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Progress of Wire Development and Process Improvement on 2G HTS at SuperPower

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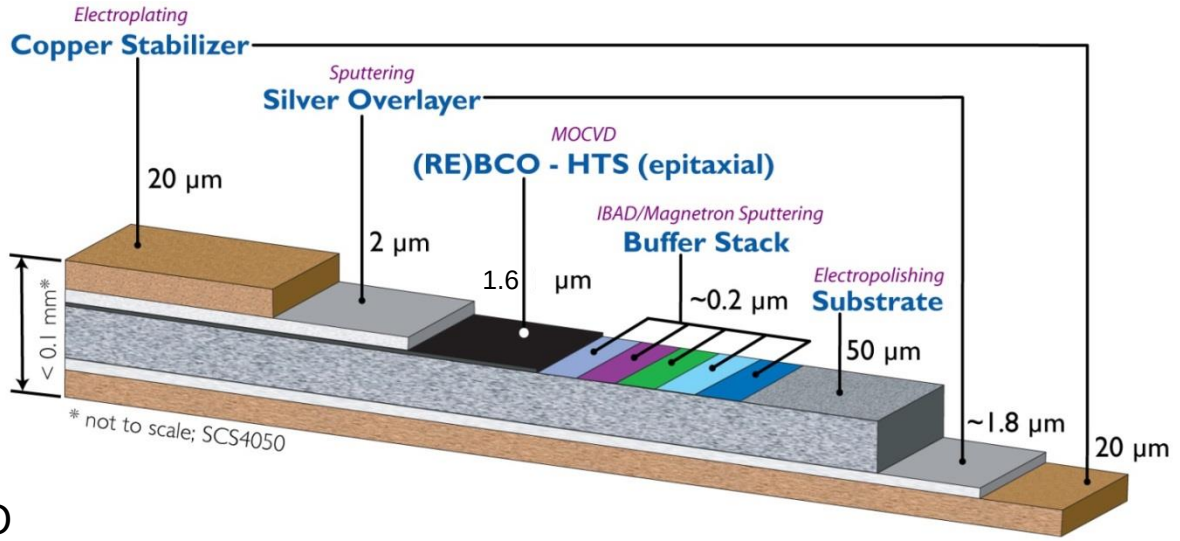
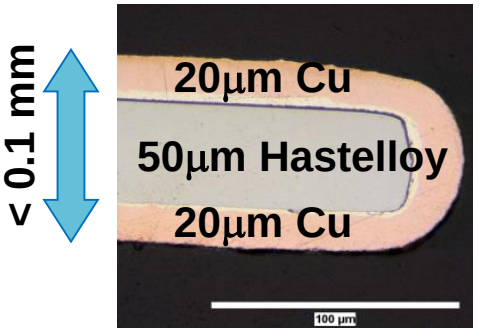
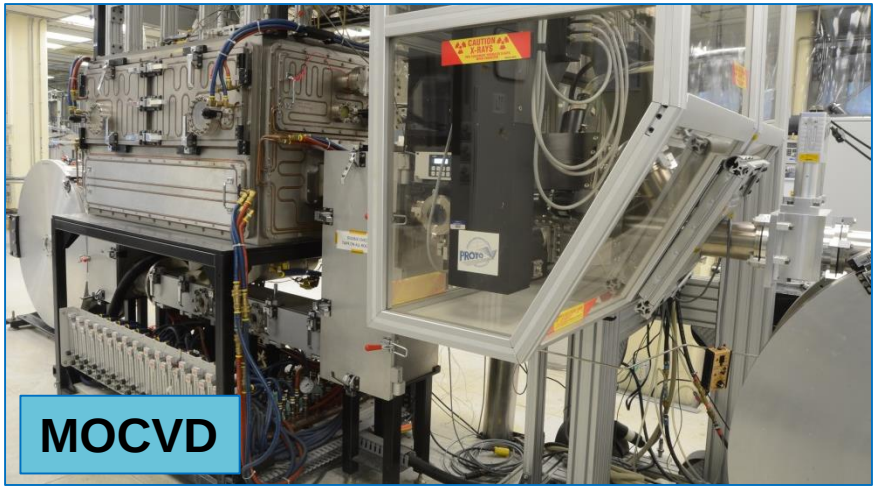
SuperPower's (RE)BCO superconductor with artificial pinning structure provides a solution for demanding applications

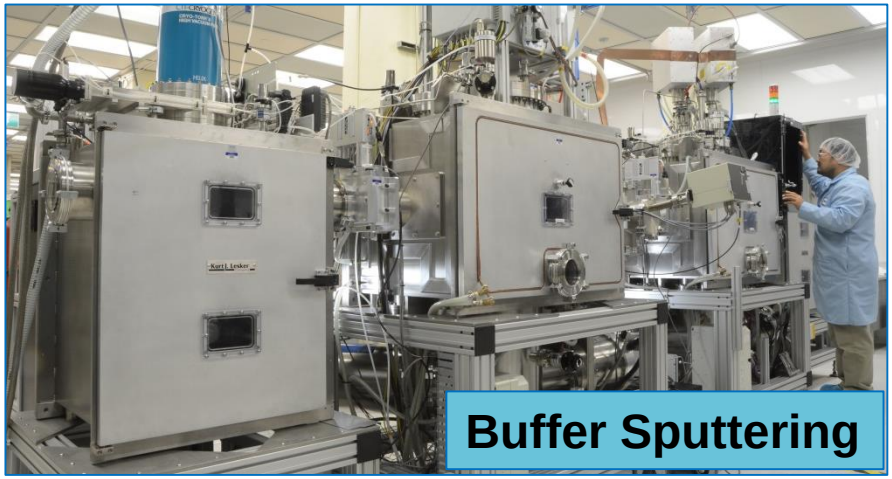


- Hastelloy® C276 substrate
  - high strength
  - high resistance
  - non-magnetic
- Buffer layers with IBAD-MgO
  - Diffusion barrier to metal substrate
  - Ideal lattice matching from substrate through REBCO
- MOCVD grown (RE)BCO layer with BZO nanorods
  - Flux pinning sites for high in-field I_c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



