superior performance. powerful technology.

HTS Conductor Forum – Representative Manufacturer's Point of View

DW Hazelton

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SuperPower Inc. is a subsidiary of Furukawa Electric Co. Ltd.

Engineering progress drives 2G HTS adoption

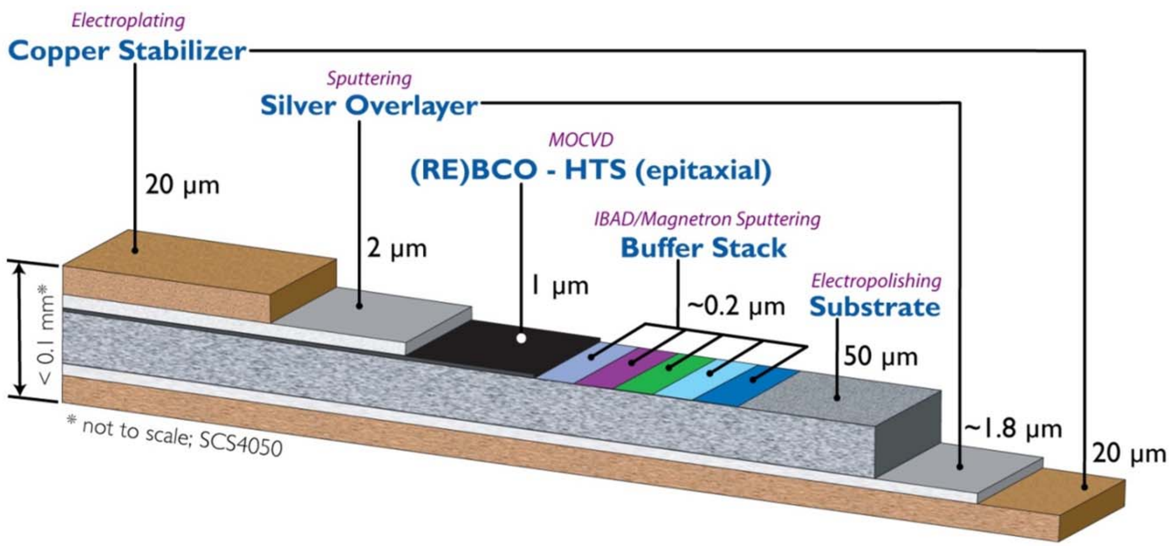
Feature	Approach	Assessment
Robust wire design Mechanical strength	“Hastelloy” based substrate supporting structure	Tensile strength Peel strength Splicing stress
In-field performance Critical current (Ic) under magnetic field	Flux pinning with engineered nanostructure Consistent & uniform process	Enhanced Ic at low (4.2-40K) temp. and under perpendicular field components (2-15T)
Alternative constructs Higher operating currents Special application requirements	Cable constructs Bonded conductor designs Alternative materials	Higher operating currents Stronger conductors with application specific properties

Wire performance critical to practical applications

- $I_c(B, T, \theta)$
  - Temperature, magnetic field and field orientation dependence of I_c
  - Minimum I_c at operating condition
- Mechanical properties (electromechanical performance)
  - Workability for fabrication into various devices
  - Irreversible stress or strain limits under various stress condition, in terms of I_c
- Uniformity along length (I_c and other attributes)
- Thermal properties (thermal expansion coefficient and thermal conductivity)
- Quench stability (NZPV and MQE)
- Insulation (material and method)
- Splice
  - Resistance (resistivity)
  - Mechanical strength (tensile and bending)

