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Present status of RE-123 superconducting wire development at SSTC

Yutaka Yamada

Shanghai Superconductor Technology Co. Ltd., SSTC
and Shanghai Jiaotong University

Jan. 22, 2019

at KEK, Ibaraki, Japan

2017. April, Joined SSTC in Shanghai

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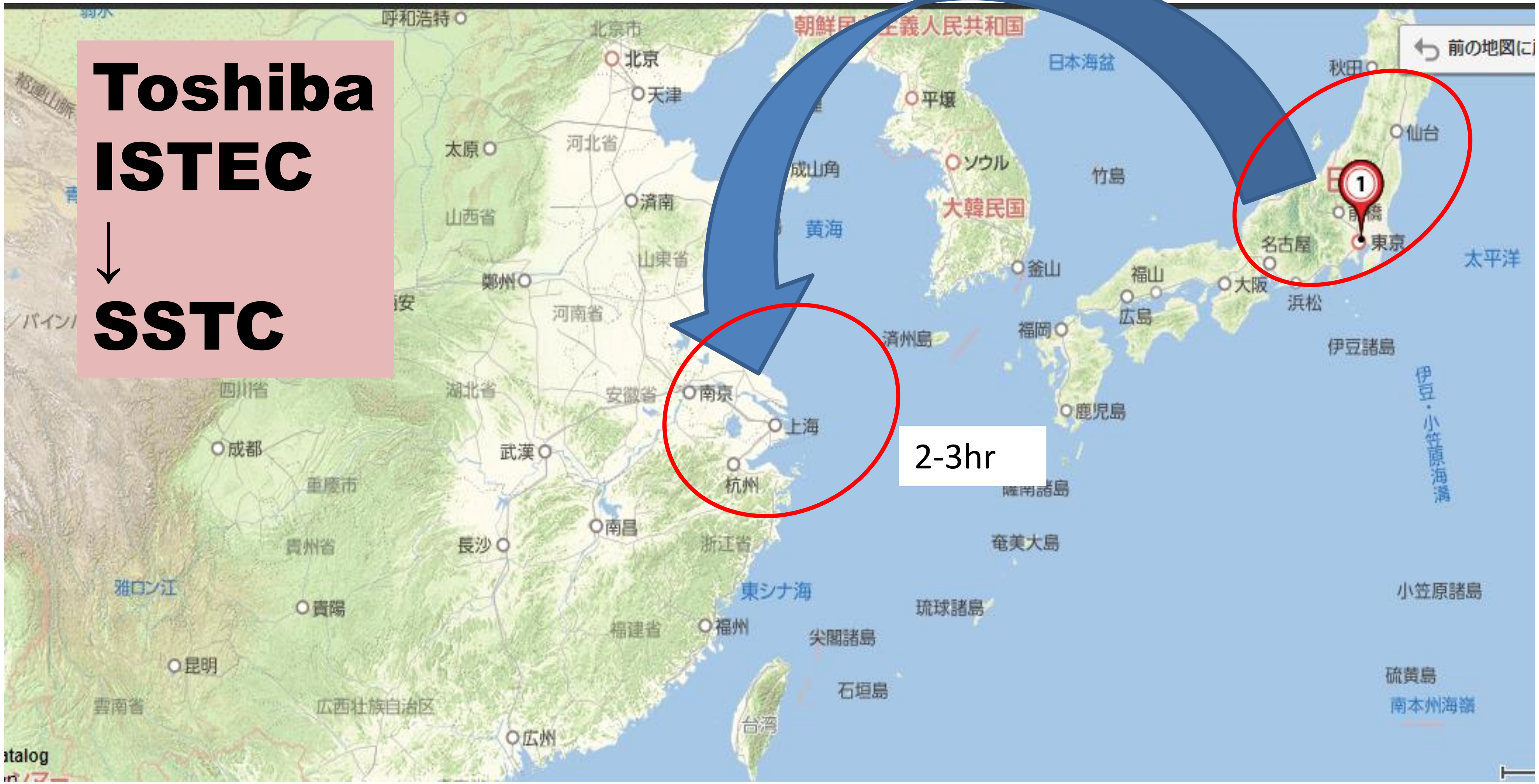

Not far from Japan.

Shanghai HTS International Conference (2018.8.15-17)

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Shanghai HTS Conference, ShHTS, (2018.8.15-17)

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Panel Discussion: The Future of 2G-HTS Wire and Application+ Prospects of China and World

Background: Since R&D achievements in long cc tape fabrication and APC(Artificial Pinning Center), over 10 years have passed. Now it seems for us to need one more influential result to commercialize, to make a large market, and to activate conferences. So now come questions.

Questions

1. At this moment, what do you think is the most important or necessary R&D from your long experience and perspective? And why?

2. Wire side: How much can you reduce the price of CC? How large market do you need?
   (There are many demands for the price reduction in the application industry.)
3. Wire side: Can you cooperate with each other? If so, under what conditions?
   (eg. for a large project, but with a limited time)

2'. Application side: What is the most promising applications?
   And what is the quantity of CC needed?
3'. Application side: How can we get the funds for R&D?
   Only traditional "governmental route" or there is other possibility in your country?

4. What do you expect from China in terms of HTS R&D, application and business?
   To do so, what is required?
   (China has 1.4 billion population, vast land, and the largest electric power consumption.)

Panel Discussion

SSTC tour : Prof. Larbalestier and others discussing with our colleagues

Introduction of SSTC
and
Recent Activity

About Shanghai Superconductor Technology Co., Ltd
上海超导科技股份有限公司(上海超電導(株))

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founded in 2011
Members:70~80
strong collaboration with SJTU (Shanghai Jiaotong Univ.)

Research Institute of Superconductivity (RIS)

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Materials

Professor Yutaka Yamada
- Former Senior Researcher at ISTEC Japan

Dr Yue Zhao
- Shanghai Oriental/P.J. Scholar
- PhD of Demark Tech. U.

Dr Xiaofen Li
- Research Fellow
- PhD of Houston University

Dr Wei Wu
- Research Fellow
- PhD of Qsing Hua U.

Dr Zhiwei Zhang
- Research Fellow
- PhD of Cambridge U.

Applications

Professor Zhijian Jin
- SJTU Smart-grid Center VP
- Ex-employee of CERN

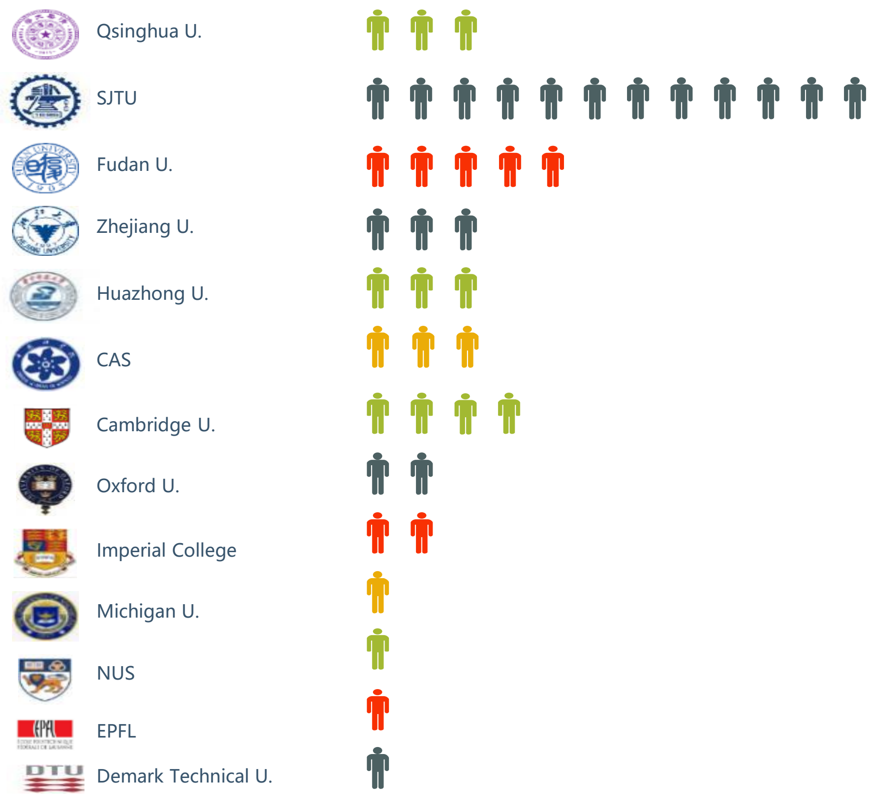
Professor Zhiyong Hong
- Shanghai Oriental/P.J. Scholar
- PhD of Cambridge U.

