SuperPower Inc.
A Subsidiary of Intermagnetics General Corporation

Progress towards Application Readiness of Coated Conductors at SuperPower

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Introduction

- **SuperPower is scaling up YBCO coated conductors for use in electric power, military, and industrial applications. Over the last two years tremendous progress has been made in our scale-up program. Performance of 6,000-7,000 amp-meters in 50-100 m lengths has been achieved.** *See O2-18 for some detail*

- **Good critical current (I_c) retention in magnetic field, proper conductor geometry, electrical stabilization and reduced ac loss are important issues for coated conductors to be used in electric power, military, and industrial applications.**

- **SuperPower developed a rare-earth substituted composition that yields high I_c in high magnetic fields at LN_2 temperature.**

- **Also developed three key post YBCO processes: slitting, Cu-electroplating and photolithography for striation. Different combinations of these processes produce different products for various applications.**

Funding Sources and Collaborations

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L. Civale and **B. Maiorov** at Los Alamos National Lab

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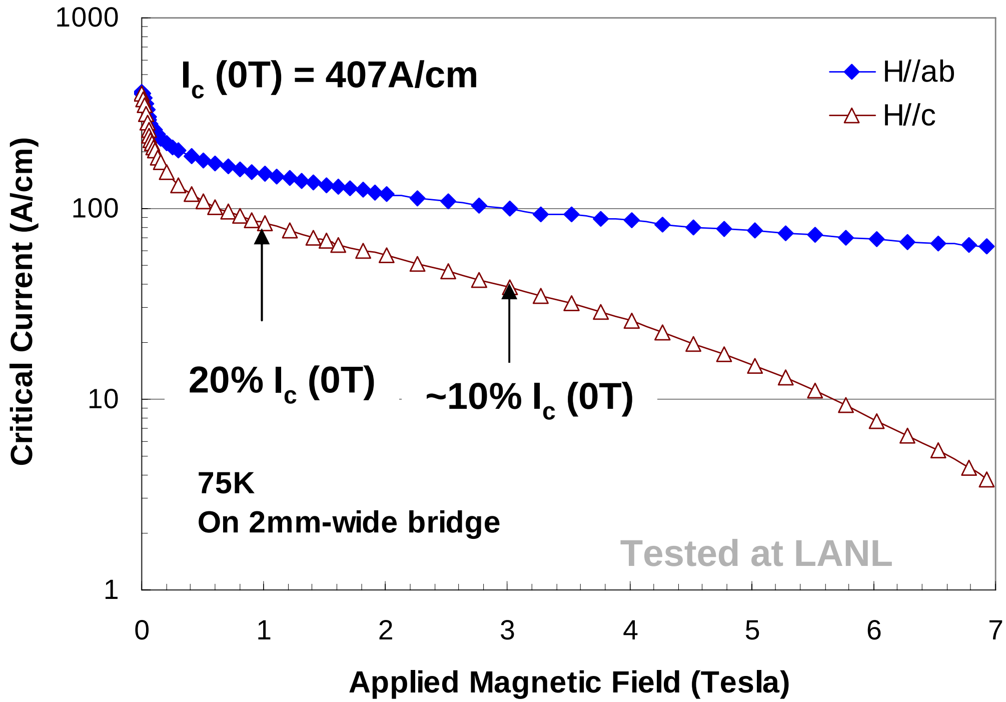
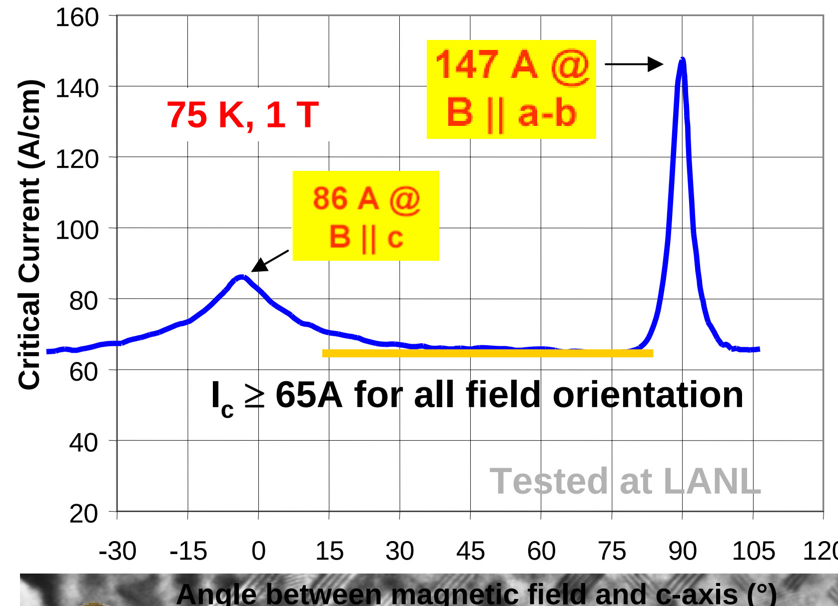
Y. Iwasa at Massachusetts Institute of Technology

