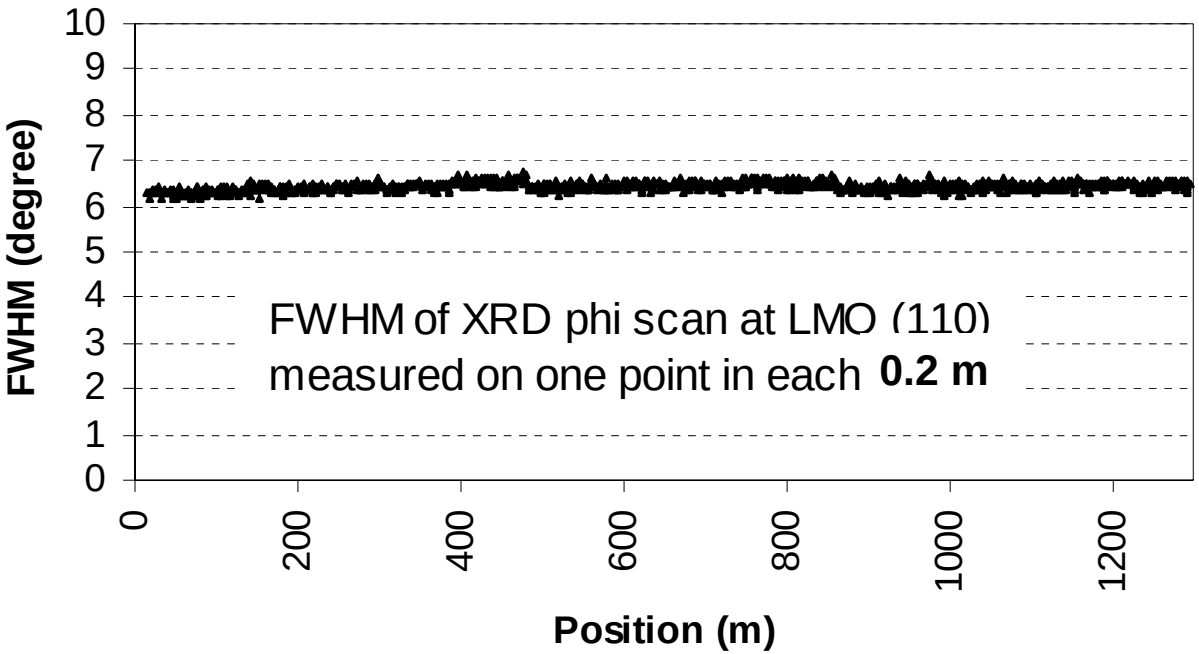


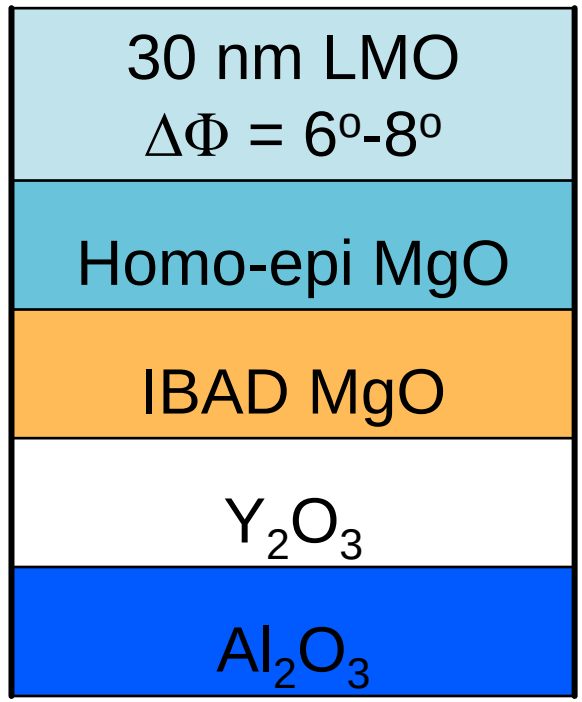
SuperPower's 2G wire technology is based on high throughput processes

Process	Throughput of 4mm wide tape (m/h)
MOCVD	**180 (for ~ 1 μm HTS layer)**
Homo-epi MgO + LMO	**345**
IBAD MgO	**360**
Alumina + Yttria	**750**