Dr Zhuyong Li
- Research post-doc
- PhD of Chonnam U.

Dr Linpeng Yao
- Research post-doc
- PhD of SJTU

Dr Zhen Huang
- Associate Research Fellow
- PhD of Cambridge U.

Graduate Profile



- 4 professors，5 post-docs，20+ PhDs
- Most projects involve collaboration between company and university
- 20+ full time technical engineers at SST for the development of research work

Production Line: IBAD+PLD

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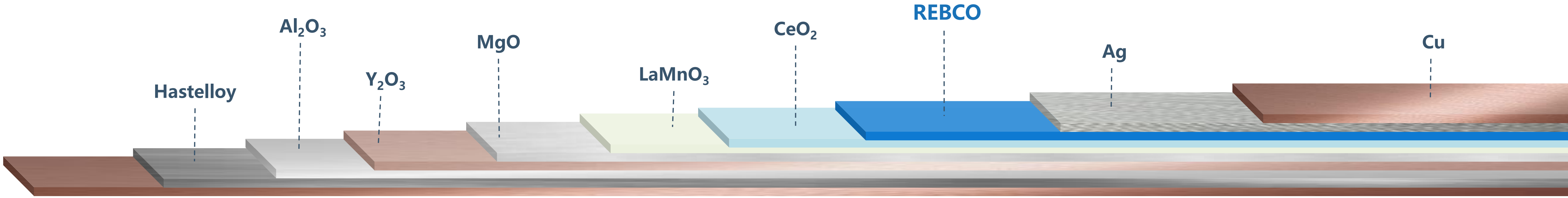
Polishing	R2R RF Magnetron Sputtering	R2R IBAD	R2R HTRF Magnetron Sputtering	R2R PLD	R2R DC Magnetron Sputtering	Slitting Machine	Continuous Electroplating	Continuous Lamination



Independent Design and Manufacturing

- Substantial cost reduction (manufacturing/maintenance/upgrade)
- Improved yield (70%) through beneficial interactions between optimization of production process and equipment upgrades

Product Line and Specifications

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Polishing	R2R RF Magnetron Sputtering	R2R IBAD	R2R HTRF Magnetron Sputtering	R2R PLD	R2R DC Magnetron Sputtering	Slitting Machine	Continuous Electroplating	Continuous Lamination





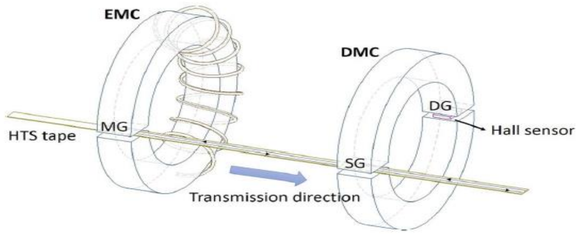



Customizable Parameters	Reference Values	
Substrate Thickness	50 μm	
Width	2-10 mm	
Piece Length	Up to 300 m	
Critical Current	Self-field	Ic (77 K, s.f.): Up to 500 A/cm-w
	In-field	Ic (30 K, 5 T): Up to 550 A/cm-w (B//c)
		Ic (4.2 K, 10 T): Up to 1000 A/cm-w (B//c)
Copper Stabilizer	Surround coating, 5-35 μm per side	
Lamination Material	Copper / Stainless Steel	
Lamination Thickness	50-125 μm per side (25 μm increment)	
Joint Resistance	25 nΩ·cm²	
Allowable Transversal Stress (LN2)	400 MPa / 1.1 GPa	
Others	Tailored to specific requirements	

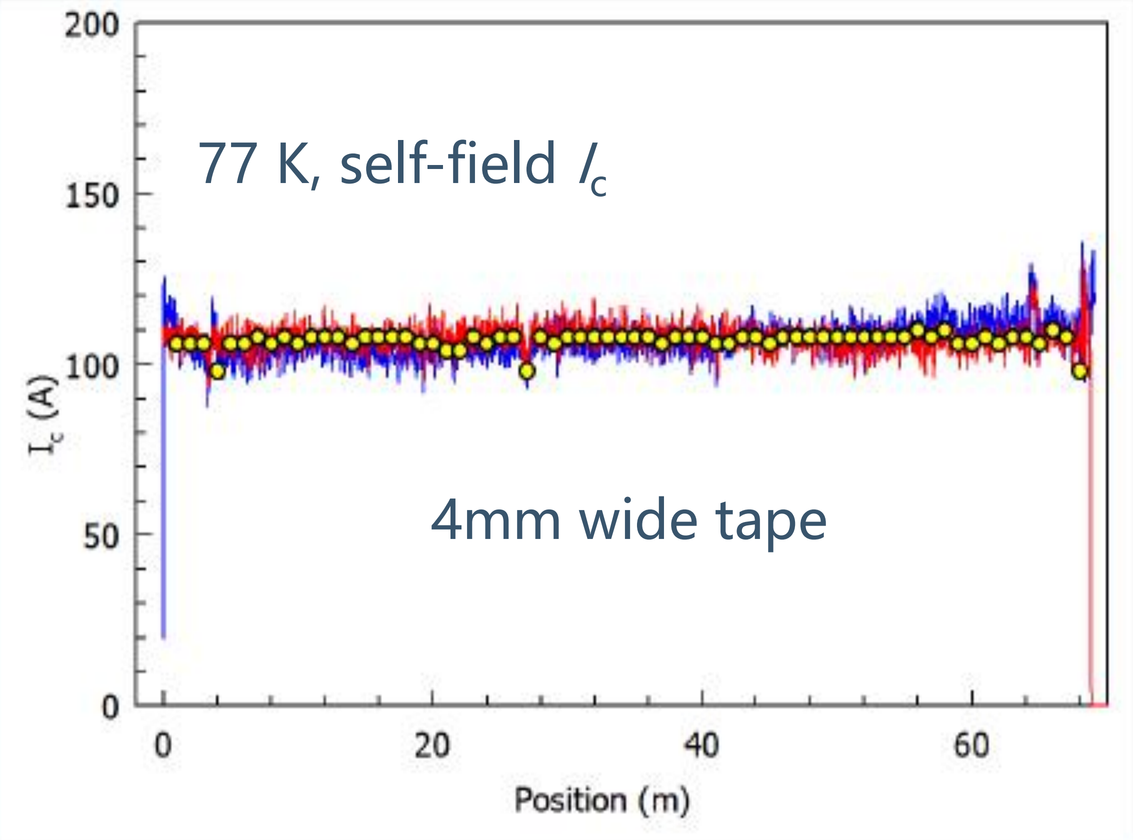
(Updated to Q2, 2018)

(Higher I_c / longer piece length available upon request)

High Speed Ic Measurement by Mcorder



~800A
>150m/hr
Short waiting time
Thick tape acceptable



- Blue and Red lines represent data collected by inductive measurements;
- Yellow dots indicates data collected by transport measurement.