2G HTS wire has been produced with continuous upgrades at the manufacturing facility since 2006

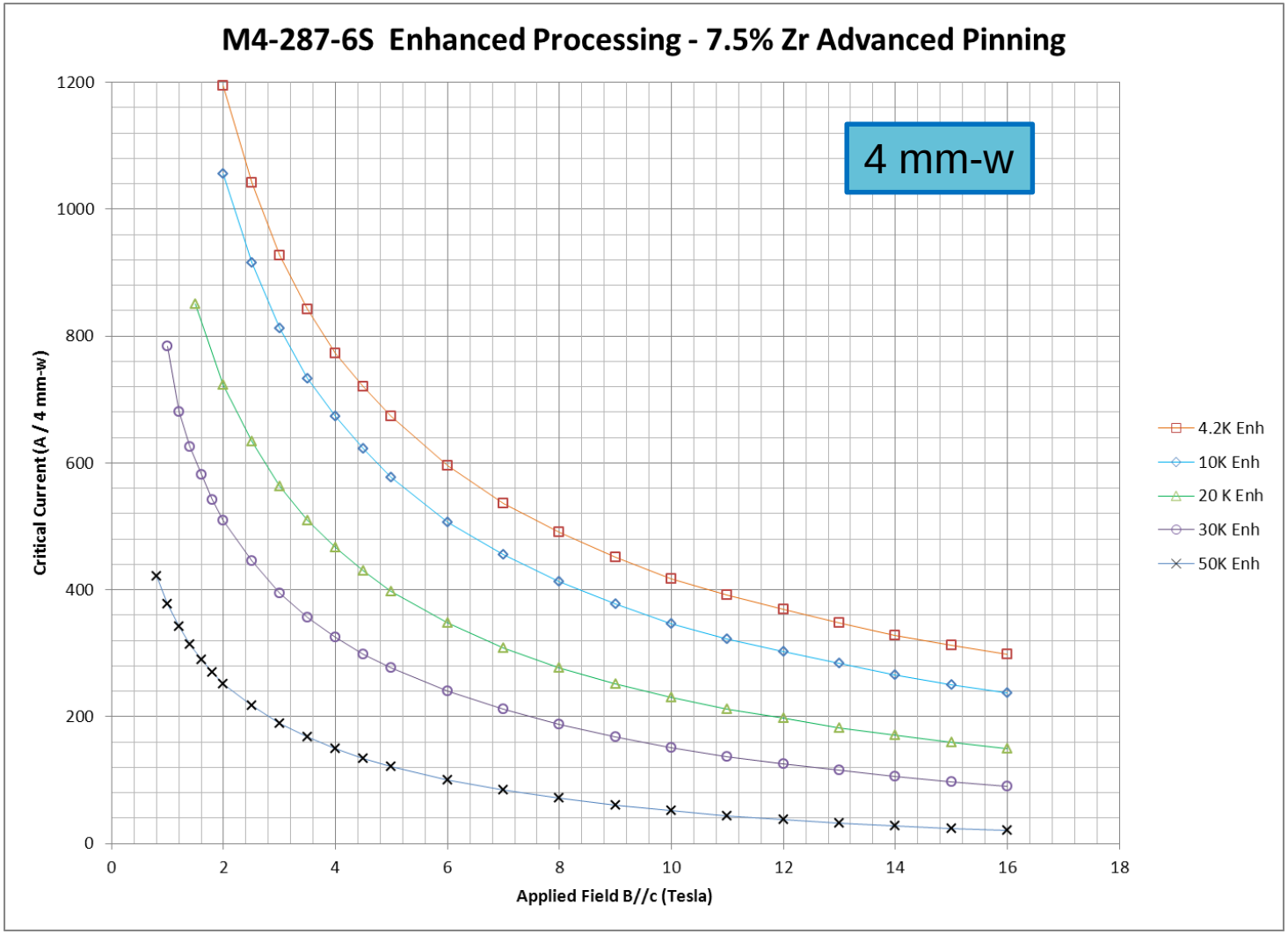




Recent step wise improvements to meet market challenges

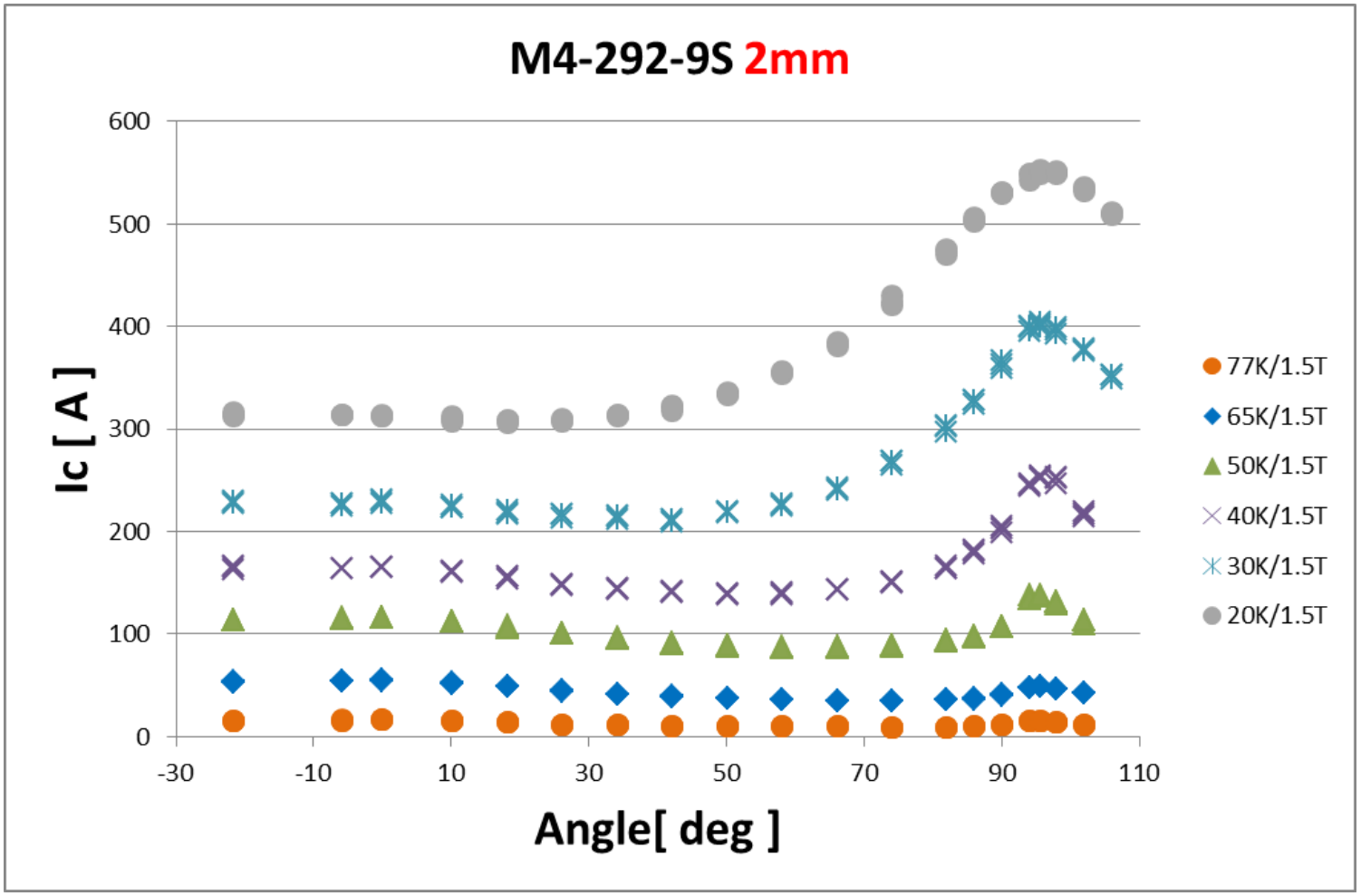
- ***Critical current***
  - Recent advances in processing have significantly increased the base I_c (77K, sf) of SP 2G HTS tapes into the 400-600 A/cm-w range
- ***Piece length***
  - Recent advances in processing have also increased the stable production piece length of SP 2G HTS tapes ~300m to 500 m
- ***Current density***
  - SP 2G HTS tapes have some of the highest conductor Je's in the industry
  - New initiatives will continue to improve performance
    - Thinner substrates (>30% Jc improvements)
    - Improved lift factors (2x +) with enhanced pinning
    - Focus on three pinning regimes: 4K-high field, 20-50K – moderate field, 65-77K low field.
- ***Continuous improvement of uniformity and reproducibility within and between run***