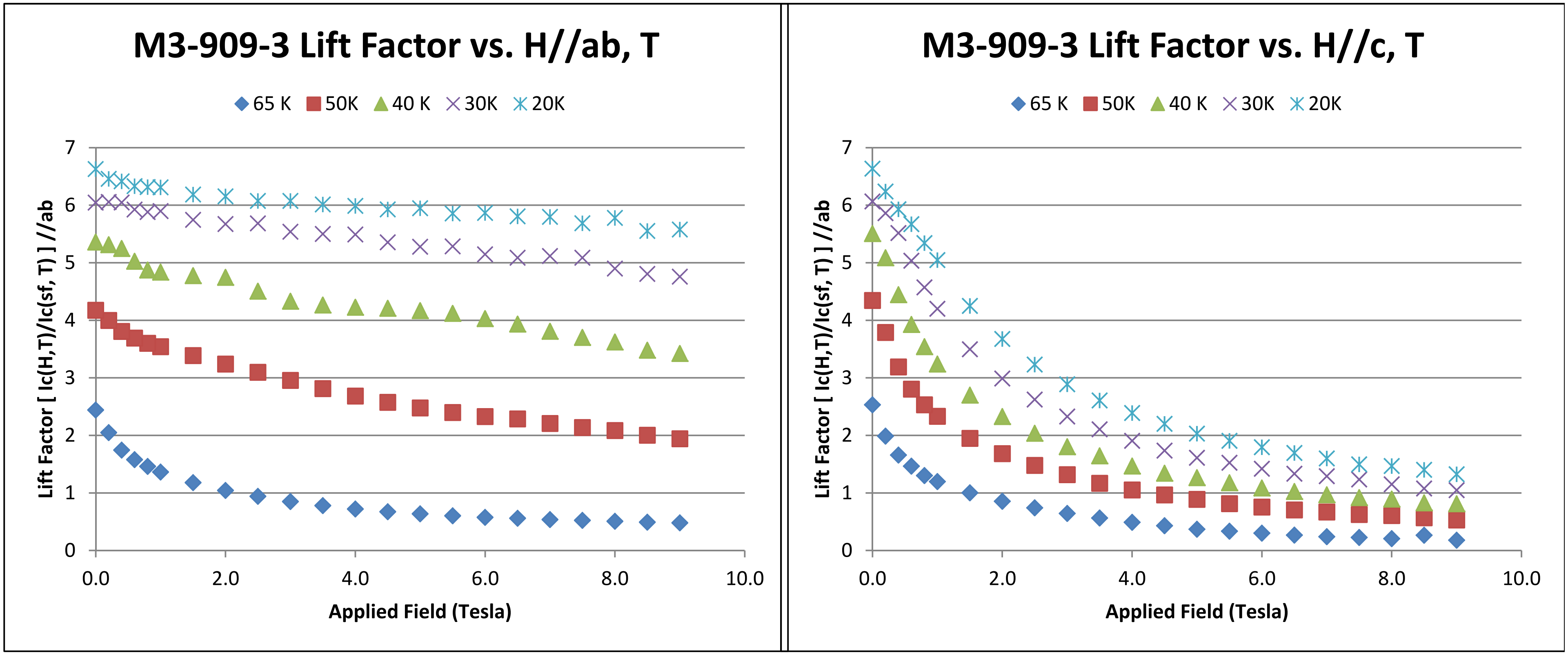
Standards for 2G HTS wire property testing are under development

SuperPower's ReBCO superconductor with artificial pinning structure provides a solution for demanding applications



- Hastelloy® C276 substrate
  - high strength
  - high resistance
  - non-magnetic
- Buffer layers with IBAD-MgO
  - Diffusion barrier to metal substrate
  - Ideal lattice matching from substrate through ReBCO
- MOCVD grown ReBCO layer with BZO nanorods
  - Flux pinning sites for high in-field I_c
- Silver and copper stabilization

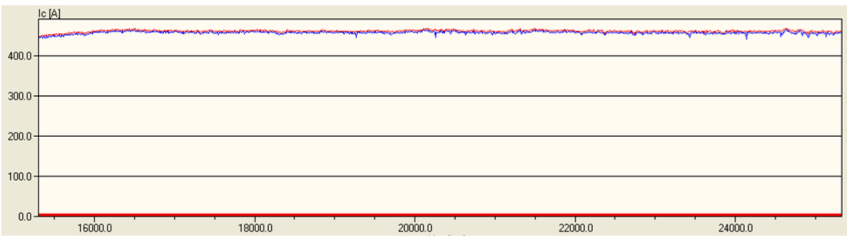
$I_c(B,T, \Phi)$ characterization is critical to understanding the impacts of processing on operational performance