Quality Control (cont.)

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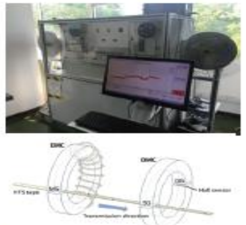
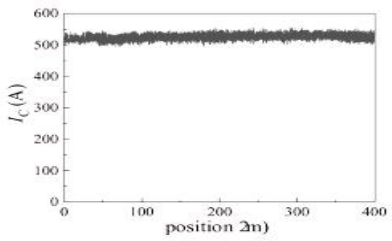
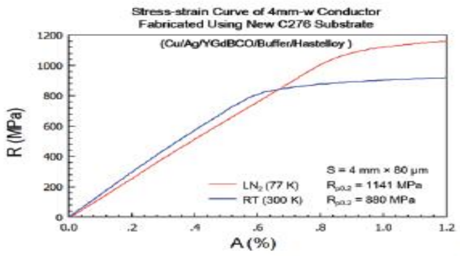
Long Tape Ic Measurement by MCorder
Speed: 200 m/hr, Ic> 500 A/cm-n, Working days: >300/yr



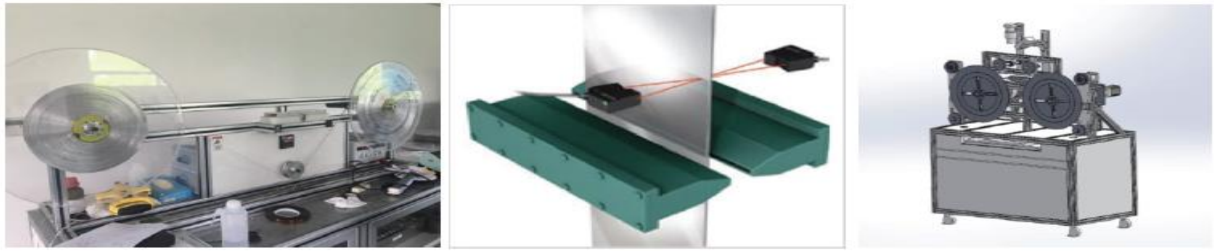


Microstructure Inspection by Metalloscope

Tensile Stress Test
Involved in Internationl Standard Round Robin Test
For Annealed/Cold-rolled Substrate

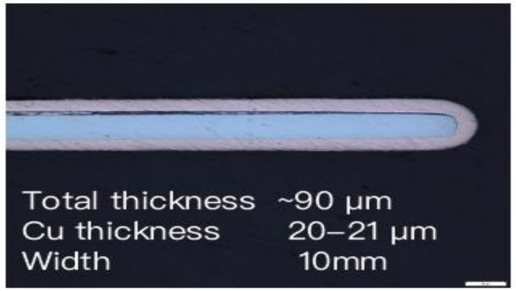


Continuous Optical Measurement
Three-dimensional Measurement by Infrared Beams (Designed by SST)

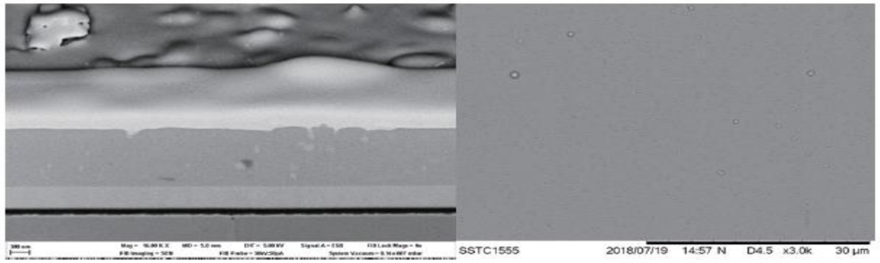


Packaging & Export

Cross-sectional optical microscope image



SEM image of a tape cross-section (left) and surface of HTS layer (right)



- Microstructure
- Superconductivity
- Dimensions
- Electro-mechanical properties

Superconducting Properties

Texture Quality of Buffer Layer

With CeO_2 structure

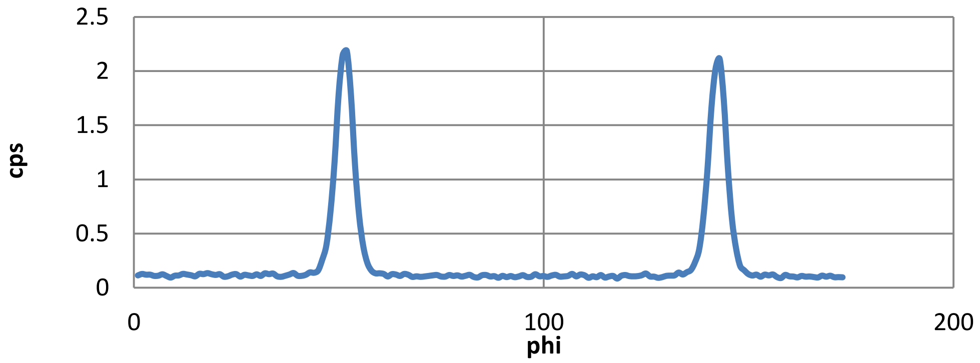
$CeO_2/LMO/MgO/Y_2O_3/Al_2O_3/C276$

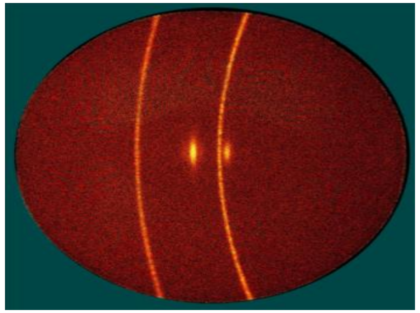
Lot. No.	In-plane texture(°)	out-of-plane texture(°)
1	**2.4**	**1.7**
2	**2.4**	**1.8**
3	**2.4**	**1.7**
4	**2.5**	**1.7**
5	**3.0**	**2.0**
6	**2.9**	**1.8**
7	**2.8**	**1.7**
8	**3.8**	**2.1**
9	**2.8**	**1.8**
10	**2.6**	**1.7**
11	**2.6**	**1.7**
12	**2.9**	**1.9**