Critical current vs. field: enhanced 7.5% Zr AP

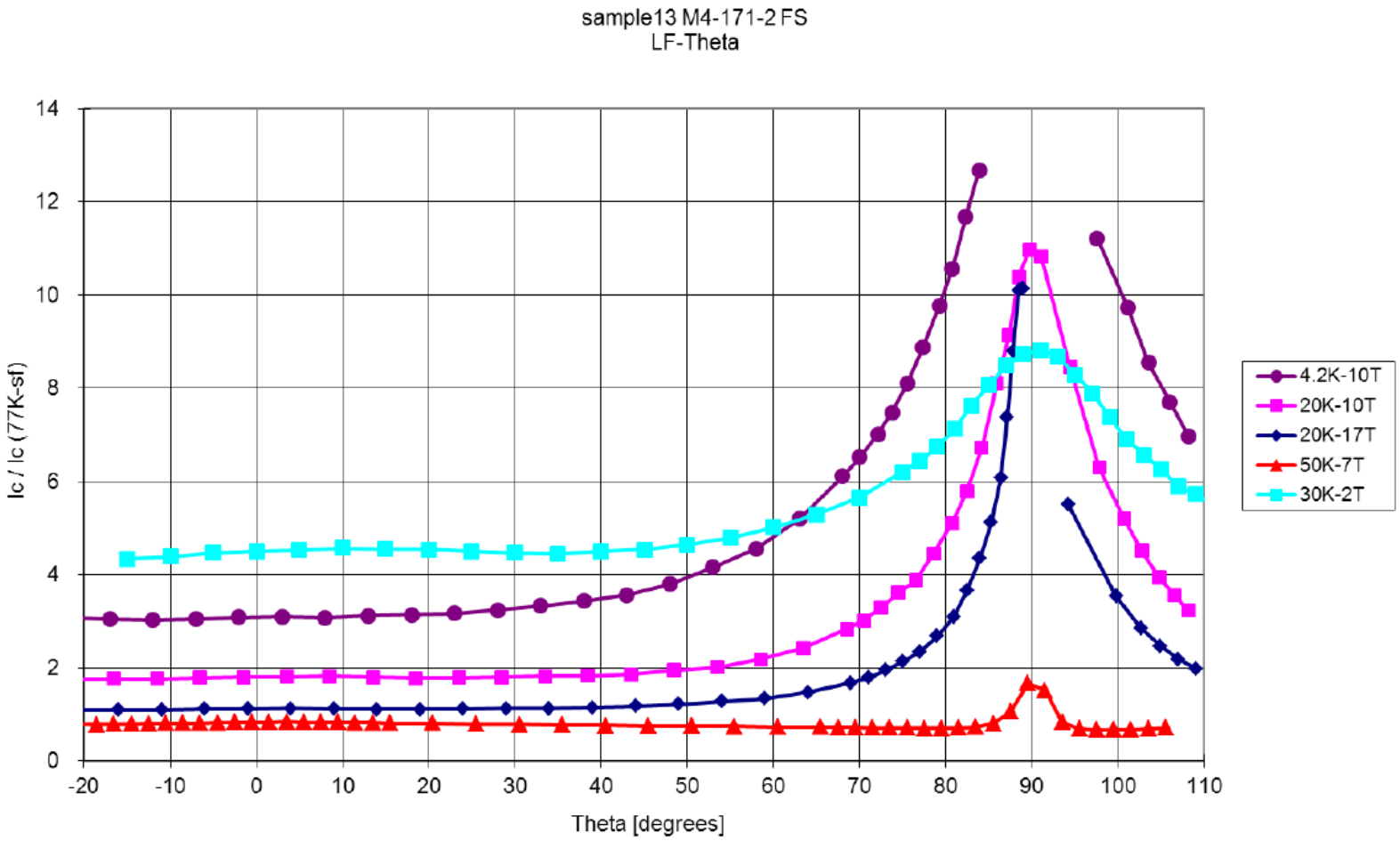


Measurements made at Tohoku University

IcBT typical data



High field IcBT data on 7.5% Zr doped sample

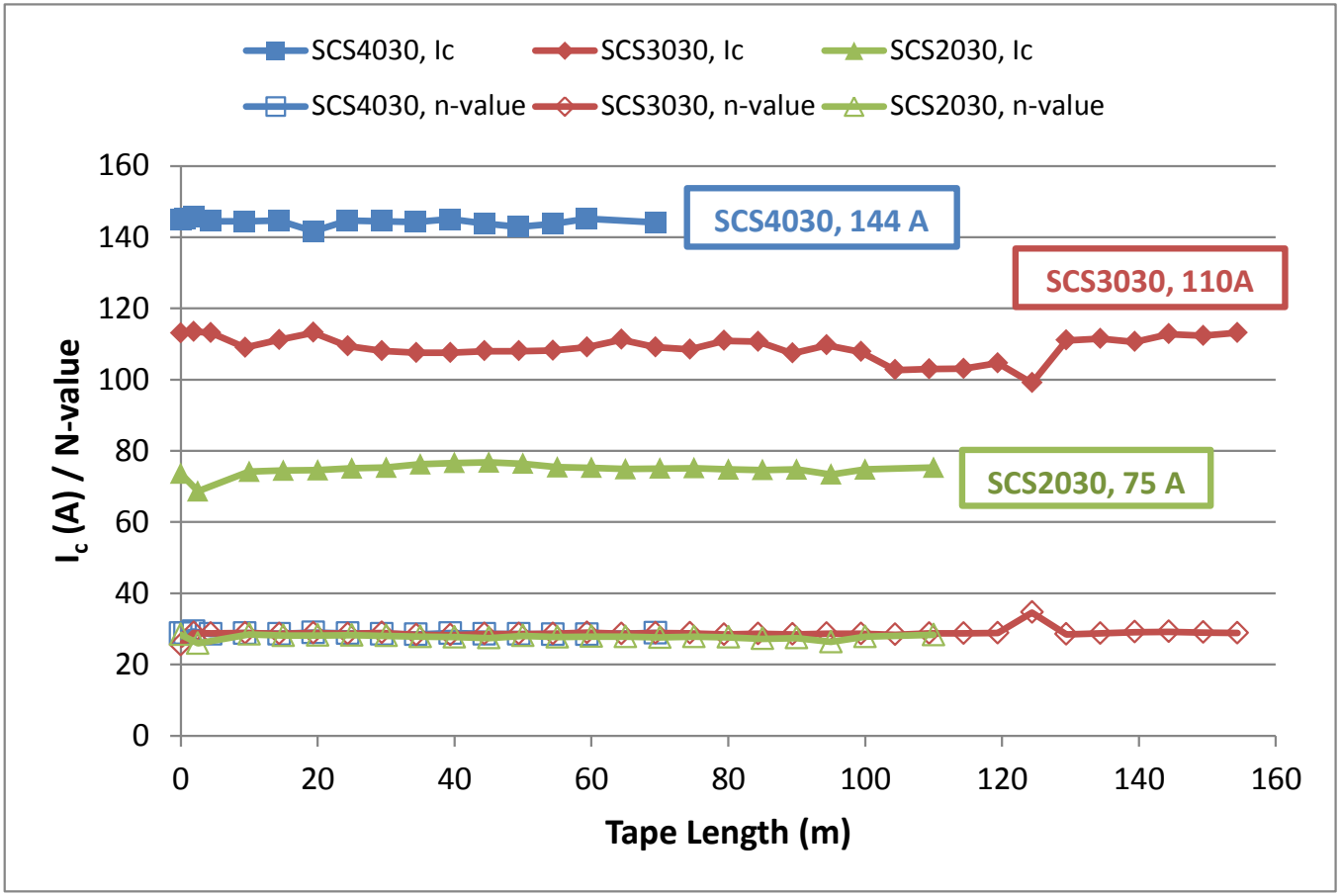


Measured at Tohoku Univ

Comprehensive testing capabilities for mechanical and electromechanical properties