N. Cheggour, C. Clickner, and **J. Ekin** at National Institute of Standards and Technology

High critical current in high magnetic fields by Sm-doping

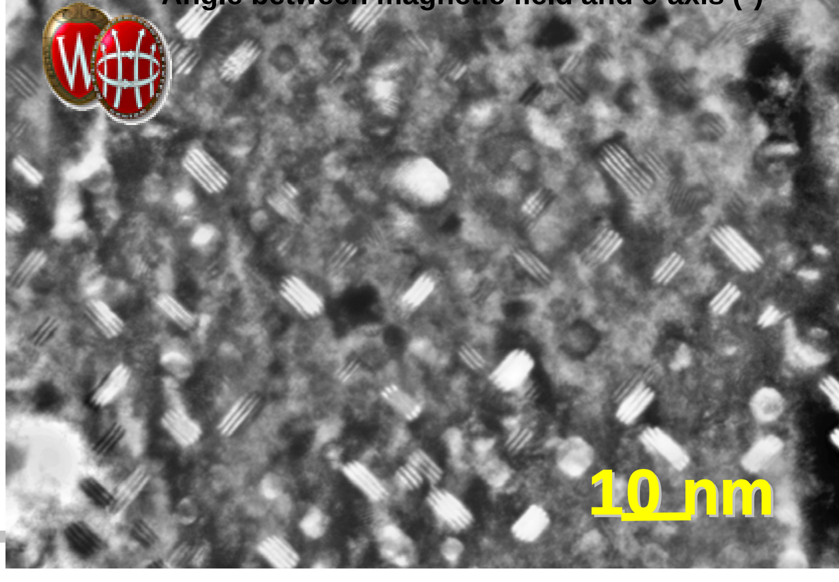




•High critical current in high magnetic field (H//ab and H//c)

•At 1 T, 75 K, minimal Ic above 65A for all field orientation

•Nano-precipitates observed in films. Further work underway to establish correlation



Post-YBCO Processes

Long-length,

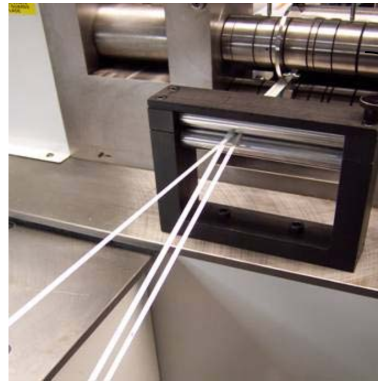
1.2cm wide,

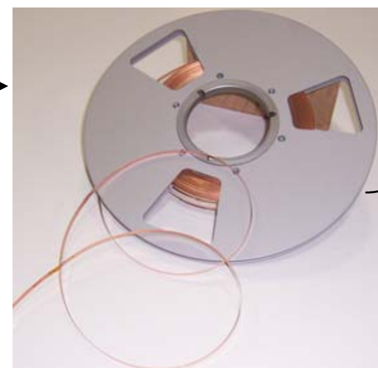
w/ thin Ag layer

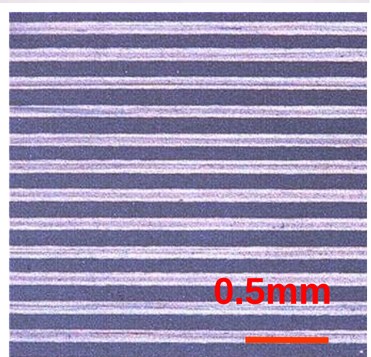
Slitting

Cu E-P

Photolithographic striation







4mm wide

Electroplated with surround Cu.

