SuperPower Inc.
A Subsidiary of Intermagnetics General Corporation

Advances in Scale-up of 2G Conductor at SuperPower

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Program Objective

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- The primary objective of the program is to **scale up high performance 2G conductors via high throughput process** technologies, namely IBAD MgO & MOCVD, to full-fledged manufacturing.

Key Metrics

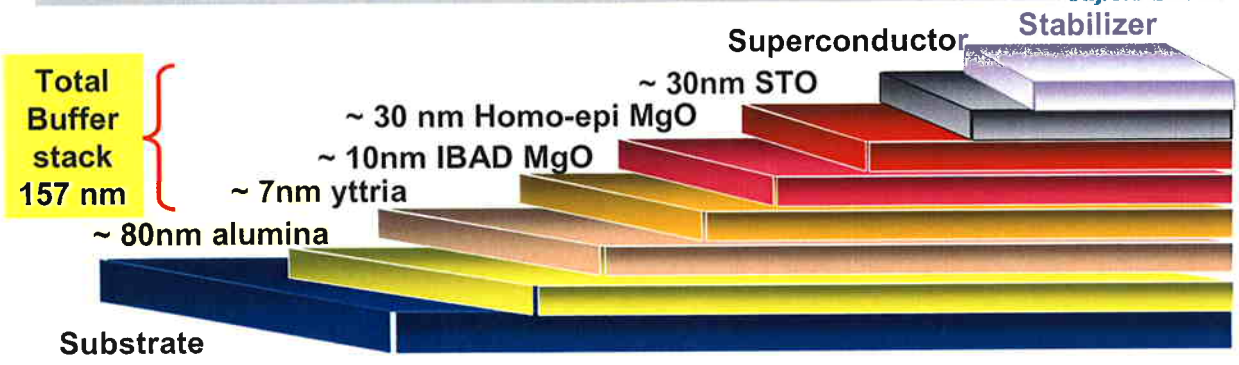
Scale-up:

- 100 m lengths of MOCVD-based conductor with Ic of 100 A/cm
- Scale up IBAD MgO & buffers to 100 m

High Throughput:

- Linear tape speed = 10 m/h of 12 mm wide conductor in every process step (equivalent to 30 m/h of 4 mm wide conductor)
  - Requires IBAD MgO-based buffers to be integrated with MOCVD
  - Requires high rate reactive sputtering of buffers on IBAD MgO

Major objective was to integrate IBAD MgO with MOCVD



Alumina --- diffusion barrier

Yttria - Nucleation layer

IBAD MgO - Template layer

Homo-epi MgO - Texture improvement layer

STO - Lattice match cap layer

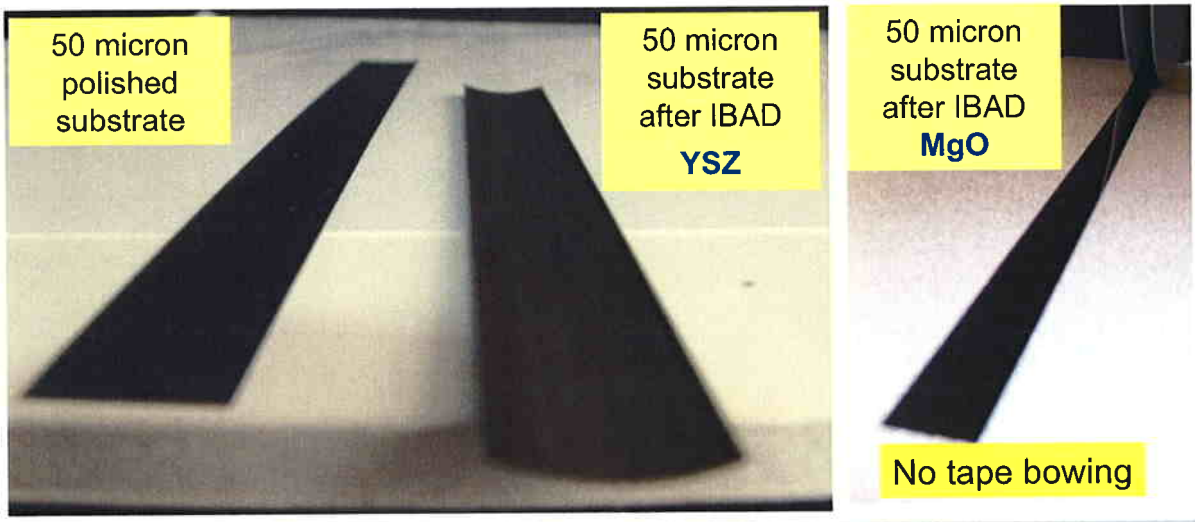
Concerns in integrating IBAD MgO w/MOCVD:

