DOE Wire Development Workshop

Session I - AMSC Highlights

John Scudiere

January 21, 2003

American Superconductor

American Superconductor Corporation

AMSC Core Business
HTS WIRE

A world leader in developing and manufacturing superconductor and power electronic products

Founded 1987 (Nasdaq:AMSC)

American Superconductor

HTS Business Unit – 2 product generations

- First generation (1G) with BSCCO-2223 is in production
  - Commercial Performance Today
  - Commercial Production Facility is On-Line

- Second generation (2G) with YBCO-123 is in development
  - Potential for significantly lower $/kAm
  - “Form-Fit-Function” Replacement for First Generation
  - Commercial wire in Pilot quantities (200km) possible within 2-3 Years

AMSC Investing in both First Generation and Second Generation Wire

AMSC's First Generation HTS Wire Plant

- World's first commercial HTS wire plant now in operation
- First sellable HTS wire from new plant achieved in Dec '02
- CY 2003 capacity 900 km/year
- Wire performance rising, costs going down
- Just-in-time plant expansion to meet growth in demand

Commercial Volumes and Commercial Prices Now Available

OEMs are planning for HTS Market Growth

- Transmission Cables –
  8-10 new cable demonstrations planned 2003-2005
- Motors –
  Full scale system demonstration(s) underway
- Generators –
  Full scale system demonstration(s) underway
- Separation/Specialty Magnets –
  Full scale system demonstration(s) underway

DOE has stimulated new commercial products

HTS Wire Sales

Two key reasons for OEMs to build full scale HTS systems now:

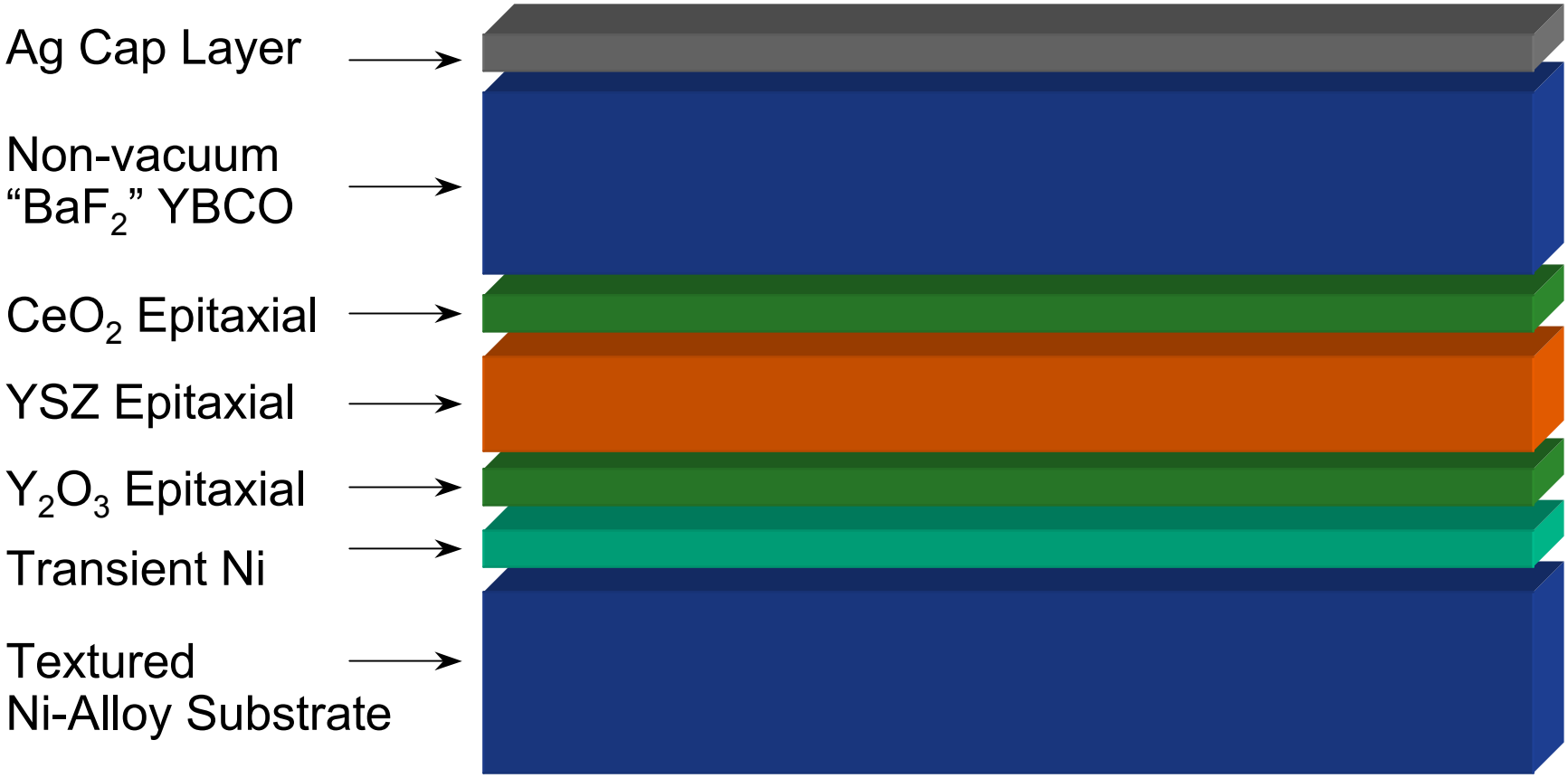
1) 1G BSCCO wire offers better cost/benefit for niche applications now. Application viable using BSCCO.

