### Superconductor Technologies, Inc.

2G HTS Coated Conductors Buffer Stack Architecture Improvements at STI

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September 19, 2017



# (4)-Step Superconducting Wire Manufacturing



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## Mechanical Strength Improvement





- Delamination Origin
  - o Stress induces by CTE mismatch of various layers
  - o Carbon presence in the surface of SDP
- Mechanical Strength Improvement
  - Test Thinner C276 substrate thickness
  - o Improved SDP chemistry to reduce carbon & enhance bond strength
    - Ref: Nicholas Long's presentation @ EUCAS 4MP6-11



#### Pin Pull Test for Delamination Strength



100 um C276 – Post Testing



50 um C276 – Post Testing

- o Pin Pull Test
  - Use epoxy to adhere dolly to film surface
  - Used calibrated automated adhesion tester to test C-axis adhesion
- $\circ~$  100  $\mu m$  substrate failed 85% of the time before reaching 7 MPa
- $\circ~50~\mu m$  substrate passed the tester max value of 7 MPa
- $\circ~$  Selected 60  $\mu m$  thick substrate based on customer request for application
  - o Alternative substrate thickness possible with additional development



#### Wrap Testing – Biaxial Tensile Stress









Sample Loaded

Sample in Test/LN2

- Built automated Ic vs. Tensile Test equipment for combined electrical and mechanical evaluations in LN2 environment
- Selected Tensile loading because of 2G HTS failure occurs at lower stress values in tensile mode based on Bi-Axial Wrap Testing
  - $\circ$  Measures direct current up to 1800A with tensile load
  - Measures Stress (load cell) and Strain(optical encoder)







• Direct Current Ic measurement @907A for 12 mm wide tape

- $\circ$  90% of Ic<sub>o</sub> retained at 0.4% strain & 450 MPa
- Retained n-value of (33+) during tensile testing



### Conductus<sup>®</sup> Critical Current Data



Tapestar data for > 100m tape with average Ic of 716A / 12 mm - 2016



Tapestar data for > 50m tape with average Ic of 673A / 12 mm – Current Product – May 2017

 $\circ$  3.3% non-uniformity ( $\sigma/\mu$ ) measured



#### **Conductus® Low Temperature Performance**



Low temperature measurements show high performance potential of STI 2G Tape

- $\circ$  I<sub>c</sub> Correlation between 77K  $\rightarrow$  30K values using STI Process for 2G Film Growth
- Angular Scan In-Field performance, 2 Tesla  $77K \rightarrow 25K$



**DOE focused on Enabling Technology for NG Machines** 

Award	\$4.5M June 2017
Provider	U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) on behalf of the Advanced Manufacturing Office (AMO)
Prime Recipient	Superconductor Technologies Inc.
Focus	Next Generation Electric Machines (NGEM) program: To improve the superconductive wires manufacturing process at high enough temperatures where nitrogen can be used as the cryogenic fluid to improve performance and yield while reducing cost. <b>Objective: 1440A/cm @ 65K in 1.5T Field, and improved cost performance</b>

"Advancing these enabling technologies has the potential to boost the competitiveness of American manufacturers and take the development of more efficient electric machines a giant step further. These technology R&D projects aim to significantly improve industrial motors for manufacturing, helping companies who use these motors in manufacturing save energy and money over the long run."

Mark Johnson, director of the EERE Advanced Manufacturing Office

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## STI / D.O.E. Program Overview





- Improved mechanical performance
  - Using thinner C276 substrates 60 μm improved bend radius by 28%
  - Improved SDP chemistry to reduce carbon
  - Extensive quality testing for each lot with automated test fixture
    - TapeStar (Ic), Tensile vs. Ic (Mechanical & Ic combined), Working on Magnetic & Ic (DOE)
- Designed new tensile load tester to provide strain vs Ic data
  - Measured Ic of 907A, retaining 90% of Ic at 0.4% strain
- I<sub>c</sub> Range [500-800] Amps/cm @ 77 Kelvin, Self Field
  - Ongoing R&D to further improve uniformity 3% uniformity
- A variety of metal coating options available for;
  - Cables, SFCL's, Magnets, & Other Applications
- STI has 750km/year 4mm 2G HTS wire capacity
- STI/DOE Project awarded to Improve 2G HTS In-Field Performance for Electric Machines



# Safe Harbor Provisions

Statements in this presentation regarding our business that are not historical facts are "forward-looking statements" that involve risks and uncertainties. Forward-looking statements are not guarantees of future performance and are inherently subject to uncertainties and other factors, which could cause actual results to differ materially from the forward-looking statements. These factors and uncertainties include, but are not limited to: our limited cash and a history of losses; our need to materially grow our revenues from commercial operations and/or to raise additional capital (which financing may not be available on acceptable terms or at all) in the very near future, before cash reserves are depleted (which reserves are expected to be sufficient into the first quarter of 2018), to implement our current business plan and maintain our viability; the performance and use of our equipment to produce wire in accordance with our timetable; overcoming technical challenges in attaining milestones to develop and manufacture commercial lengths of our HTS wire; the possibility of delays in customer evaluation and acceptance of our HTS wire; the limited number of potential customers and customer pressures on the selling prices of our products; the limited number of suppliers for some of our components and our HTS wire; there being no significant backlog from quarter to quarter; our market being characterized by rapidly advancing technology; the impact of competitive products, technologies and pricing; manufacturing capacity constraints and difficulties; the impact of any financing activity on the level of our stock price; the dilutive impact of any issuances of securities to raise capital; the steps required to maintain the listing of our common stock with a U.S. national securities exchange and the impact on the liquidity and trading price of our common stock if we fail to maintain such listing; the cost and uncertainty from compliance with environmental regulations; and local, regional, and national and international economic conditions and events and the impact they may have on us and our customers.

Forward-looking statements can be affected by many other factors, including, those described in the "Business" and "Management's Discussion and Analysis of Financial Condition and Results of Operations" sections of STI's Annual Report on Form 10-K for the year ended December 31, 2016 and in STI's other public filings. These documents are available online at STI's website, www.suptech.com, or through the SEC's website, www.sec.gov. Forward-looking statements are based on information presently available to senior management, and STI has not assumed any duty to update any forward-looking statements.



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