- LANL has developed this structure (materials, thickness) for PLD. Will it work for MOCVD?
- Can all buffers be deposited at high rates?
- More stringent requirement on substrate quality than with IBAD YSZ

Transitioning to MgO provided an additional advantage

IBAD MgO provided the opportunity to use thin substrates (50 microns) for high Je

Previously, 100 micron thick substrates were used for IBAD YSZ because of transverse tape bowing issue with 50 micron substrates



50 micron thick substrates electropolished for IBAD MgO in ~ 300 m single pieces, at 30 - 40 m/h

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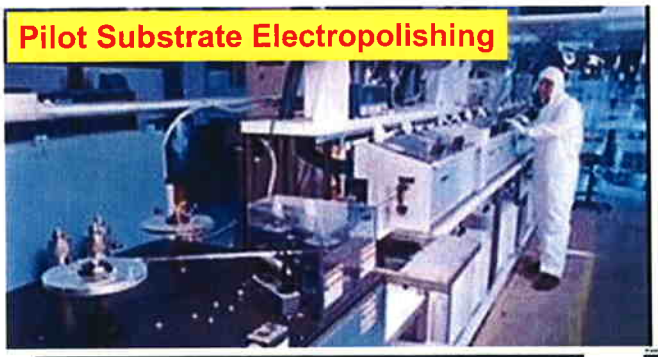
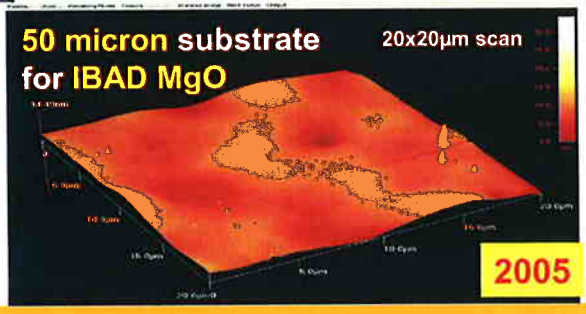


	FY04: 100 micron substrate	FY05: 50 micron substrate
Lengths	150 m	300 m
Roughness	2.8 nm	1.9 nm
Slope	~ 3.3°	~ 7°
G.B. slope	< 1°	< 1°



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

IBAD MgO is being routinely fabricated in 135 m lengths at 10 m/h even in a Prototype IBAD system