Without CeO_2 structure

$LMO/Epi\text{-}MgO/IBAD\text{-}MgO/Y_2O_3/Al_2O_3/C276$

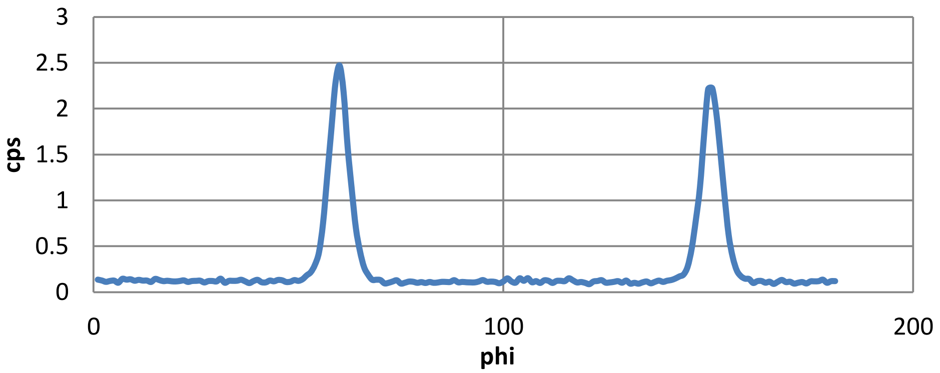
5.1°

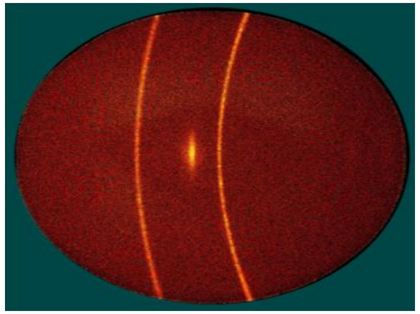




$LMO/IBAD\text{-}MgO/Y_2O_3/Al_2O_3/C276$

5.6°





Long Tape Production: Continuous effort to improve I_c and homogeneity

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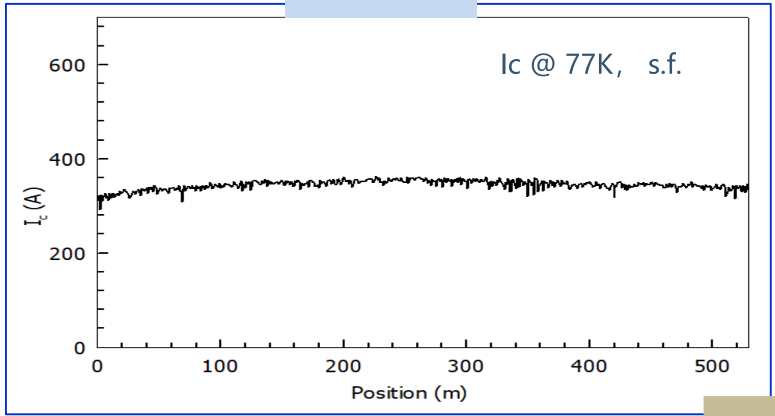
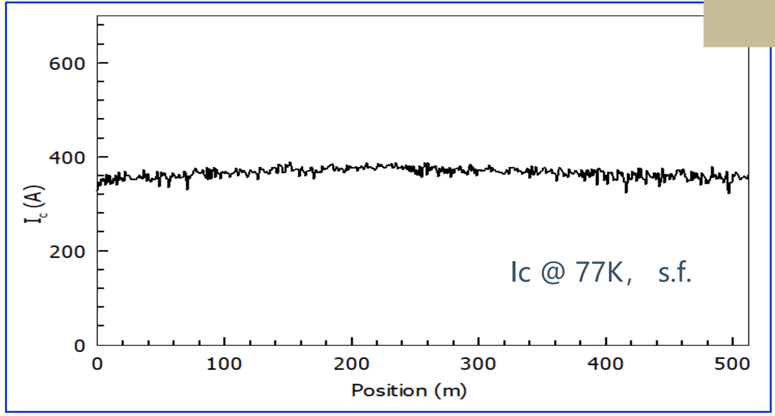
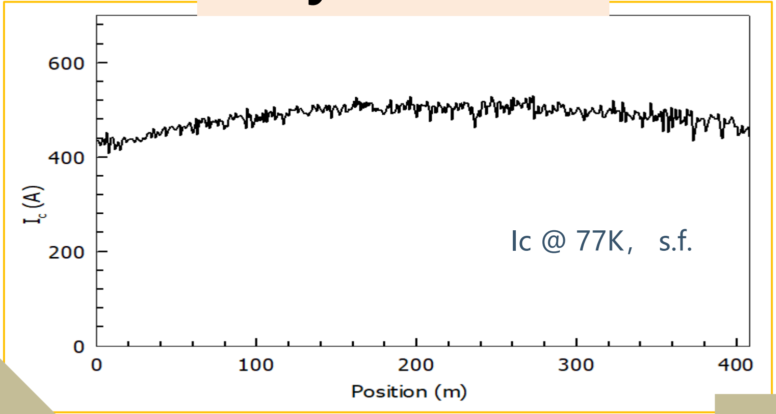
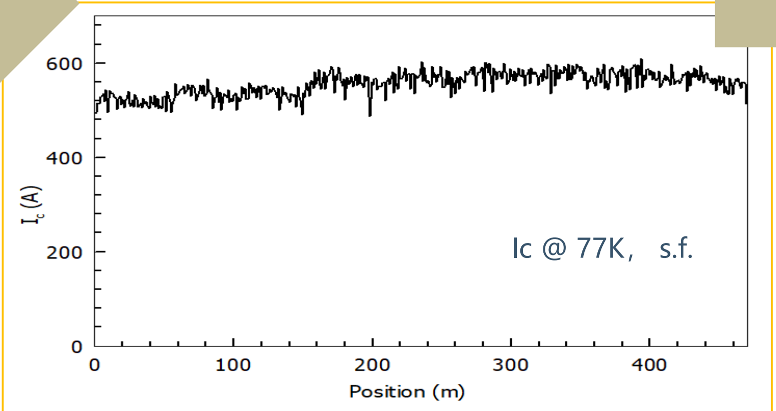
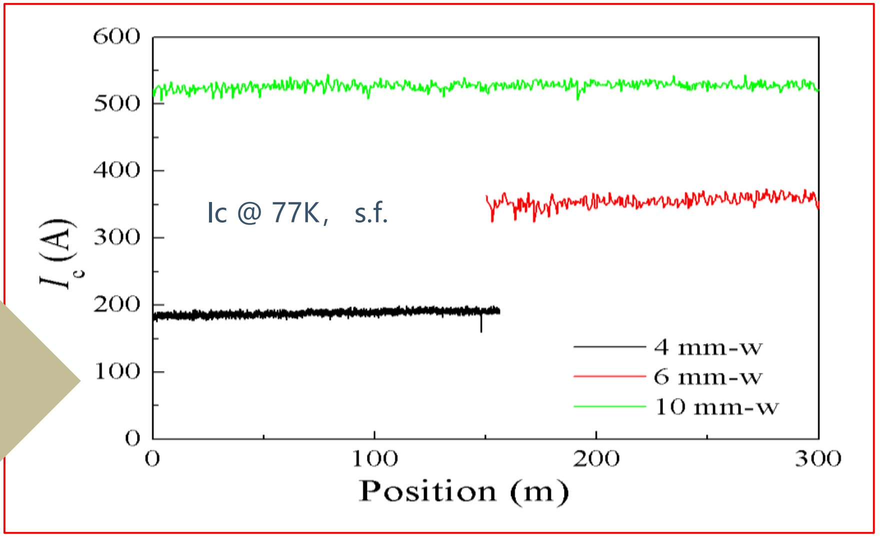
2017 → **early, mid 2018** → **-2019 Now**











10mm wide tape
cut into 4, 6mm in width
=only a small Ic reduction

- **YGd→Gd, Eu**
- **Hastelloy**
- **Buffer**

- **Heating**
- **Monitoring**
- **,,,,**

- **Improving the process and materials**
- Stable long tape production of 300-500 m piece length

High Field Low Temperature Performance (KEK)