We have extensively evaluated this route and the product aiming at cable application

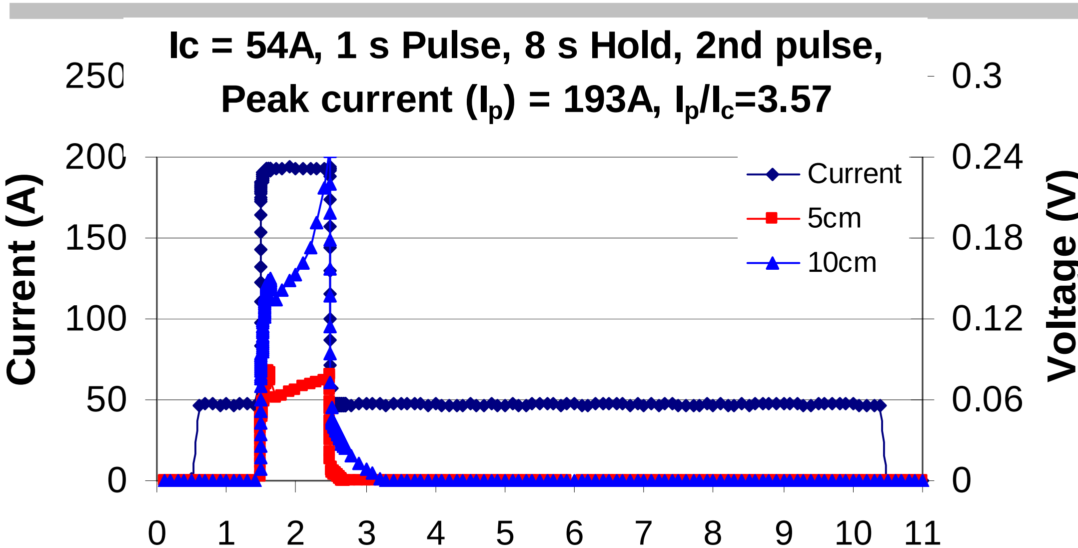
Yielded significant ac loss reduction [Selvamanickam *et al*. at ASC2004]

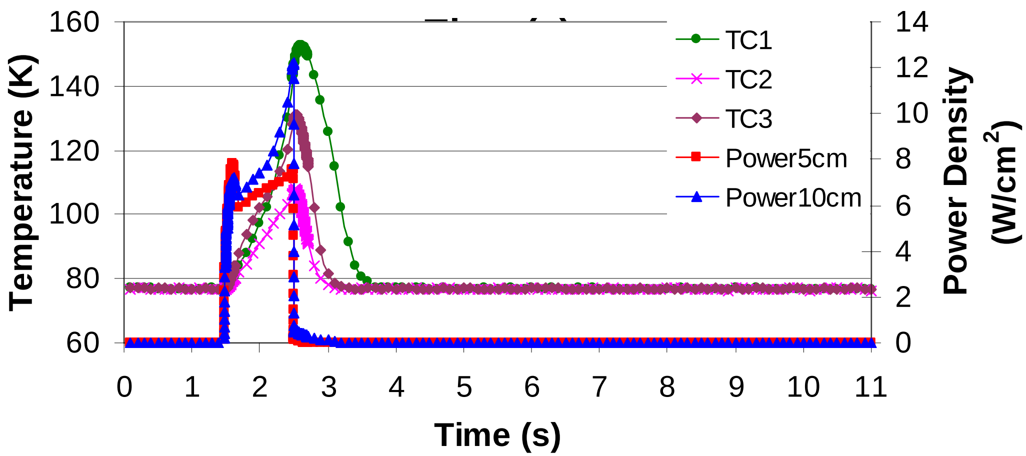
Overcurrent testing shows advantage of "Surround Stabilizer" conductor structure