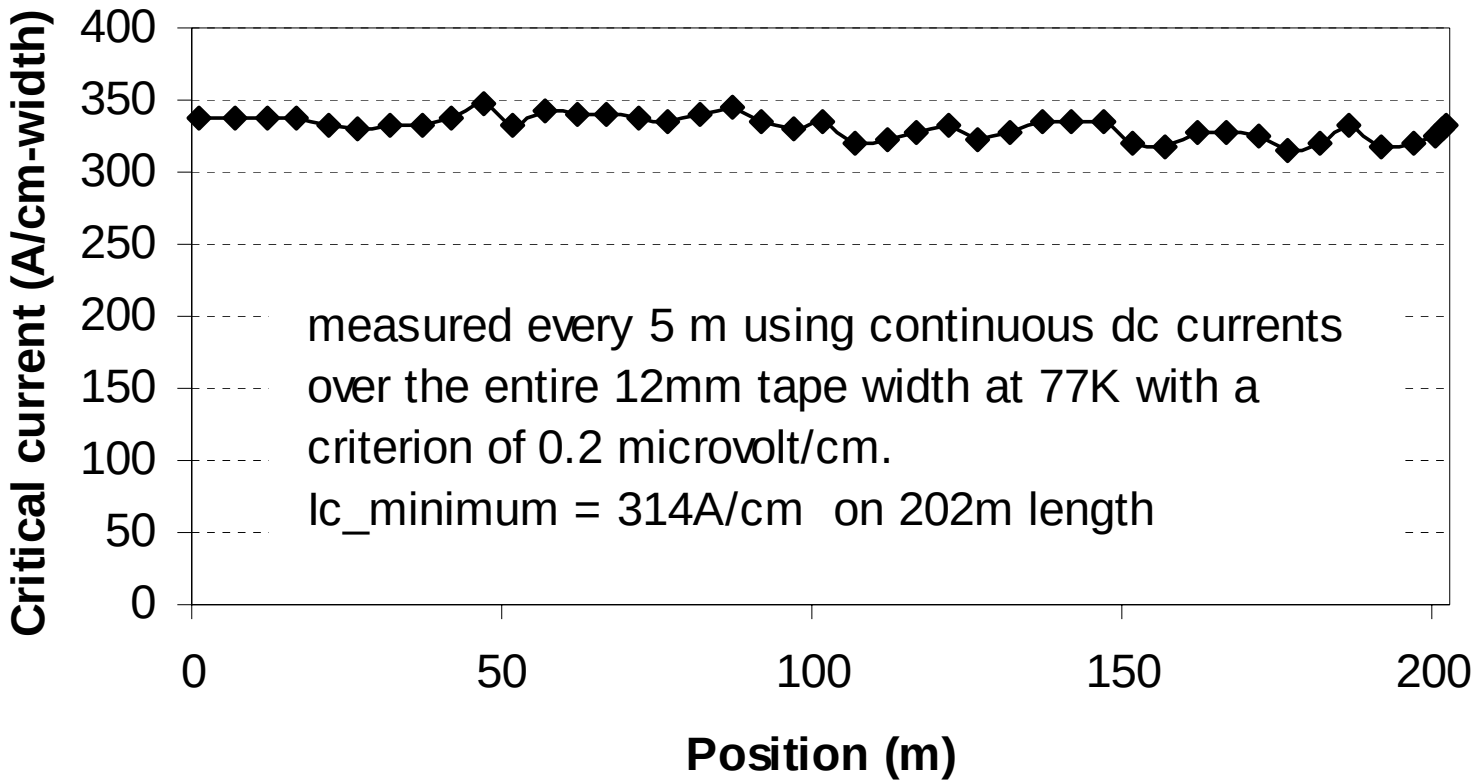
Excellent in-plane alignment has been uniformly distributed on 1.3 km+ lengths

The FWHM values of the phi-scan at (110) of LMO, the cap layer of the 5-layer buffer stack, typically range from 6 to 8 degrees for the km+ lengths