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2017 Data

Critical Current Measurement of Commercial REBCO Conductors at 4.2K

K. Tsuchiya @ High Energy Accelerator Research Organization (KEK Japan)

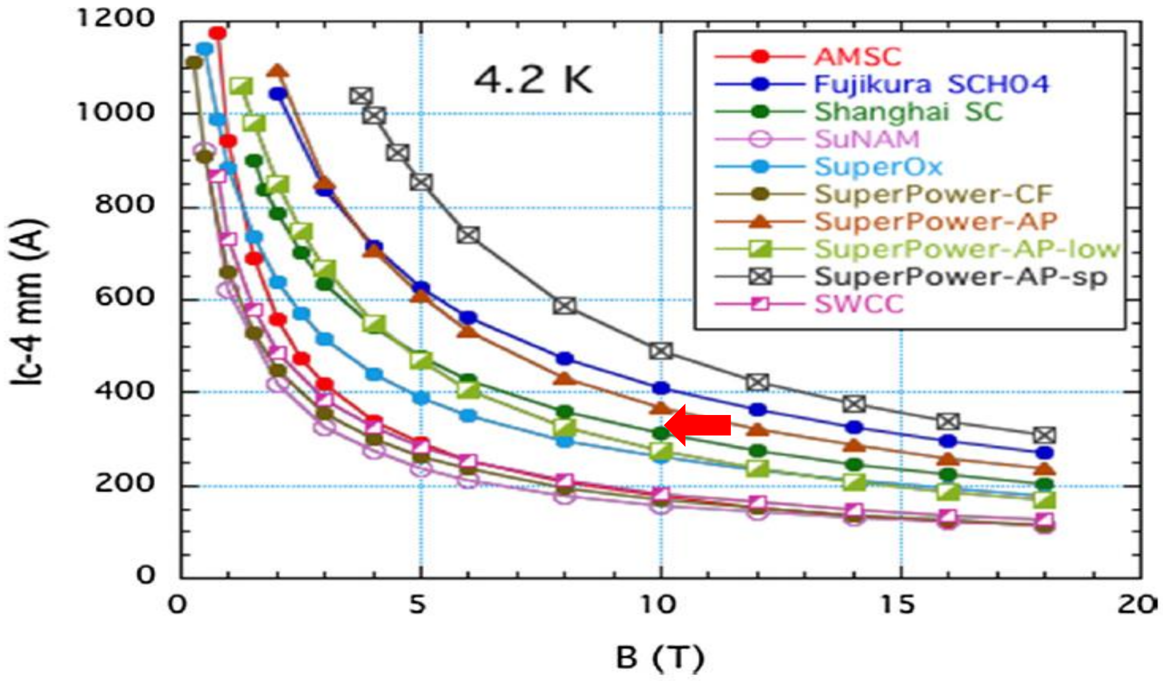

Fig. 5. Transport I_c for 4-mm-wide conductors versus B for commercial conductors in perpendicular fields at 4.2 K. The estimated errors of the I_c values are less than 2–3%.

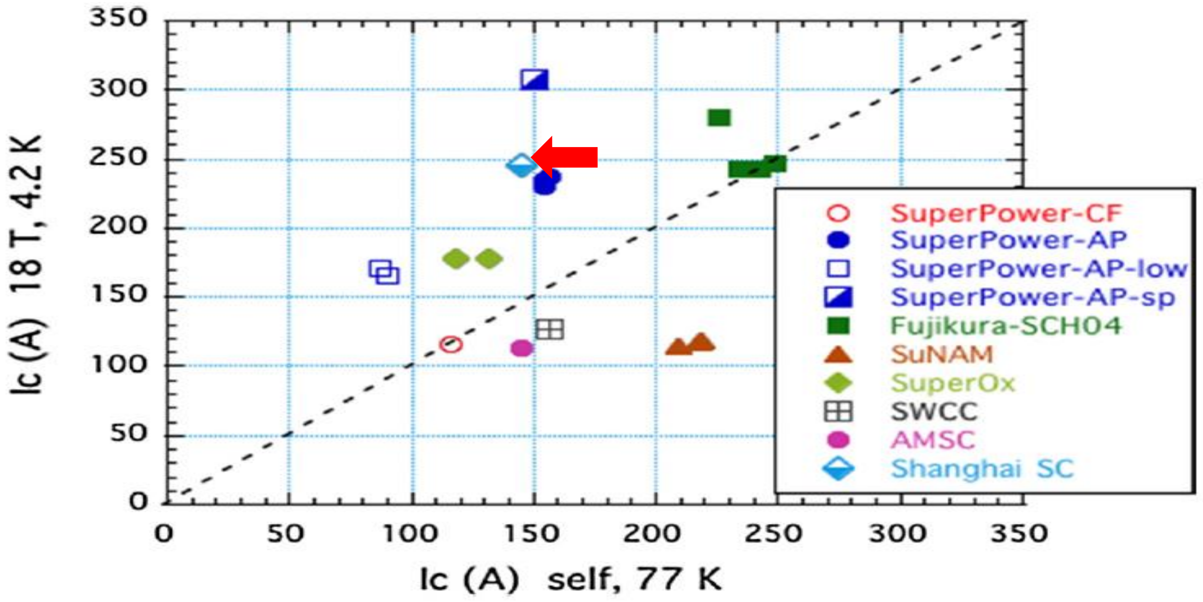

Fig. 6. I_c values of the REBCO conductors measured at 4.2 K and 18 T versus I_c of the same conductor measured at 77 K and under the self-field condition.

Tsuchiya K et al. Critical current measurement of commercial REBCO conductors at 4.2K, Cryogenics 85 (2017) 1-7 May 2017

High Field Low Temperature Performance (KEK)

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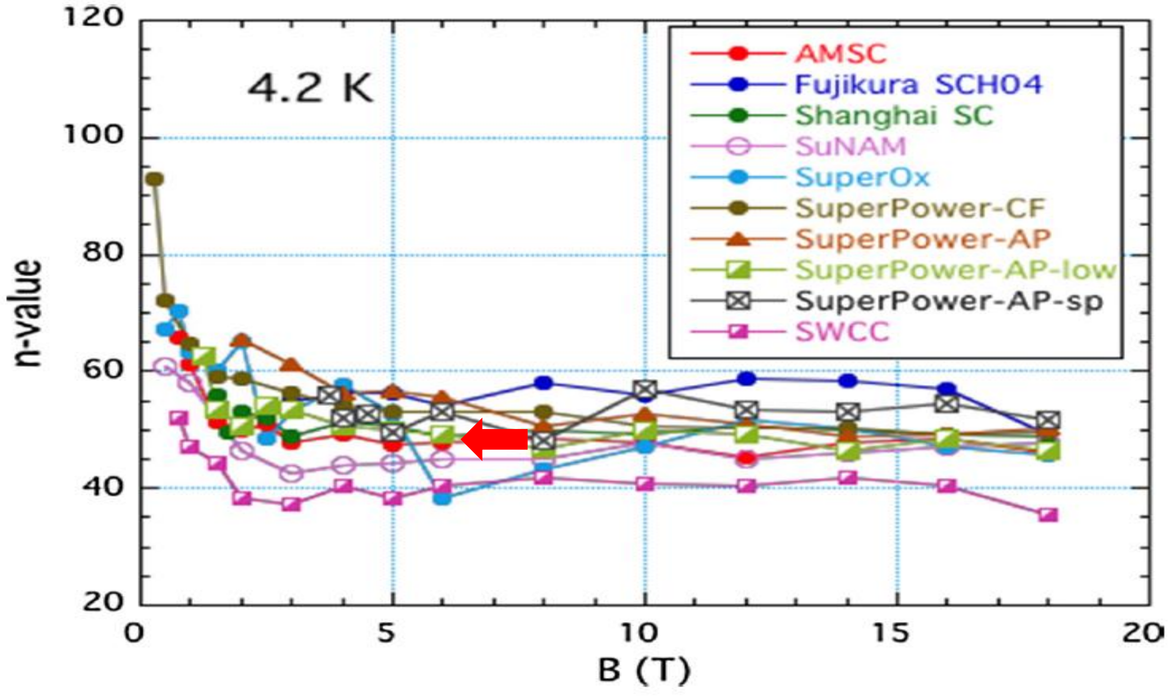

Fig. 7. n-Value versus *B* for commercial conductors in perpendicular fields at 4.2 K.