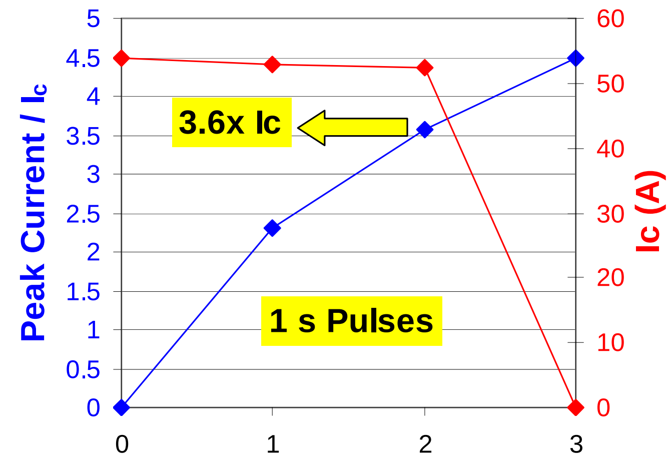
	Current & Power applied to burnout conductor (Ic ~ 60A)			
Conductor Type	Conductor 1	Conductor 2	Conductor 3	Conductor 4
Single side Cu (40 microns)	233A – **18.6W/cm^2**	205A - **18.1W/cm^2**		
"Surround Stabilizer" Cu (20 microns all sides)	279A – **33.3W/cm^2**	277A – **27W/cm^2**	158A (Etched out Cu from substrate side) –**15.3W/cm^2**	194A (Etched out Cu from substrate side) – **21.8W/cm^2**

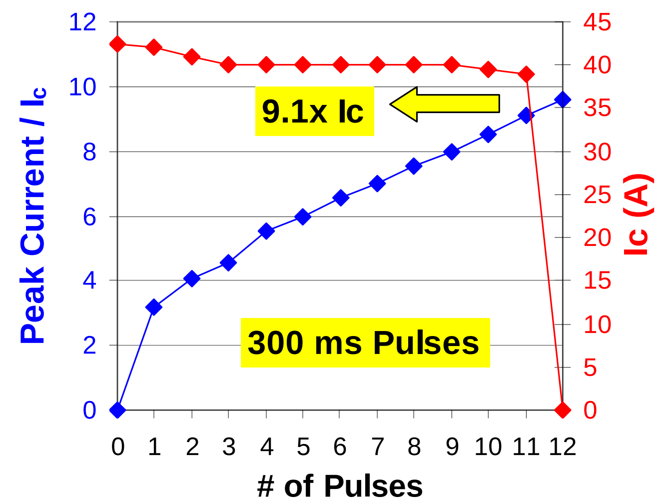
"Surround Stabilizer" conductor structure enables 50 - 100% increase in power handling capability

Overcurrent handling capability of “Surround Stabilizer” structure verified with Pulsed Currents