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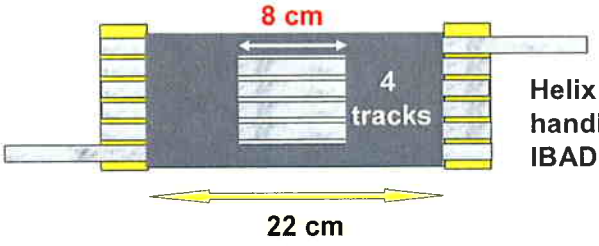
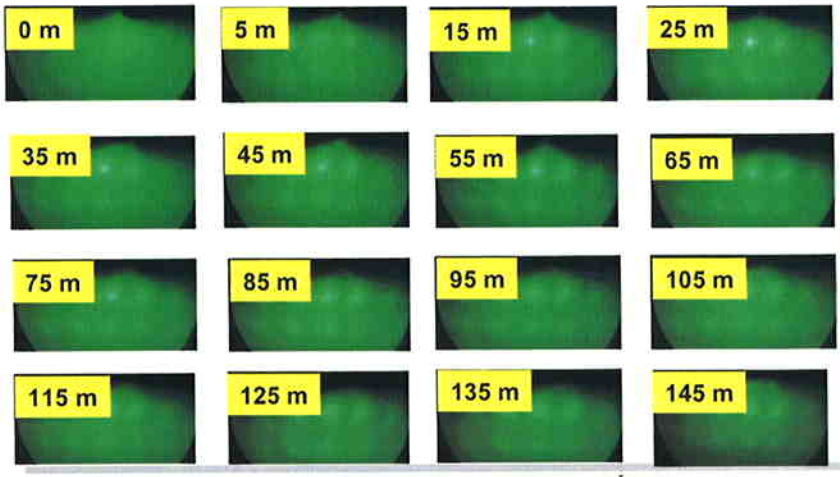


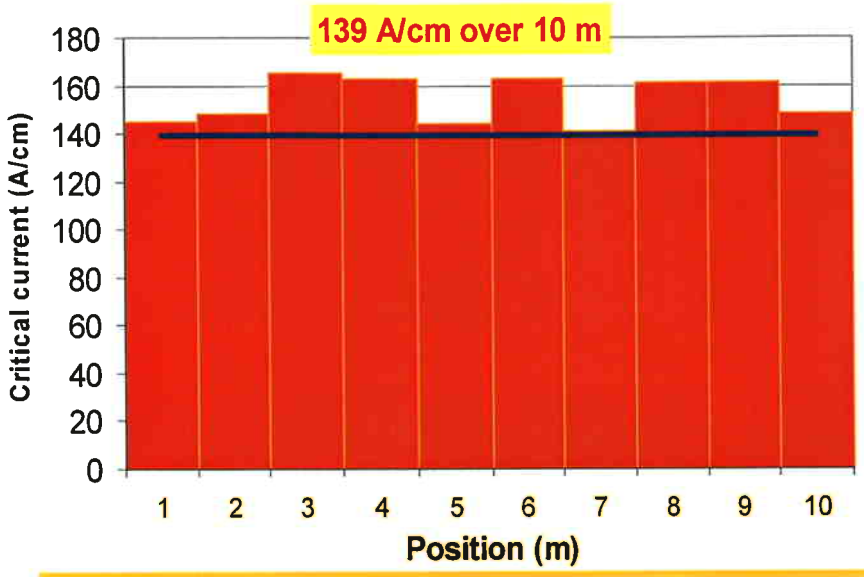
Helix tape handling in Proto IBAD system



July 2004: One 40 m IBAD MgO produced at 10 m/h

July 2005: Twelve 135 m IBAD MgO tapes fabricated on 50 micron thick substrates at 10 m/h

High Ic MOCVD tapes produced in 10 m lengths on RF-sputtered STO on reactively-sputtered MgO



10m length MOCVD-YBCO conductor on RF-sputtered STO/reactively-sputtered MgO on 50 micron substrate.