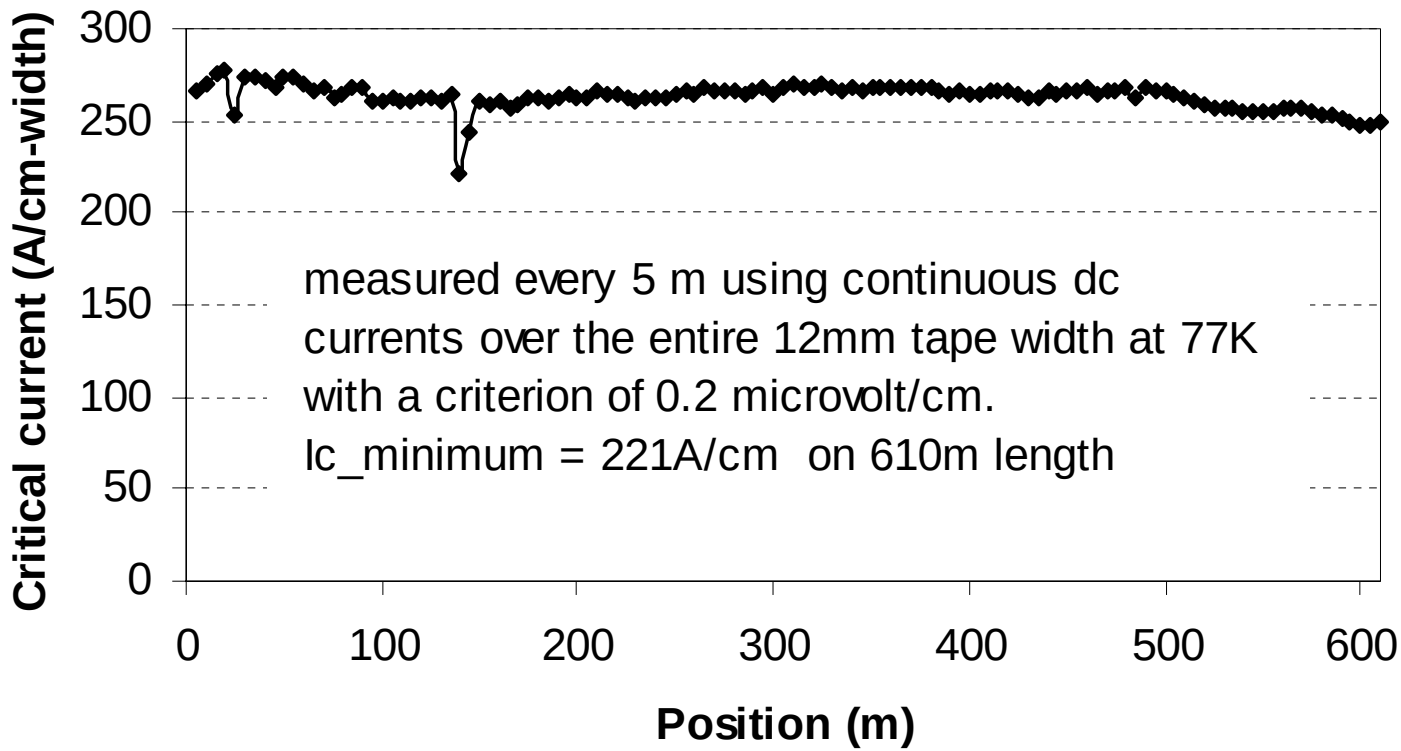


High critical currents in long lengths processed at high speeds



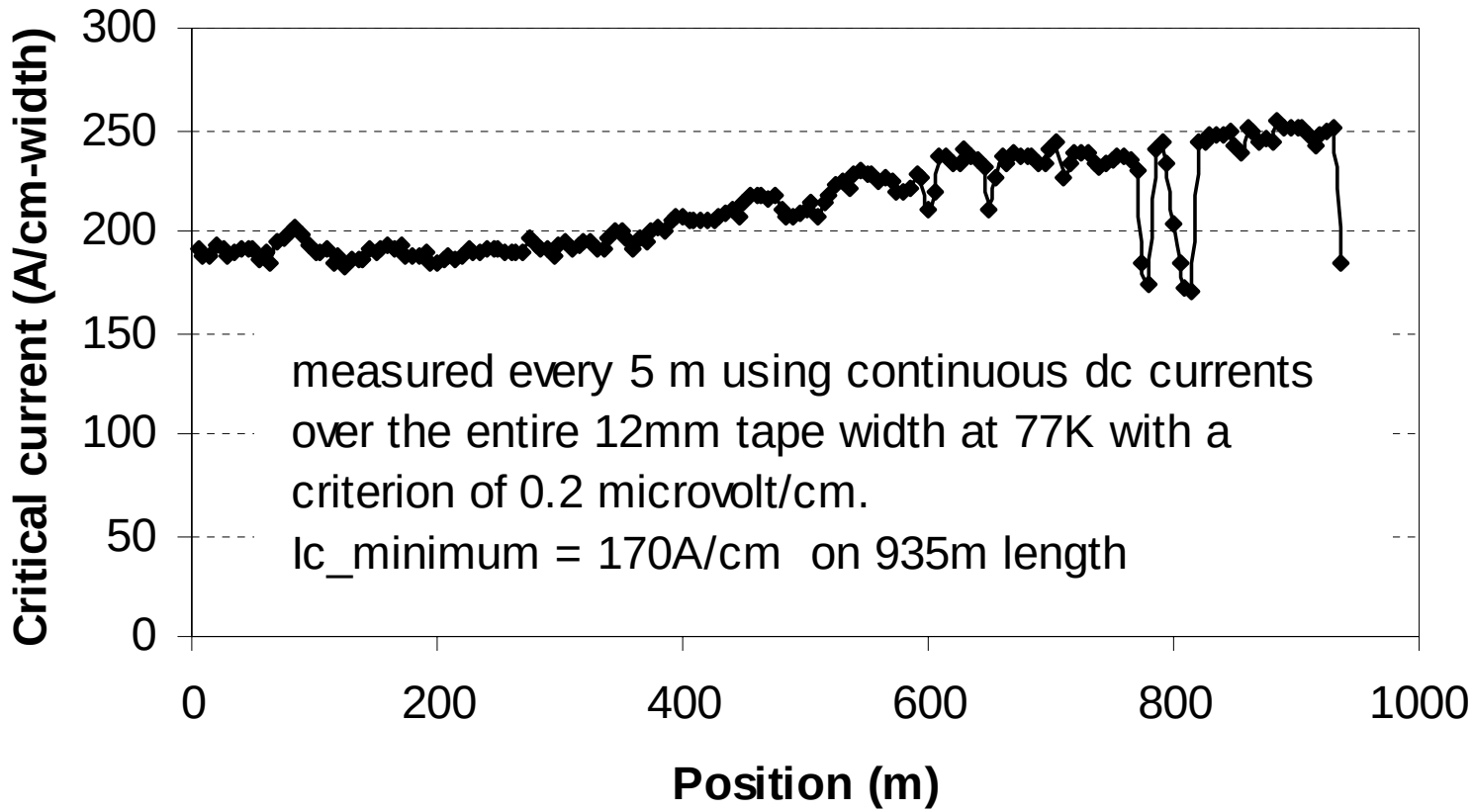
- Minimum Ic = 314 A/cm over 202 m
- processed with MOCVD throughput of 90m/h