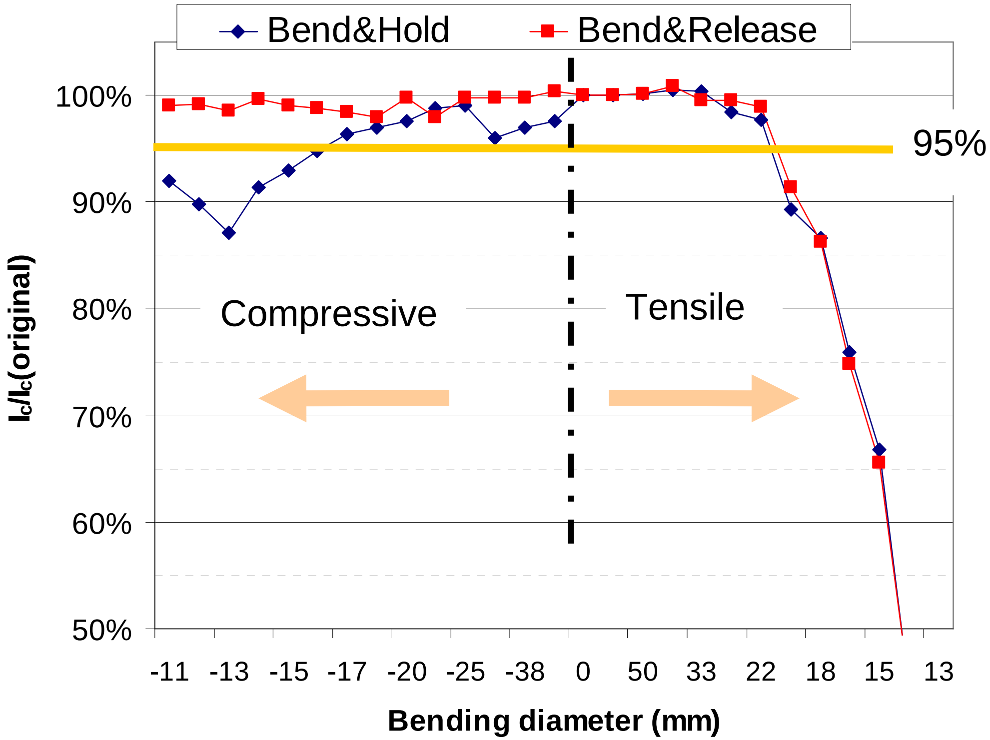


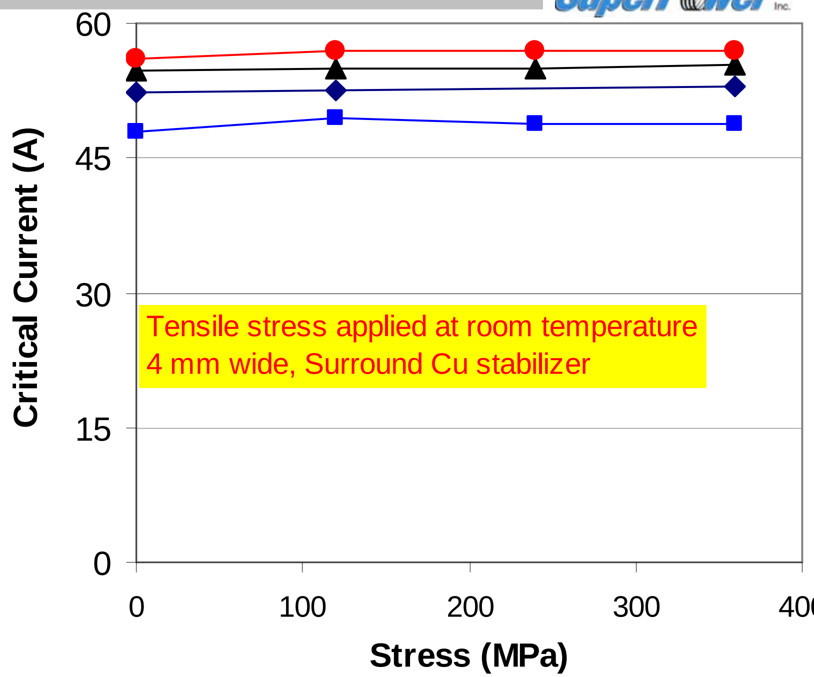


Minimal Ic degradation and no tape burn out even at overcurrent levels of 9 times Ic with 300 ms pulses and 3.5 times Ic with 1 s pulses