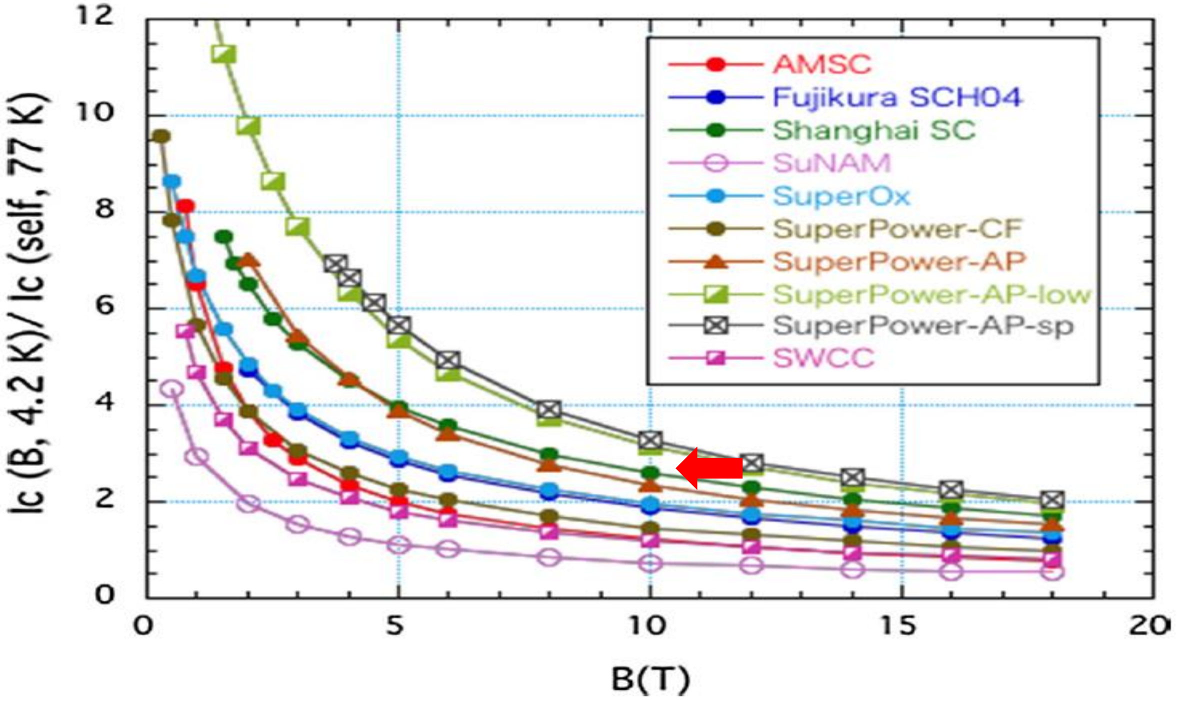

Fig. 8. *B* dependence of lift factor, I_c (*B*, 4.2 K)/I_c (self, 77 K), for various commercial REBCO conductors.

Tsuchiya K et al. Critical current measurement of commercial REBCO conductors at 4.2K, Cryogenics 85 (2017) 1-7 May 2017

High Field Low Temperature Performance (NHML)

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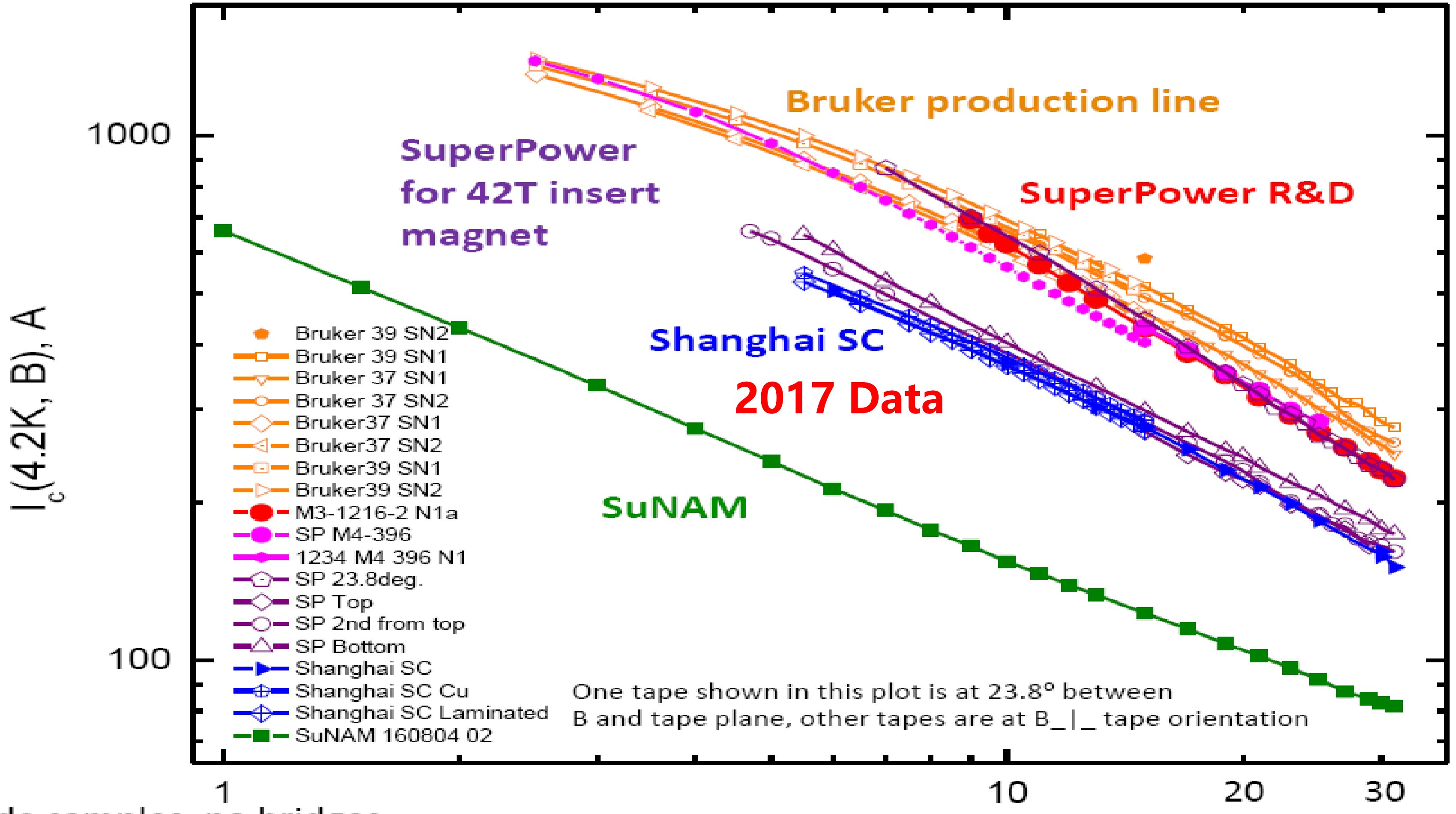
Comparison transport I_c(4.2K, B) for ReBCO tapes from different manufacturers
Bruker production line tapes show higher I_c(4K,B) then SuperPower R&D tapes
Shanghai SC tapes show I_c (4K,B) comparable to SP tapes used for 42T insert