Measurements made at the University of Houston

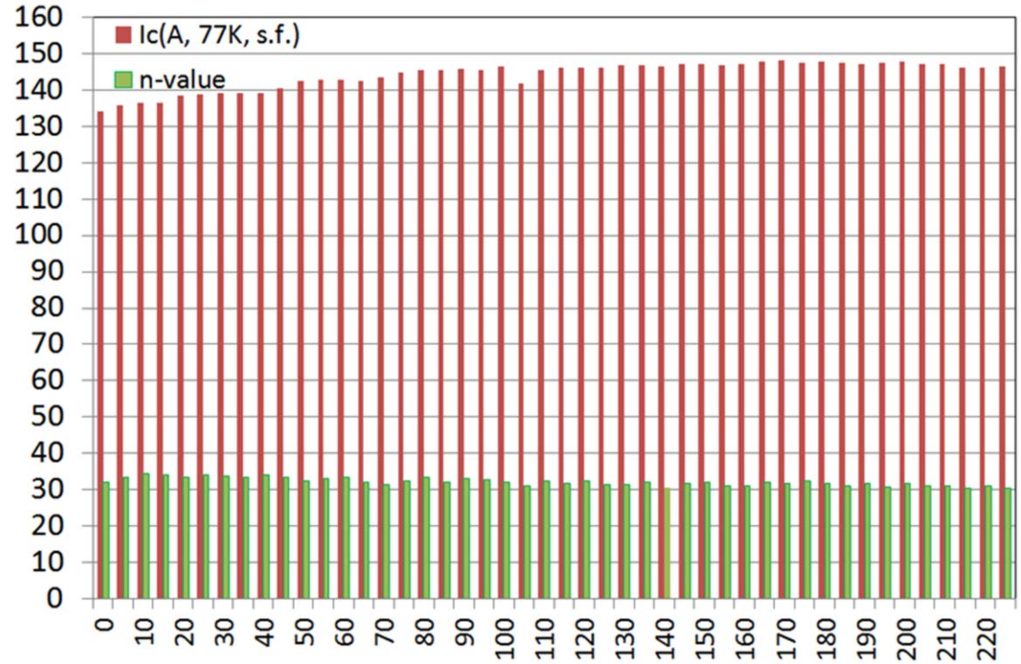
- Lift factor, $I_c(B,T)/I_c(\text{sf, 77K})$, particularly a full matrix of $I_c(B,T, \Phi)$ is in high demand.
- Frequently sought by coil/magnet design engineer, for various applications.
- Used to calculate local I_{op}/I_c ratio inside coil body, and design quench protection.

I_c uniformity along length (TapeStar, transport)



Position (cm) (on a 12 mm wide wire)

- Magnetic, non-contact measurement
- High spacial resolution, high speed, reel-to-reel
- Monitoring I_c at multiple production points after MOCVD
- Capability of quantitative 2D uniformity inspection



Position (m) (on a 4 mm wide wire)

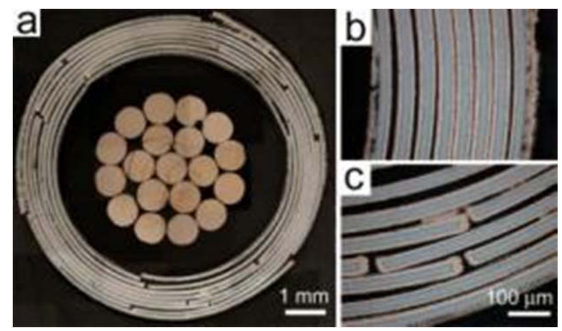
(four-probe transport measurement)

SuperPower Inc.
A Furukawa Company

Engineering new wire innovations to address customer requests and meet application requirements

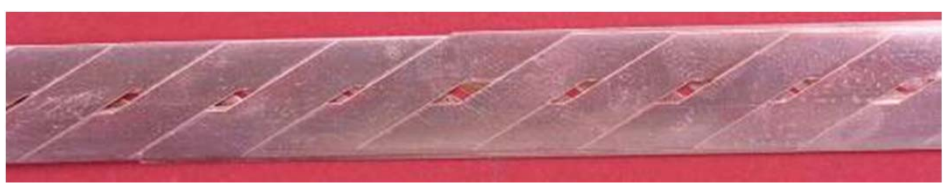
- Additional wire insulation methods
  - Today: Kapton®/Polyimide wrapped
  - Other options under development: thinner profile, better coverage

- Additional wire architectures under development
  - Higher current carrying capability
    - Multi-layer combinations
    - Cable on Round Core (CORC)
    - Roebel cable
  - Custom attributes
    - FCL – normal state resistance feature



Courtesy: Advanced Conductor Technologies

KIT
Karlsruhe Institute of Technology



ROEBEL cable made by KIT with SuperPower® 2G HTS Wire

Capability for bonded conductors being developed [higher amperage, specialty applications (FCL)]

- Bonded conductors offer the ability to achieve higher operating currents
  - LV windings of FCL transformer
  - HEP applications
  - High current bus applications
- Bonded conductors offer higher strength
  - FCL transformer fault currents
  - High field HEP applications with high force loadings
- Bonded conductors offer the ability to tailor application specific operating requirements, i.e. normal state resistance for a FCL transformer

Summary

- SuperPower 2G HTS conductor offers a flexible architecture to address the broad range of demanding applications requirements.
- SuperPower is engaging major resources in improving its manufacturing capabilities to deliver a consistent, reliable, high quality 2G HTS product
  - Improved consistency of lift factor
  - Improved piece length
  - Improved current density
  - Improved uniformity
- Alternative conductor configurations are being developed to address customer demand