Measurements by Jankowski & Iwasa, MIT

4 mm wide, Cu stabilized conductor shows superior bend & tensile properties



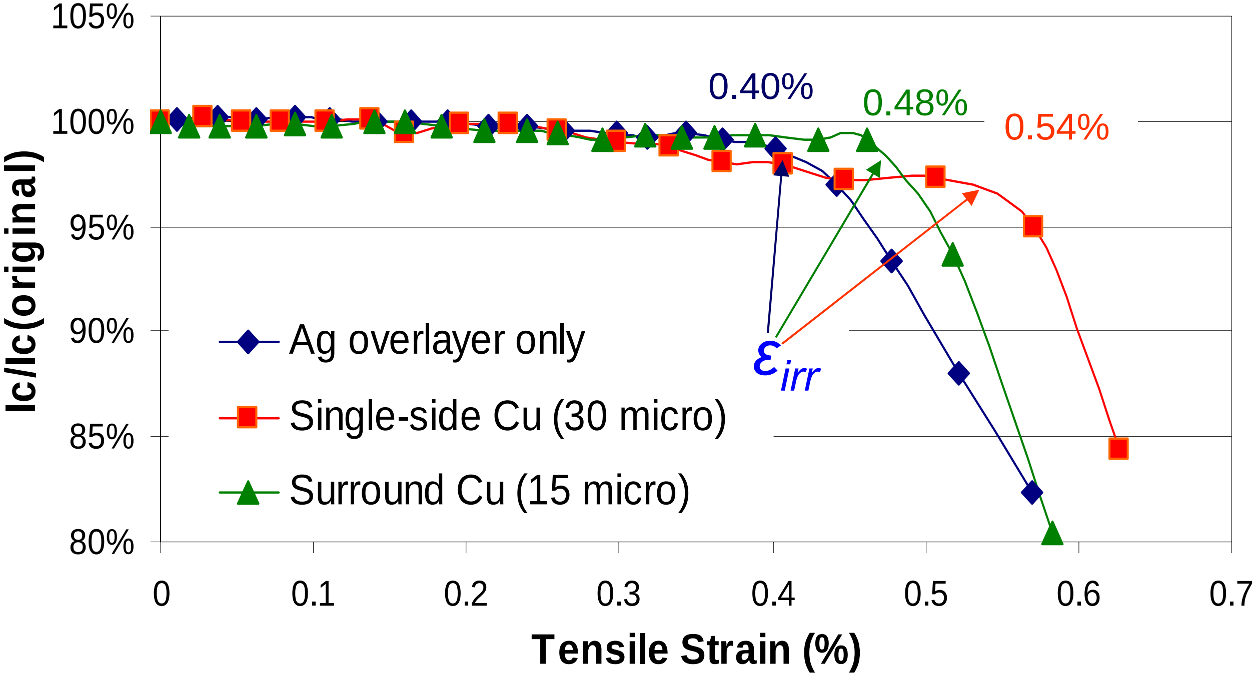


95 % Ic retention when bent:
Tension - **25 mm diameter** both Bend & Hold and Bend & Release
Compression - **16 mm diameter** in Bend & Hold and **< 11 mm diameter** in Bend and Release

Critical Tensile Stress of IBAD-based conductor > **360 MPa**
Critical Tensile Stress of RABiTS-based conductor = **150 MPa***
Critical Tensile Stress of 1-G conductor = **150 MPa**

*AMSC presentation, DOE Peer review 2003

4 mm wide, Cu stabilized conductor shows excellent irreversible axial strain and yield strength



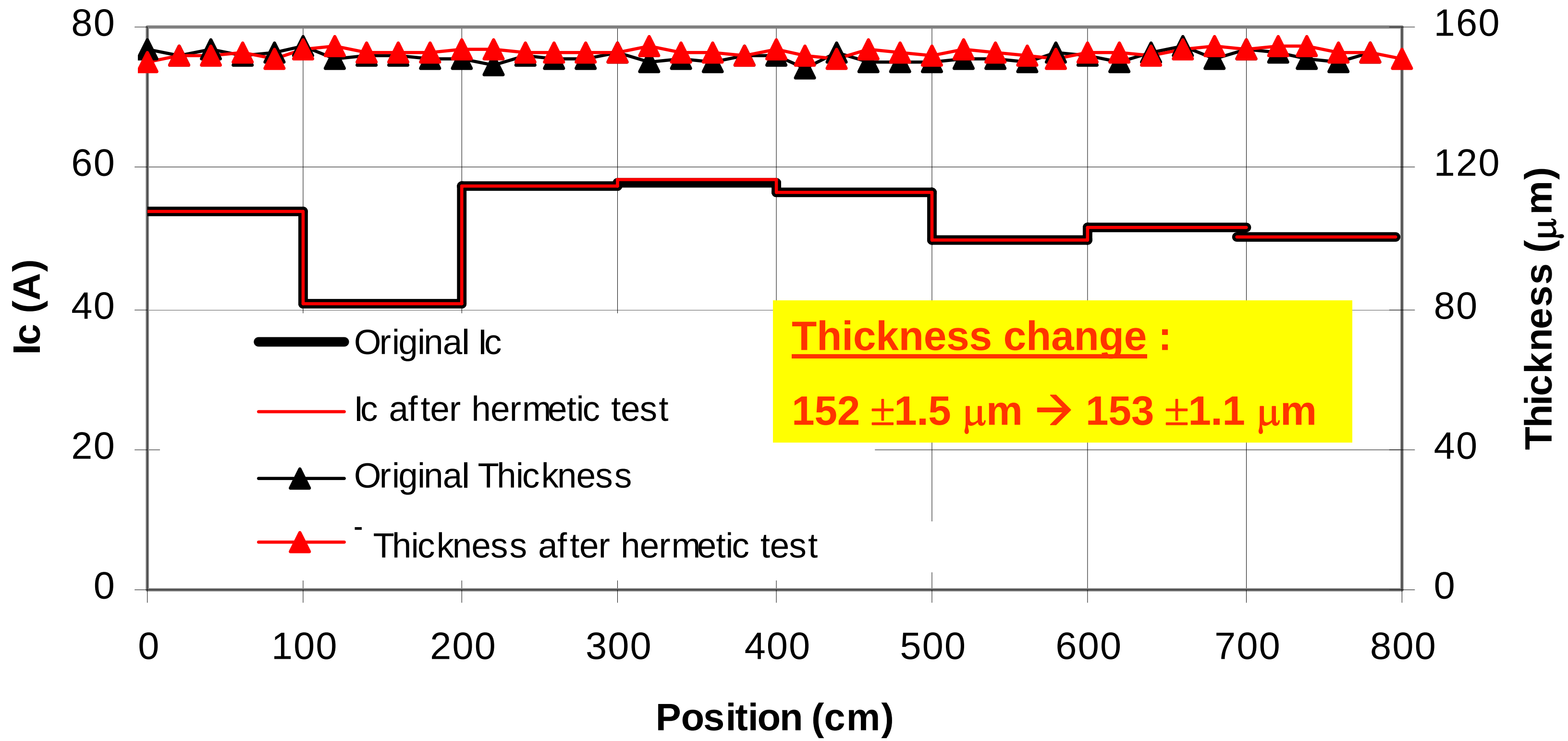
	σ_y (MPa) at 0.2%
Bare Metal Sub.	**455 (295K)** **690 (76K)**
Ag overlayer Only	**693 (76K)**
S.R. Cu (15 μm)	**454 (295K)** **640 (76K)**