- Uniformity over 202 m = 2.4%

High critical currents in long lengths processed at high speeds



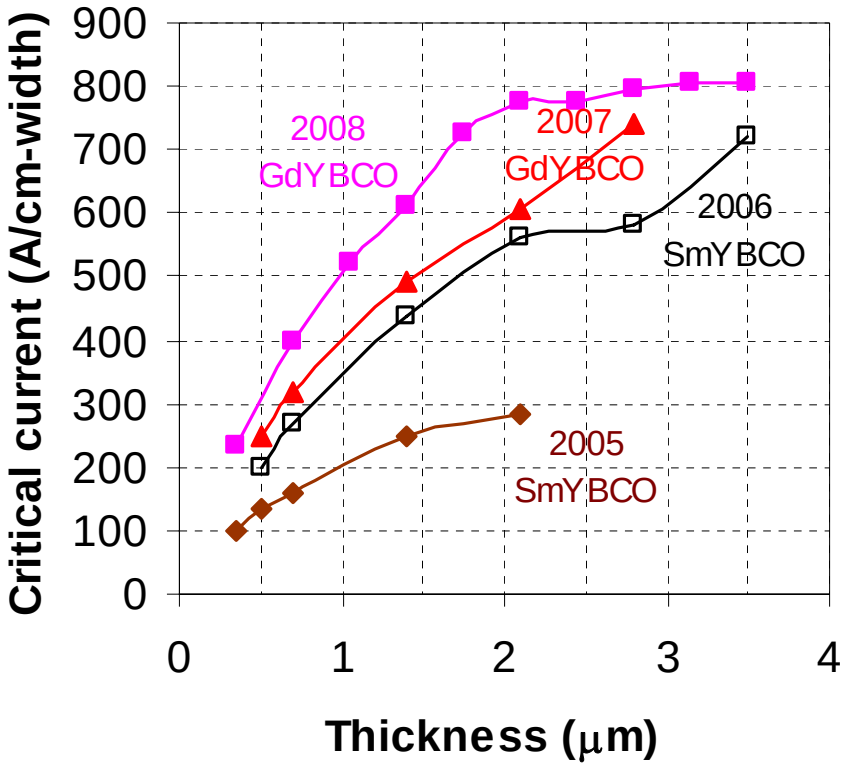
- Minimum Ic = 221 A/cm over 610 m
- Processed with MOCVD throughput of 90m/h
- Uniformity over 610 m = 2.65%