2) **OEM manufacturers believe that significantly lower cost 2G YBCO wire is close at hand (2-3 years). Significantly larger markets will be accessible.**

   Therefore, it is time for them to develop commercial systems with BSCCO today to prepare the market for rapid penetration when low cost YBCO is available.

Our community needs to deliver

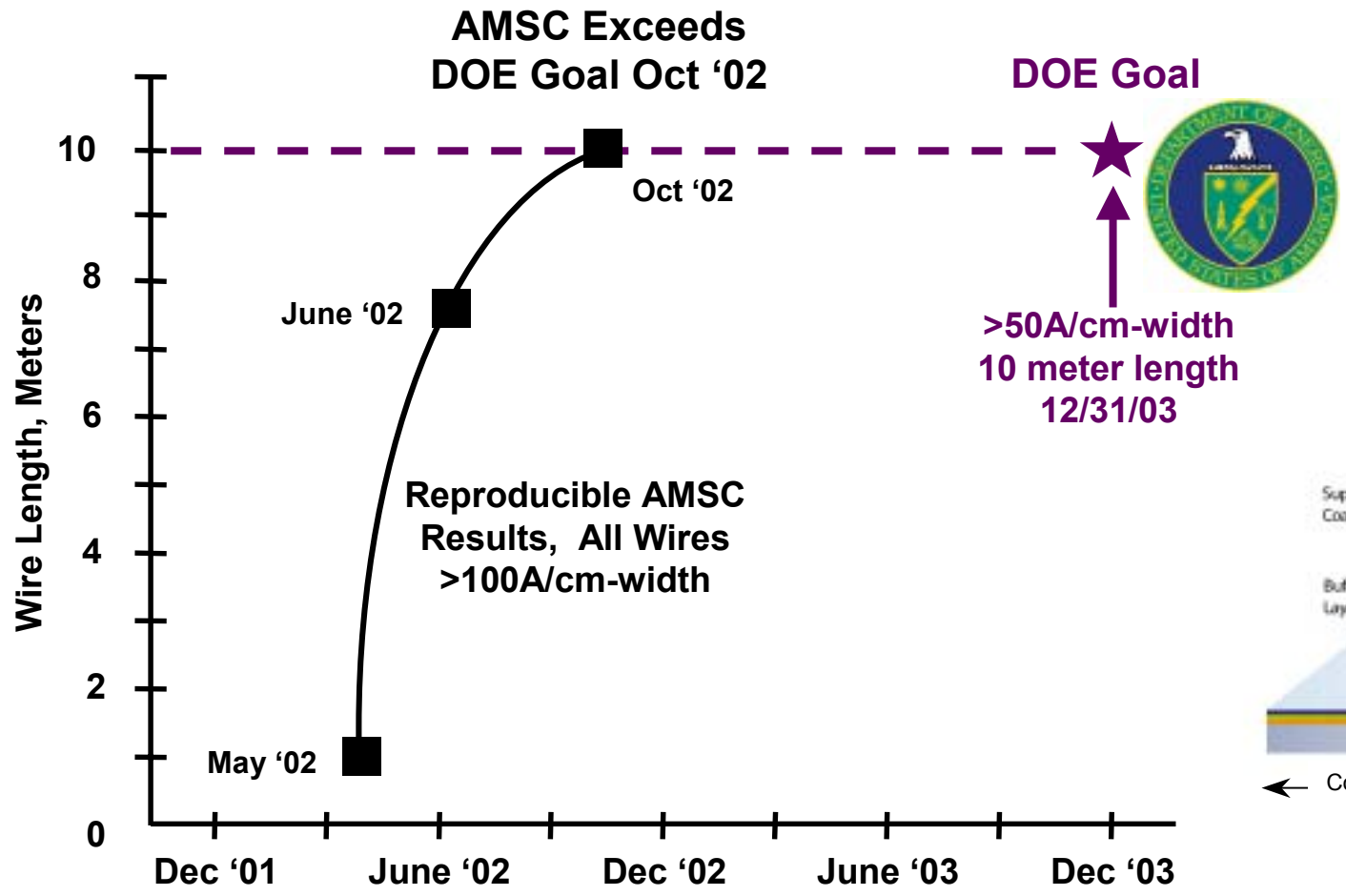
AMSC's RABiTS™ / MOD Second Generation "Tape" Architecture