End-to-end Ic* = 139 A/cm. Standard deviation = 6%

*YBCO film thickness = 1.1 microns

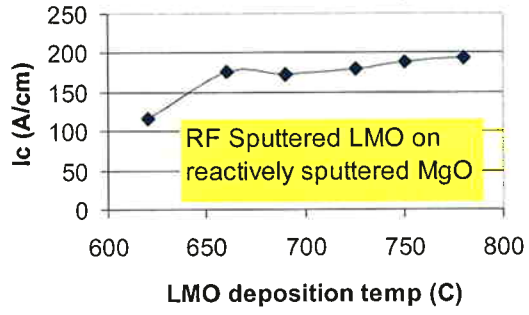
Need for an alternative to STO

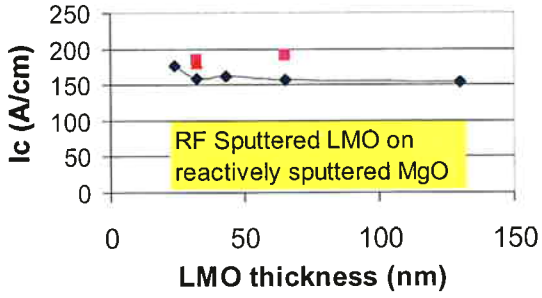
Issues with STO:

- Sr-Ti targets are not available for high rate reactive sputtering
- High deposition temperatures (~ 850 C) are needed with RF sputtered STO on reactively sputtered MgO
- Deposition rate is limited. Processing speed for 10 m tape was 3.6 m/h

Advantages of LMO:

- Lower deposition temperature and larger temperature window than STO
- Higher deposition rate enables high speeds even with RF sputttering:
  177 A/cm* with 24 nm LMO @ 10 m/h
- Higher Ic than STO (~ 40 A/cm higher) - Bonus!





*MOCVD films are 1.1 microns thick

LMO is an excellent alternative to STO especially in combination with MOCVD YBCO and reactively-sputtered MgO

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

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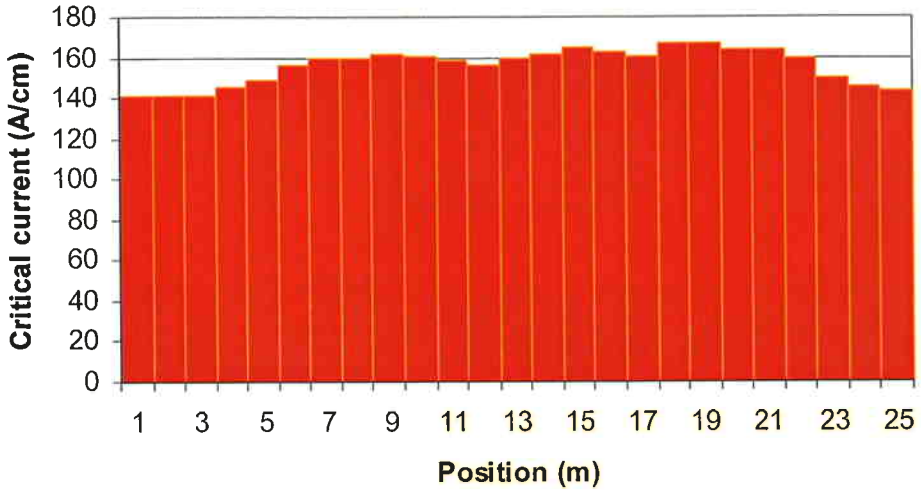
IBAD MgO @ 10 m/h