➤**Axial-strain performance of the prototype practical conductor "comfortably meet the most severe benchmarks for applications"**

➤**IBAD-based conductors are twice more robust than others, both 2G and 1G**

No noticeable change in I_c & thickness after hermetic test of 4 mm wide, Cu stabilized conductor

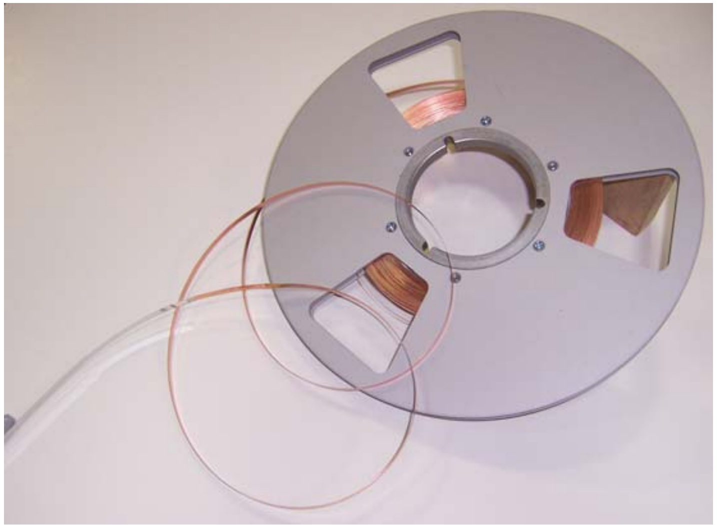
Hermetic test (10atm, 24h in LN_2): inherited test requirement from 1G



"Surround Stabilizer" conductor structure completely encapsulates HTS & protects it from environment

1 m 2G cable fabricated: Shows robustness of 4 mm 2G conductor

- 61 m of fully processed conductor i.e. slit to 4 mm width and plated with copper “Surround Stabilizer” shipped to SEI. Av. Ic of all tapes = 122 A/cm.