~4mm wide samples, no bridges

High field data from magnet time Jan. 18-20, 2017

I_c improvement at lower temp. at high-field

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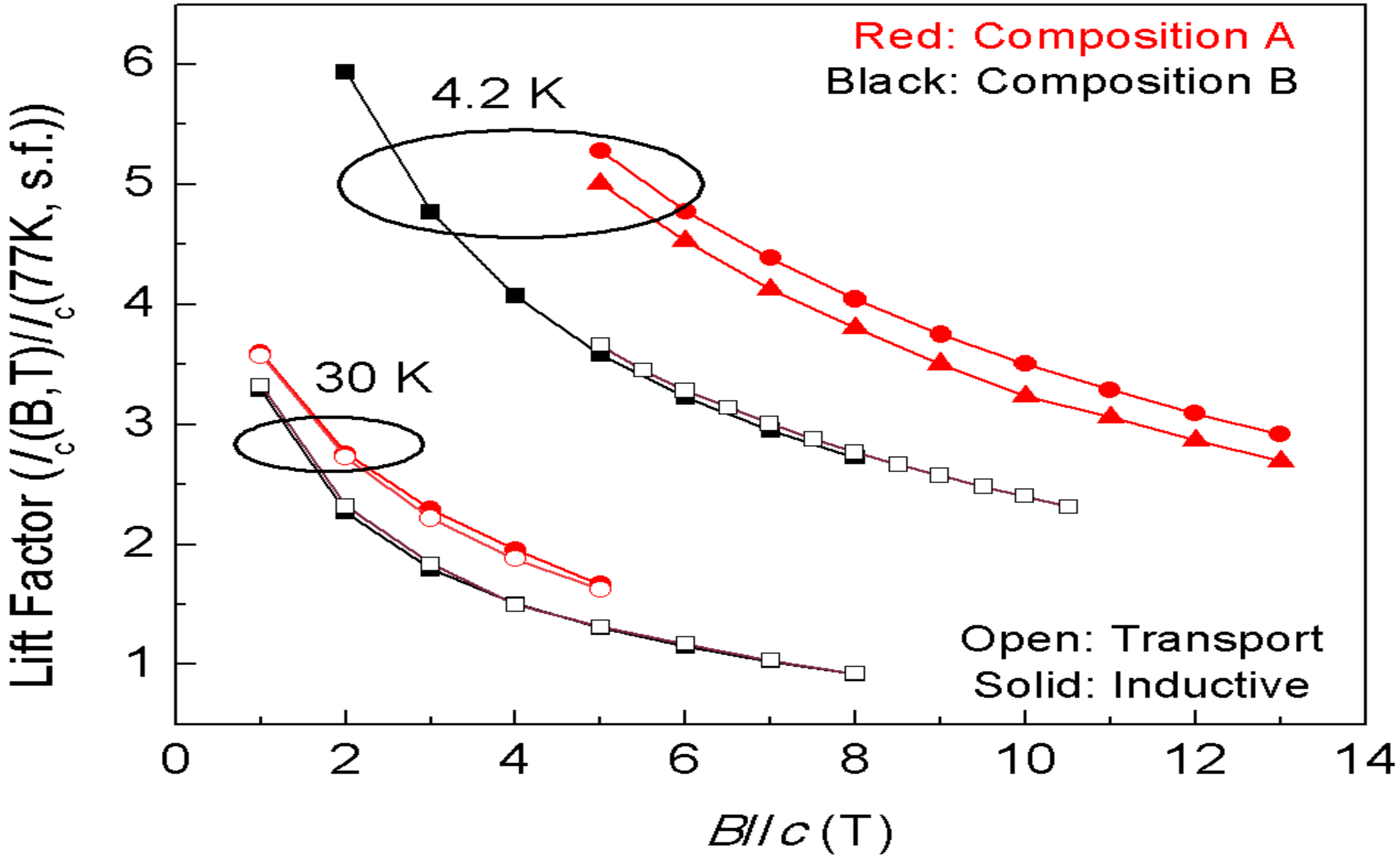
Low-temperature, in-field I_c determined by lift factor

Lift Factor= $I_c(T, B)/I_c(77K, s.f.)$



L.F. measured by Transport method values are consistent with those calculated by magnetization method（Bean model）

Transport Ic were measured by RRI,KEK and NHMFL

Enhancement of low temperature & in-field I_c

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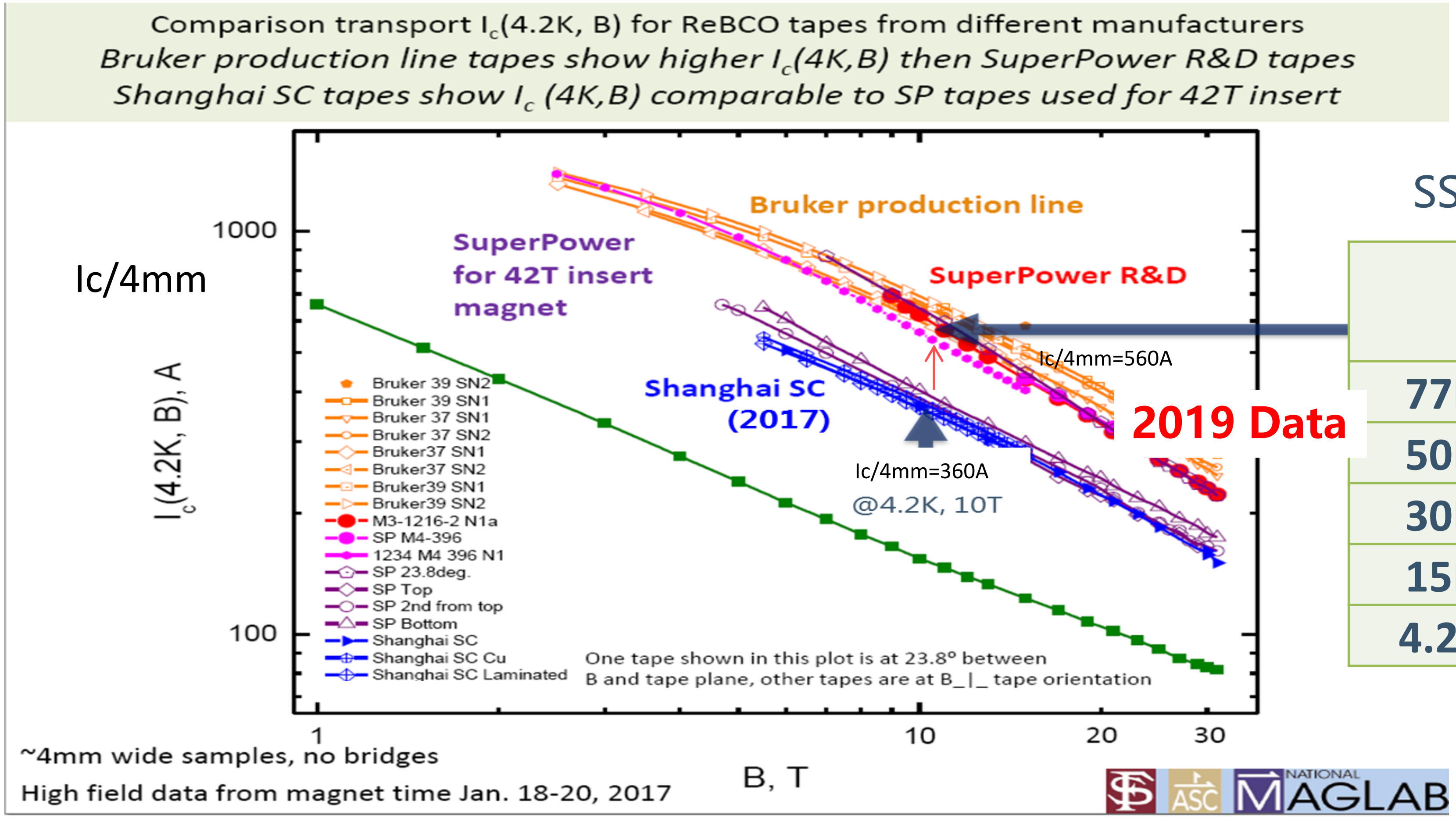