RF-Sputtered LMO @ 10 m/h

Reactively-sputtered MgO @ 10 m/h

MOCVD @ 10 m/h × 2 passes



Ic* of 142 A/cm over 25 m MOCVD tape with all high throughput buffers

*YBCO film thickness = 1.1 microns

MOCVD has been scaled up to 158 m with IBAD YSZ

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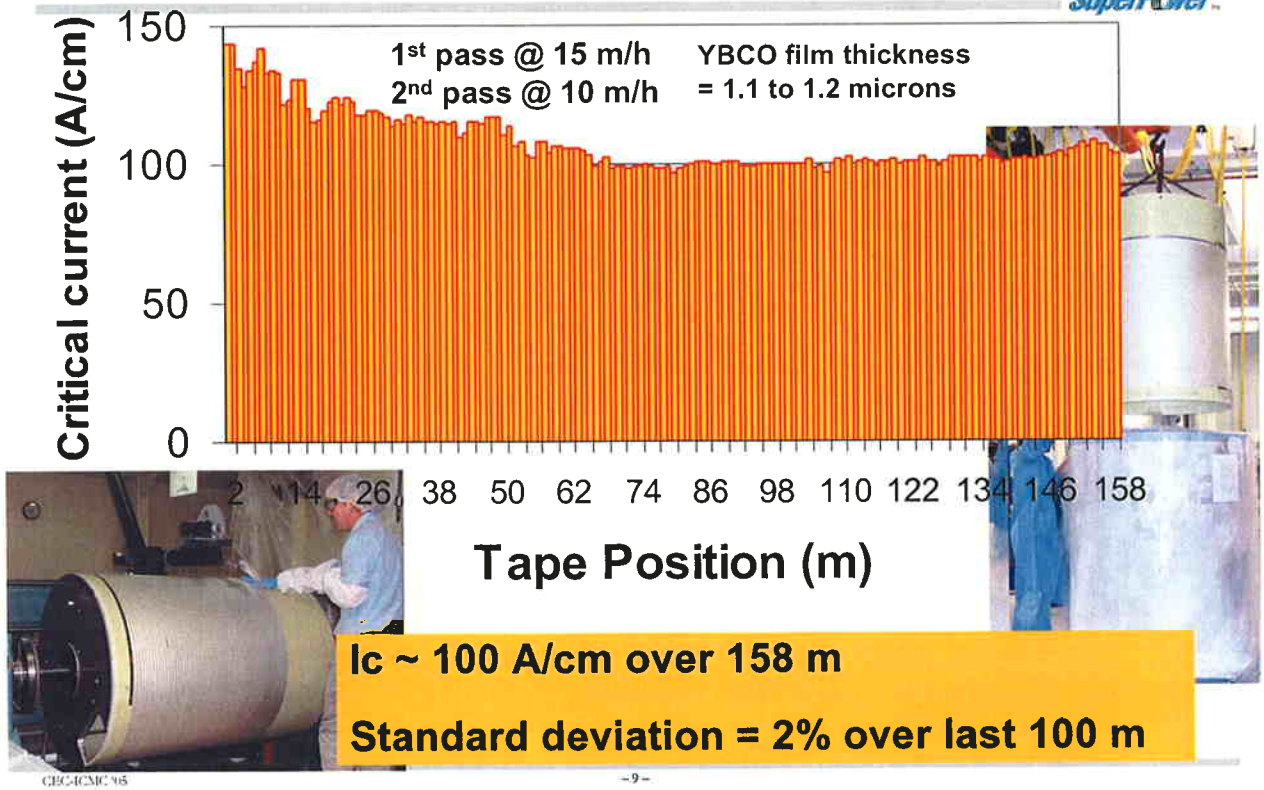
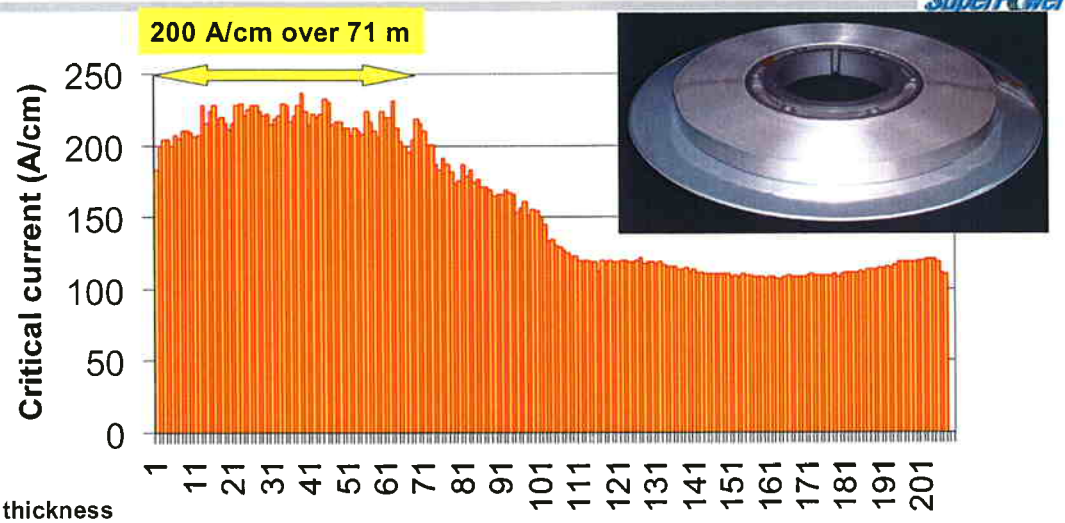