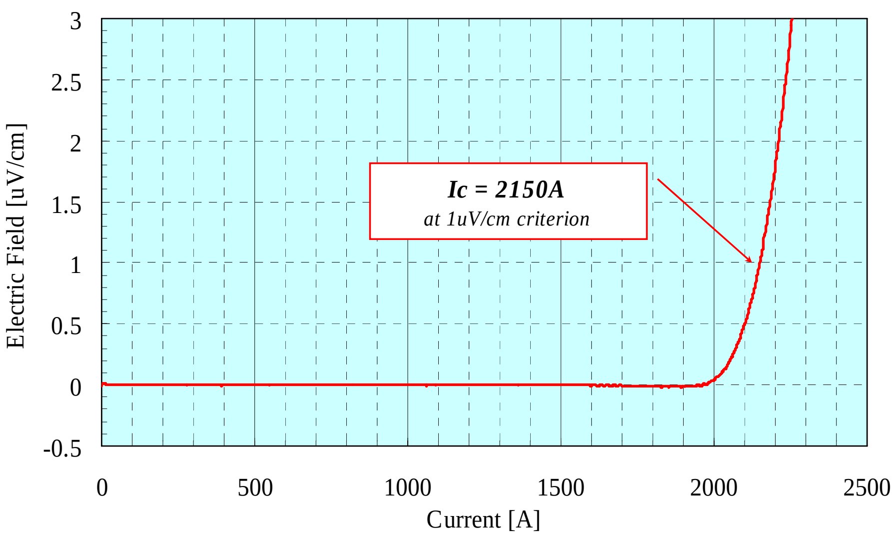


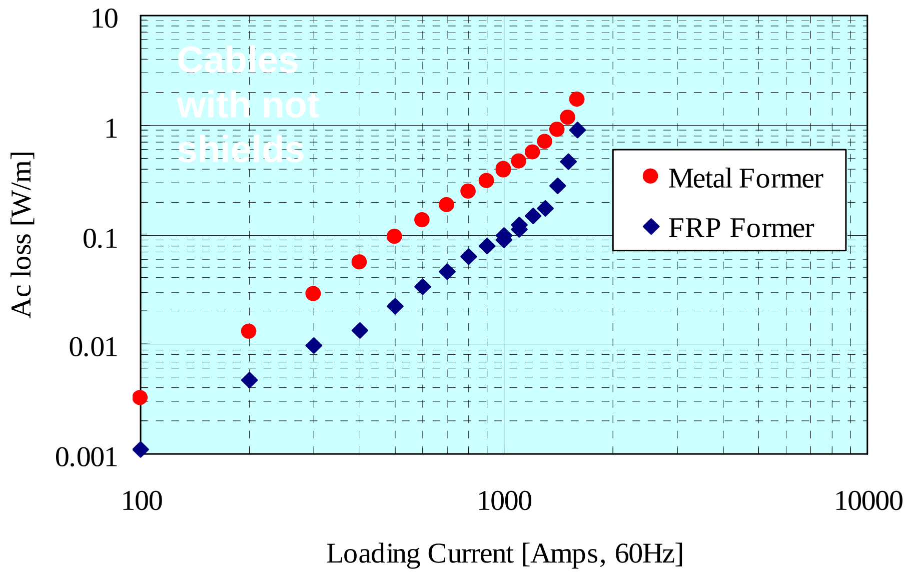
Total # tapes ea. 1.2 m	48
Average Ic of tapes	50.4 A
Average Ic × # tapes	2421 A
Estimated Ic of cable (accounting for field)	2140 A
Measured Ic of cable	2150 A

1 m long 2G cable: Tapes spiral wound with HTS layers in tension

No degradation in Ic of cable even though the HTS layers were spiral wound in tension with a small diameter former (16 mm)

First demonstration of a 2G cable with acceptable ac losses for practical HTS applications





	Albany Cable SuperPower/SEI	AMSC-Southwire Cable* AMSC/Southwire/ORNL
AC loss @ $I_{peak}/I_c = 0.67$	**0.1 W/m – FRP former**	2 W/m
	0.4 W/m – Metal former	(*AMSC presentation DOE Peer review 2003)

AC losses of new 2G cable is 5 - 20 times less than that of 2G cable previously demonstrated

Summary

- Sm-substituted coated conductors show high critical current in high magnetic fields
- Post-YBCO processes developed at SuperPower yielded high-quality practical conductors
- Excellent environmental stability, electrical stability and electrical mechanical properties indicate that SuperPower's 4mm wide conductors with surround Cu stabilizer are applications-ready