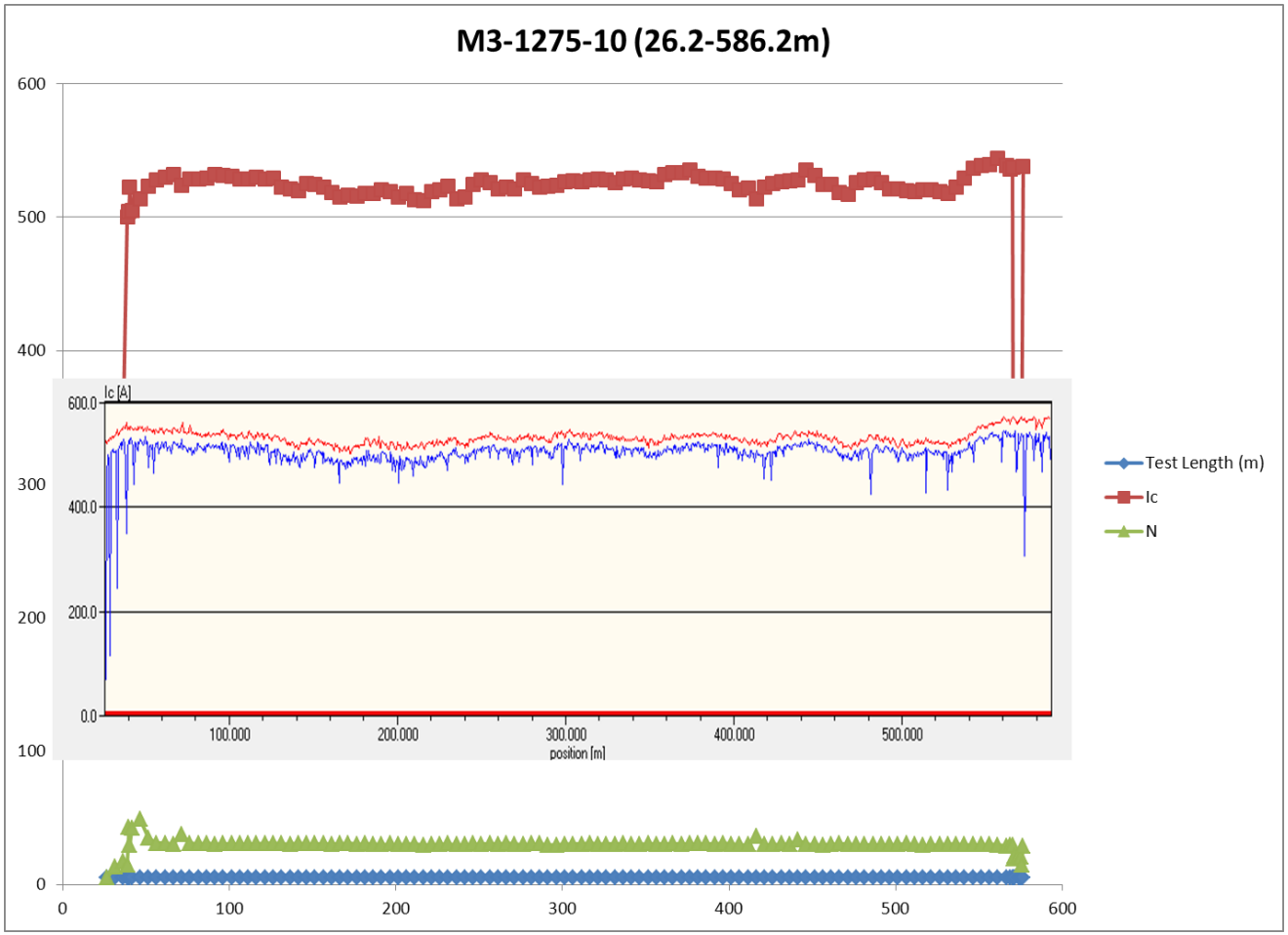
- Axial tensile test at room temperature or at 77K (with I_c)
  - Measurement of elastic modulus and yield stress
  - Determination of critical stress and irreversible stress (strain)
- Measurement of delamination strength – various testing methods
  - Peel test: at room temperature and with varying peeling angle
  - Pin-pull (c-axis tensile) test: at room temperature
  - Anvil (c-axis tensile) test: at room temperature or at 77K (with I_c)
- Transverse (c-axis) compressive test at 77K (with I_c)
  - Measurement of critical compressive stress
- Torsion-tension test at 77K (with I_c)
  - Measurement of critical tensile stress under twist

Development progress of 30µm substrate



- Base performance of 30µm substrates are comparable to 50µm
- Routine production in place