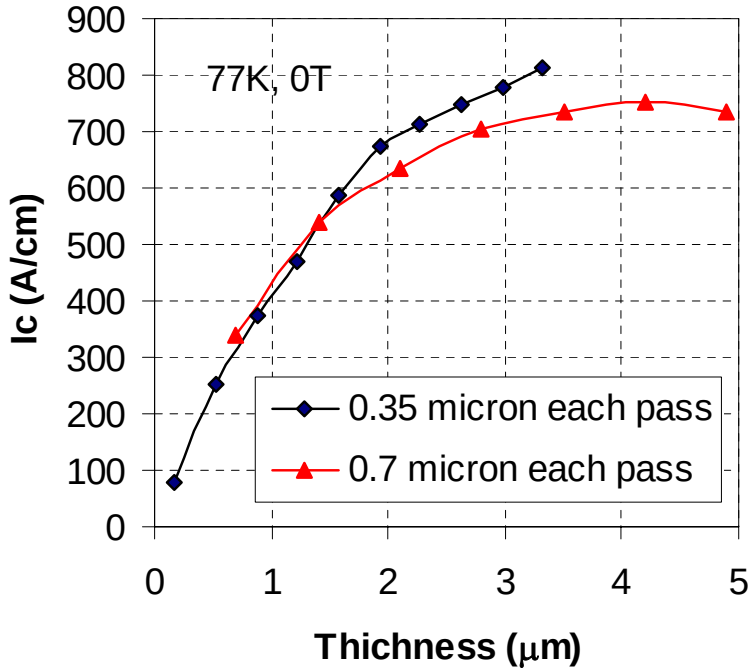
High critical currents in long lengths processed at high speeds



- Minimum Ic = 170 A/cm over 935 m
- Processed with MOCVD throughput of 135m/h
- Ic × L = 158,950m