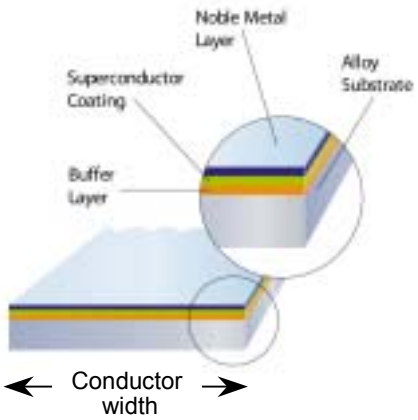


"Tape" = Substrate + Buffer + HTS + Ag Cap

American Superconductor

AMSC Shatters DOE Second Generation Coated Conductor Goal More Than One Year Early





American Superconductor

CY 2002 2G Tape Results

(1) **AMSC delivered 140A/cm, 1 meter tape to ORNL during fall, 2002.**
AMSC demonstrated 100A/cm (77K, sf) @ 10 meters.
AMSC demonstrated 132A/cm (77K, sf) @ 7 meters.
AMSC demonstrated 200A/cm (77K, sf) @ 1cm (on both RABiTS and IBAD).

(2) **Demonstrated >20 n value.**

(3) **NIST measured 0.47% critical strain (77K, sf).**

(4) **Uniformity - 3% σ for Ic, measured on 5 cm scale.**

(5) **Reproducibility – ave. Ic for 10 consecutive meter-length runs is 100 A**

(6) **Scalability - >100 A for multiple runs between 7-10 meters long.**

(7) **HTS Jc maintained for thicker layer – see Session IV, Rupich**

A Good Low-Cost Platform

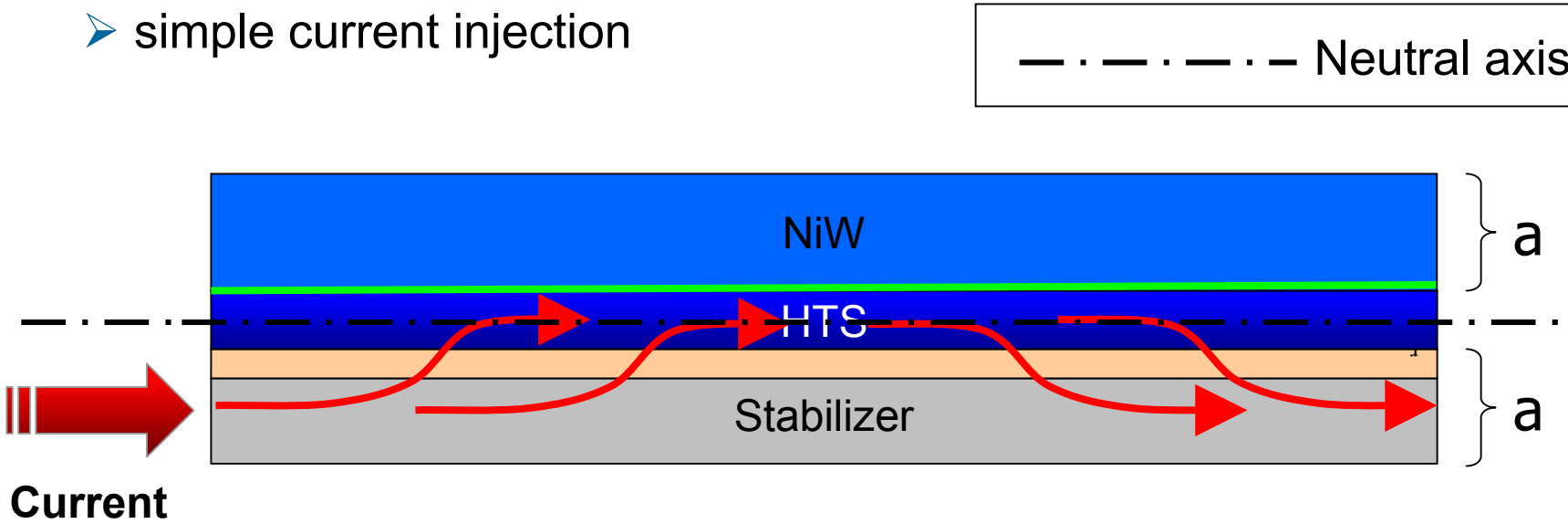
A "Tape" is NOT a Commercial Conductor

- Commercial Geometry, must include:
  - Stabilizer
  - Strengthening
- Joining (tape and stabilizer) and slitting techniques
- Ic uniformity over length and between lengths
- Splicing technique