Recently delivered ~500m length w/ Ic >525A on 30 μm substrate

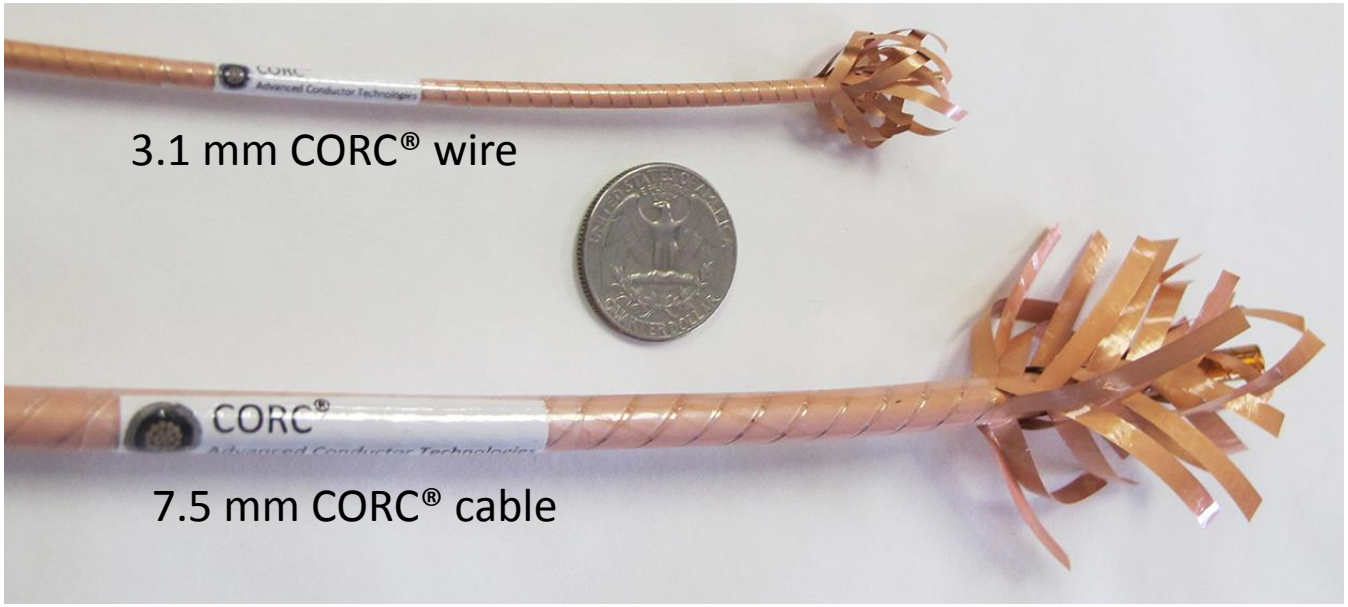


CORC® Cables and Wires

Advanced Conductor Technologies

- Developing high-current CORC® cables and wires
- CORC® performance tailored to each application
- Rotating machines will focus on CORC® wires

Advanced Conductor Technologies LLC
www.advancedconductor.com



CORC® cables

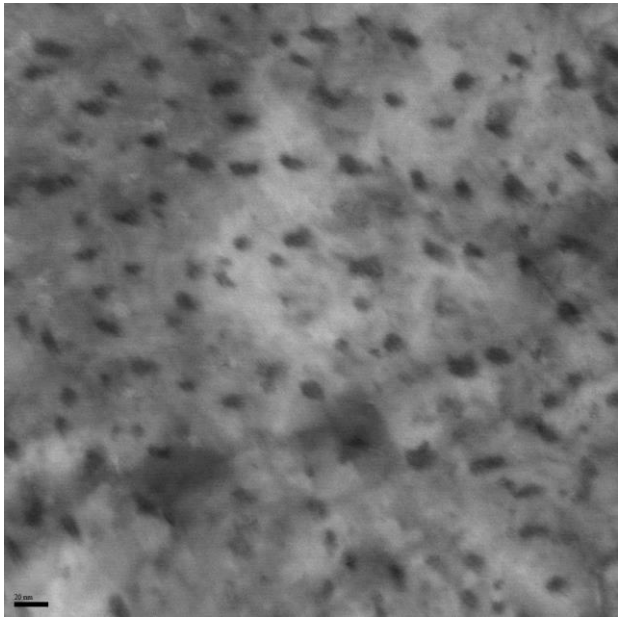
- Cable diameter 5 – 8 mm
- 20 - 30 mm twist pitch
- Wound from 4 mm wide tapes

CORC® wires

- Wire diameter 2.5 – 4.5 mm
- 6 - 10 mm twist pitch
- Wound from 2 mm wide tapes