Capability of 320 A achieved in 4 mm widths





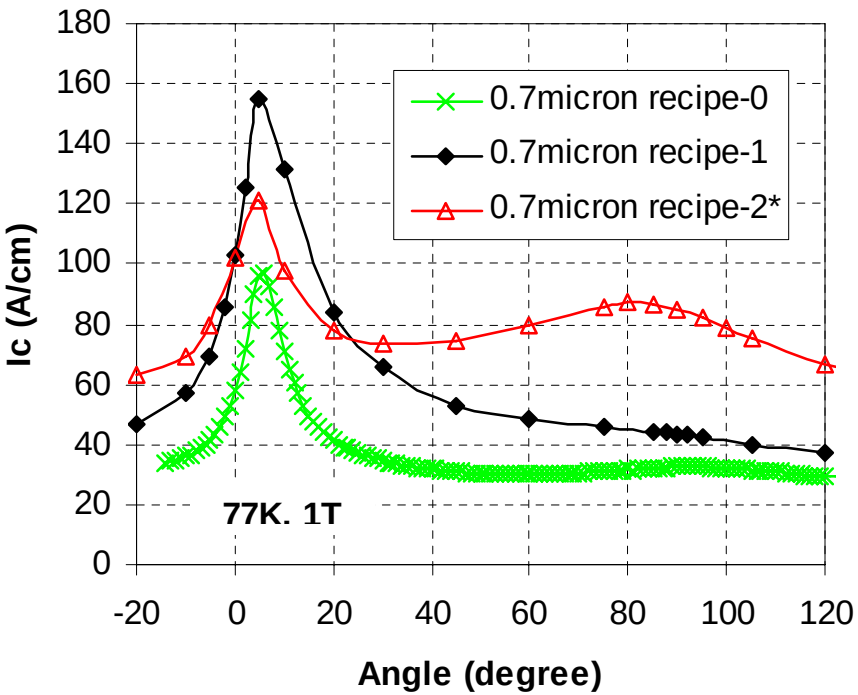
Over 1.2 m length
Ic = 964 A = 803 A/cm

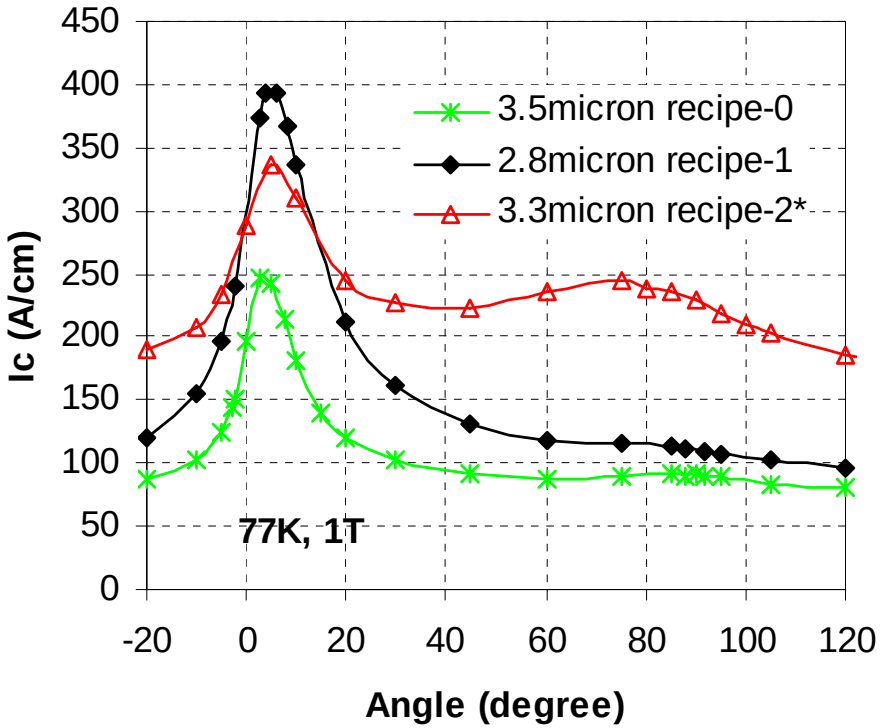
Over 1 m length
Ic = 976 A = 813 A/cm

2.1 μm film made in 6 passes: **Ic = 929 A = 774 A/cm (Jc =3.68 MA/cm²)**

3.3 μm film made in 10 passes: **Ic = 976 A = 813 A/cm (Jc = 2.44 MA/cm²)**

Dramatic improvements achieved in in-field performance of SuperPower 2G wire





For 0.7micron recipe-2*

Recipe-1: strong pinning for B//ab

Recipe-2*: strong pinning for B//c

For 3.3micron film of recipe-2*

Ic_minimum(77K, 1T) = 185.6A/cm

Ic_minimum(65K, 3T) = 267.3A/cm

Ic(77K, B//c=3T) = 71.8A/cm

Best in-field performance of all commercial 2G wire

Data from Y. Zhang, M. Paranthaman, A. Goyal, ORNL

Summary

- Prototype applications including cable and high field coil with SuperPower's 2G wire demonstrated the viability for commercialization.
- SuperPower's 2G technology development is focused on three key metrics for a broad market penetration and improvement has been made on all areas.
  - High throughput:
    - 750m/h for sputtering Al2O3+Y2O3 base layer
    - 360m/h for IBAD MgO template
    - 345m/h for sputtering Homo-epi MgO+LMO buffer
    - 180m/h for MOCVD REBCO
  - High Ic:
    - 813A/cm-width at 77K and self-field over 1 meter length
  - Long lengths:
    - 314A/cm-width over 202m
    - 221A/cm-width over 610m
    - 170A/cm-width over 935m
- Superior mechanical properties and in-field performance make 2G HTS wires suitable for high field and high stress applications

Questions?

Thank you for your interest!

For further information about SuperPower,
please visit us at: www.superpower-inc.com
or e-mail: info@superpower-inc.com