Ic ~ 100 A/cm over 158 m

Standard deviation = 2% over last 100 m

200 m long 2G conductor by MOCVD



YBCO film thickness
1.47 microns @ start &
1.32 microns @ end

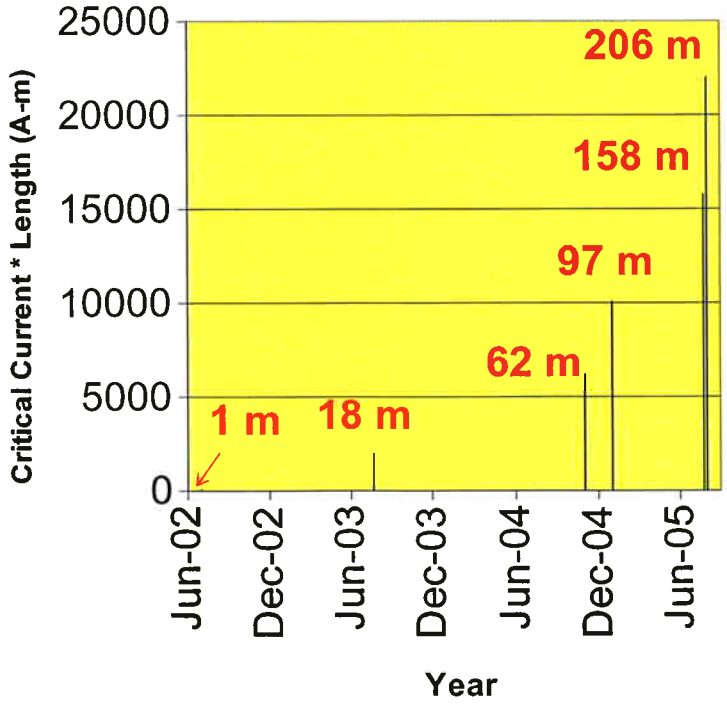
MOCVD 1st pass: 10 m/h
MOCVD 2nd pass: 10 m/h

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

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

Standard deviation of 4.3% over the last 100 m

SuperPower progress in MOCVD scale-up



1 m to 206 m in 3 years

Summary

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- 50 micron substrates polished by electropolishing in 300 m lengths at 30 - 40 m/h with surface quality suitable for IBAD MgO (compared to 150 m of 100 micron substrates last year)
- Twelve 135 m long IBAD MgO tapes fabricated with proto IBAD facility (compared to one 40 m tape last year).
- LMO demonstrated as a better alternative to STO for IBAD MgO-MOCVD conductor – lower deposition temperature, wider window, higher rate, higher current.
- **Demonstrated 142 A/cm over 25 m long MOCVD conductor with all-high throughput buffer** deposition with IBAD MgO i.e. both LMO & homo-epi MgO deposited at 10 m/h (compared to 118 A/cm over 1.8 m last year)
- 158 m conductor with 100 A/cm (15,800 A-m) (compared to 18 m with 118 A/cm last year). ***First demonstration of 100 m conductors with any process other than PLD.*** 100 m segment of conductor has uniformity of 2% (compared to > 10% in 10 m lengths last year)
- **206 m conductor with 107 A/cm (22,030 A-m).**
  First 71 m of the tape has Ic of 200 A/cm with 4.3% uniformity.
  Last 100 m of conductor has uniformity in Ic of 4.3%.