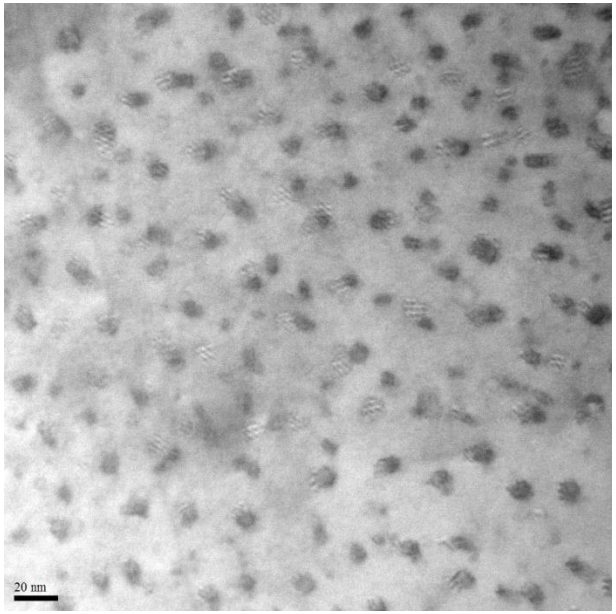
TEM analysis for enhanced Zr doping

Zr = 7.5%



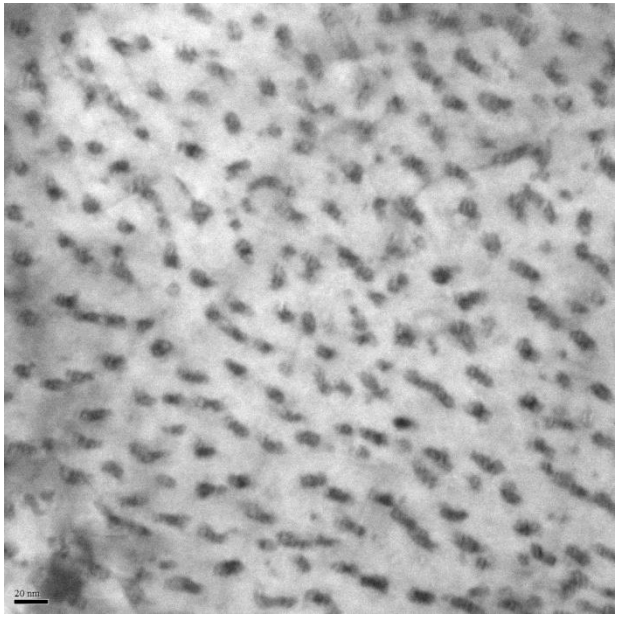
Size : 4.4~6.2nm
Distance : 20.8~26.8nm

Zr = 11.5%



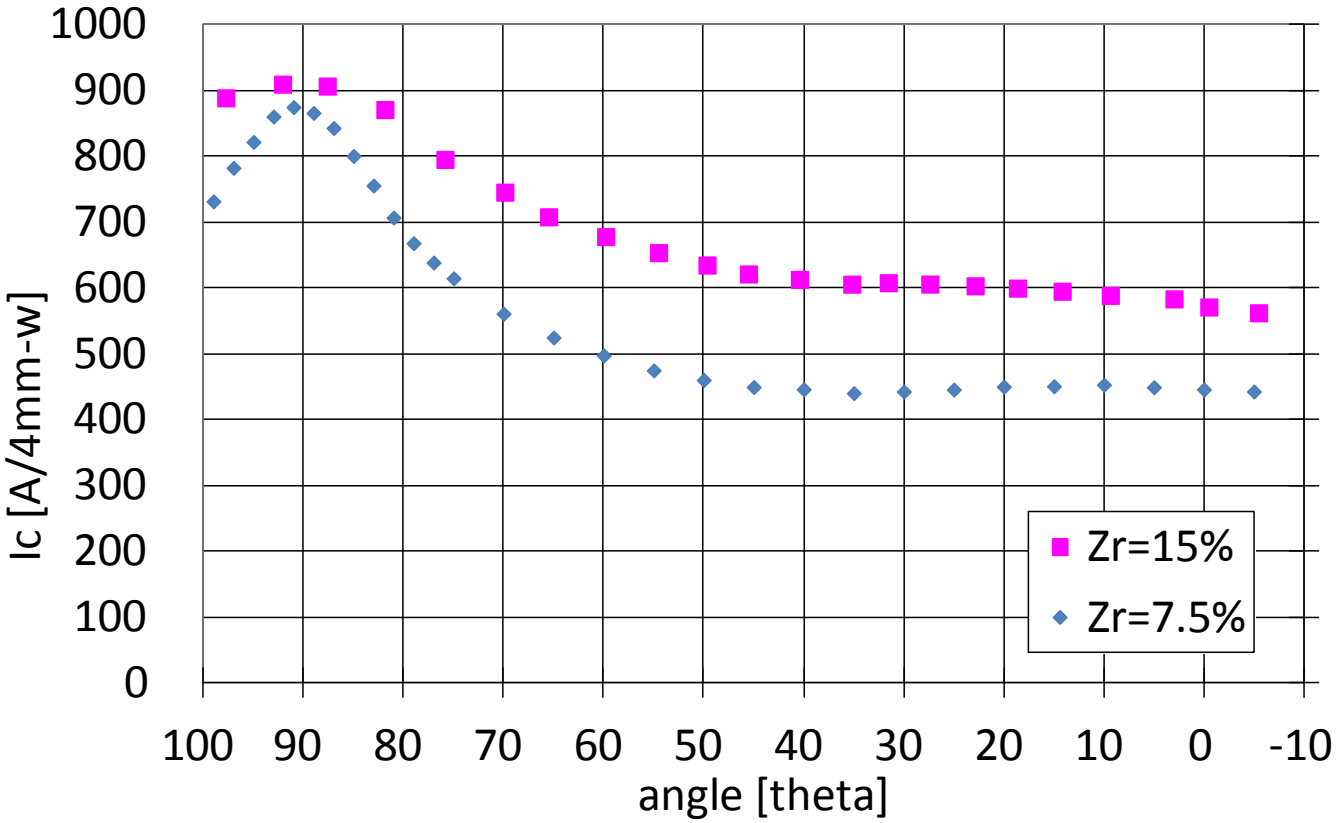
Size : 4.4~5.6nm
Distance : 16~20.7nm

Zr = 15%



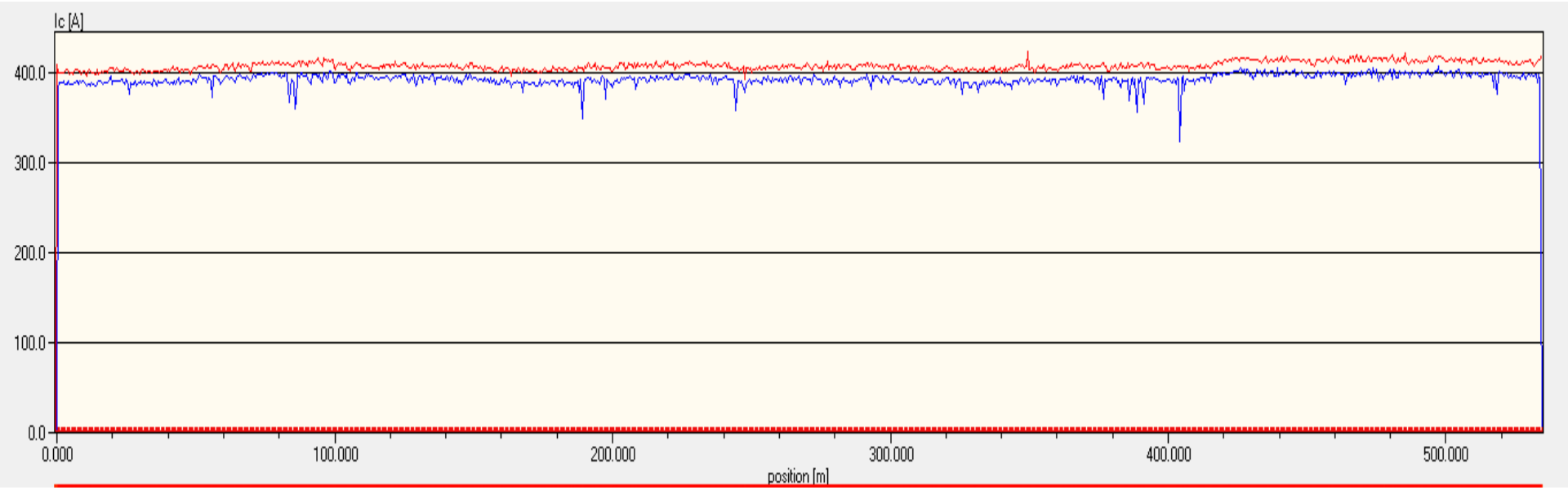
Size : 4.4~5.6nm
Distance : 12.8~18.3nm

In-field performance at 30K/2T



- 15% Zr doping samples show higher I_c performance in mid-field

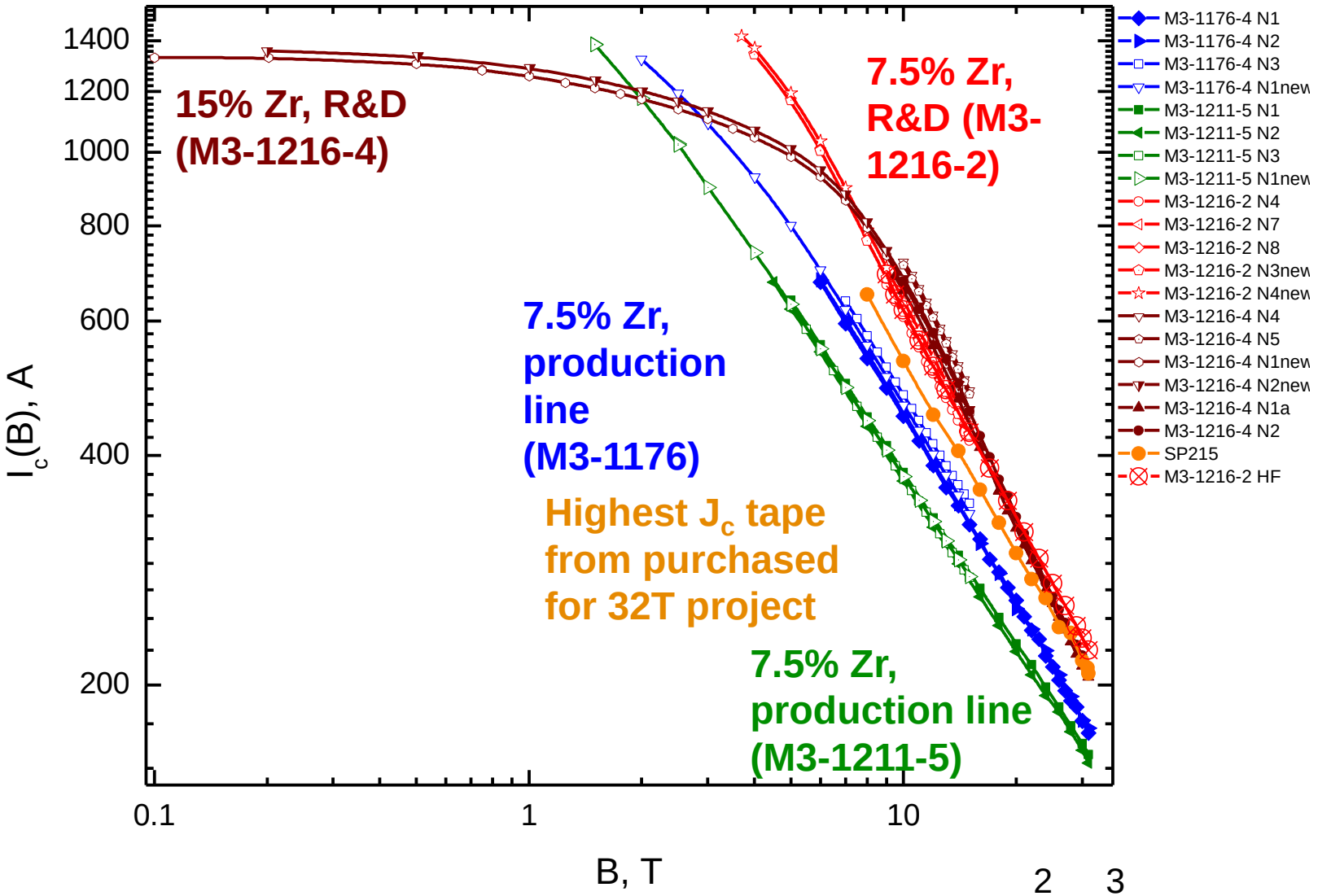
Long tapes with Zr = 15%



- Further work is underway before official release of Zr enhanced wires
  - Repeatability of I_c performance at 20~50K and 2T thru 5T
  - Dispersion of I_c performance
  - Mechanical property

Combination of I_c(B,4K) measured in resistive and superconducting magnets

Below ≈2T 15% Zr tape has lower I_c than 7.5% Zr production line tape



Summary

- Strong focus on processing to improve uniformity, repeatability, piece lengths and yield.
- Maximize current capacity while developing next generation equipment
  - When is the time to pull the trigger?
- Enhance performance parameters for developing operating spaces
  - Thinner substrates
  - Thicker films
  - Optimized pinning
- Continue to improve mechanical properties
  - Delamination mitigation
  - Ic (ε)

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Thank you for your attention

FURUKAWA ELECTRIC GROUP