Commercial Wire Geometries Need to be Built and Tested

"Neutral Axis" Conductor Design = "Wire"

- electrical stability by Cu stabilizer (50-75 μm)
- high mechanical stability – HTS along centerline
- simple current injection



"Wire" = Finished Conductor (Tape + Stabilizer +)

American Superconductor

CY 2002 2G Wire Results

(1) **Demonstrated Neutral Axis geometry:**

- ✓ Lamination
- ✓ Stability
- ✓ Slitting
- ✓ Joining

(2) **Demonstrated >20 n value.**

(3) **NIST measures 254 MPa for AMSC annealed substrates (77K).**

(4) **NIST measured 0.4% critical strain (77K, sf).**

(5) **Demonstrated 0.33% compressive strain tolerance (77K).**

(6) **Demonstrated 13mm bend diameter with 98% Ic retention.**

(7) **Demonstrated 30mm dia. magnet (0.11T), 100% Ic retention.**

Commercial Wire Geometry is promising

Characterization Includes:

- Critical current, end-to-end
- Critical current uniformity
- Ic vs. tensile strain
- Ic vs. compressive strain
- Ic vs. T and B
- Ic vs. bend diameter
- Coil testing
- Jc intergrain and intragrain
- Transport MOI
- MOI under strain
- AC loss
- Electrical and thermal stability
- TEM buffer and HTS
- Buffer crack initiation behavior
- Magnetic susceptibility
- Metal diffusion in buffer
- EBSP substrate/buffer
- Resistance to environment
  - Temperature and humidity
  - Liquid nitrogen penetration
- Resistance to mechanical aging
  - Bending and Twisting
- Thermal cycling
- Fatigue testing

AMSC Key 2G Focus Areas

- Increase Ic (texture and thickness)
- "Tape" - Understanding manufacture process windows (limits) to permit selection of Pilot production equipment.
- "Tape" width – Demonstrate wider 2G Tape, low cost 2G tape is only possible if wide tape is stabilized and slit to wire.
- Commercial "Wire" geometries – Demonstrate and characterize viable commercial wire geometries:
  - Electrical and thermal stability
  - Mechanical
  - Slitting
  - Joining
- Full characterization of "Tape" and "Wire"

American Superconductor

Summary – 2002

- BSCCO products are entering commercial phase
- RABiTS™/MOD is low cost, scaleable process for 2G wire
- 10 m at > 100 A/cm-w
- POP of > 200 A/cm-w (1 cm sample length)
- *Neutral Axis* conductor design – direct BSCCO replacement
- Broad characterization of Tape and Wire underway

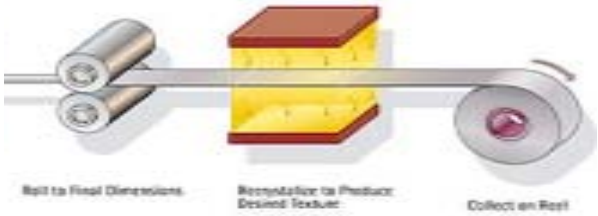
…on the path to the next Generation!

End

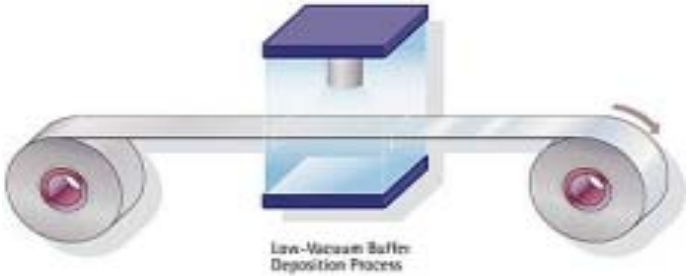
REVOLUTIONIZING THE WAY THE WORLD USES ELECTRICITY™

American Superconductor™

Low Cost 2G Manufacture Process

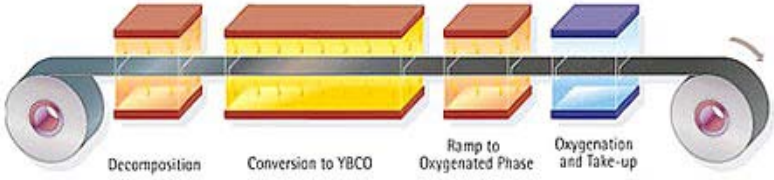


Substrate Production



Buffer Deposition

YBCO Precursor Coating



YBCO Formation

Tape Lamination and Slitting

Many Wires/Tape

American Superconductor