SST R&D / Production (late 2018)

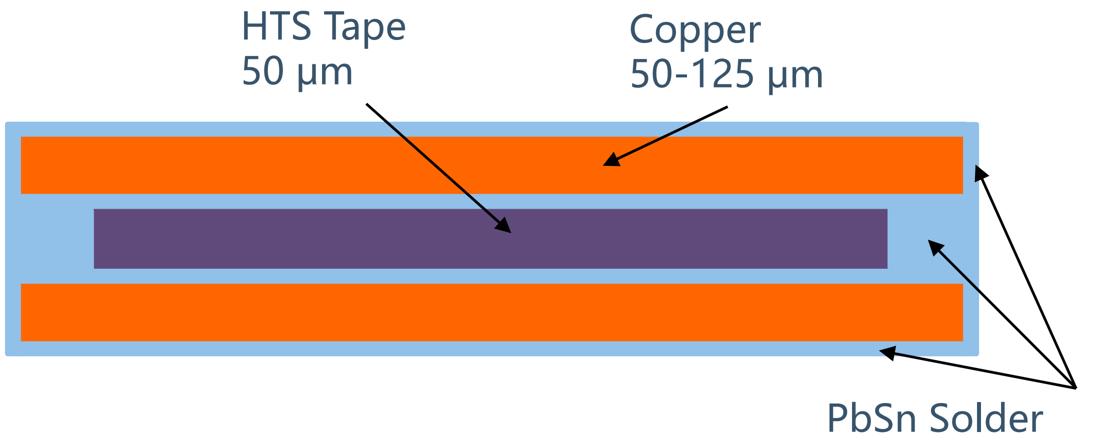
	0T	5T	10T	13T
77K	160 A			
50K	530 A			
30K	-	290A	170 A	122 A
15K	-	540A	340 A	260 A
4.2K	-	-	**560 A**	470 A

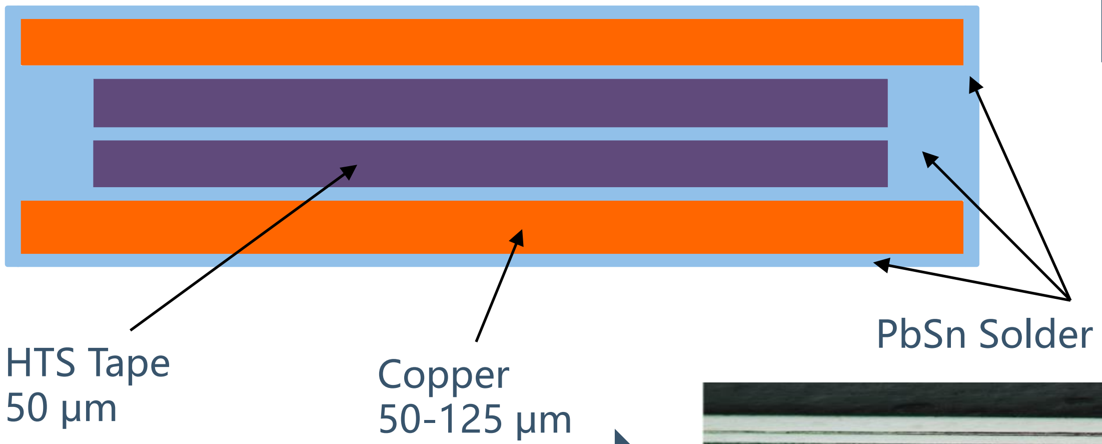
(A/4mm-w, B//c)

The R&D is done in our production line, which is easily transferred to the products.

Lamination Technique

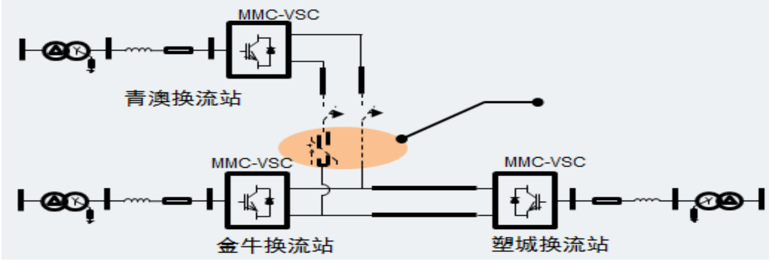
- Improving Stability of Electro-Mechanical Properties

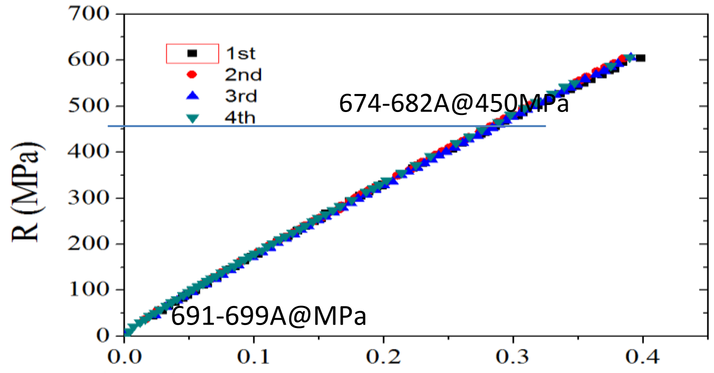




Double-insert Tapes

China Southern Power Grid
160 kV / 2 kA SFCL
Budget: ~50 million CNY for 4 years

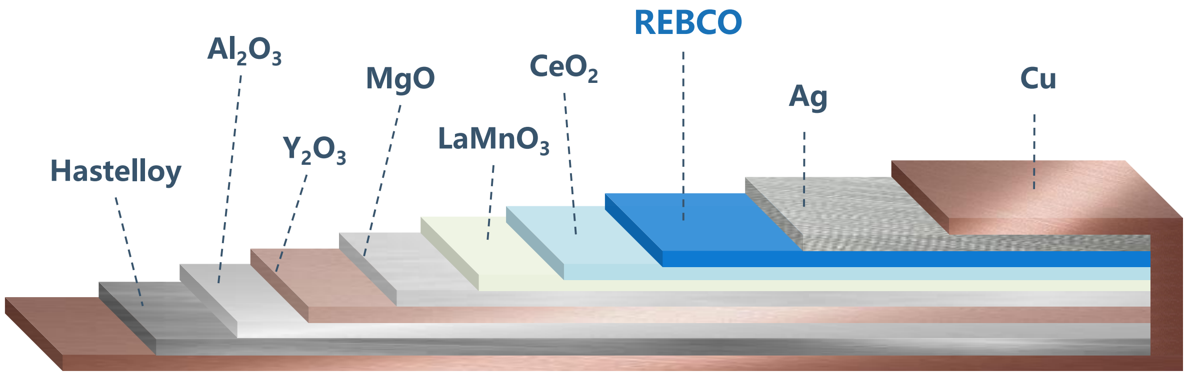


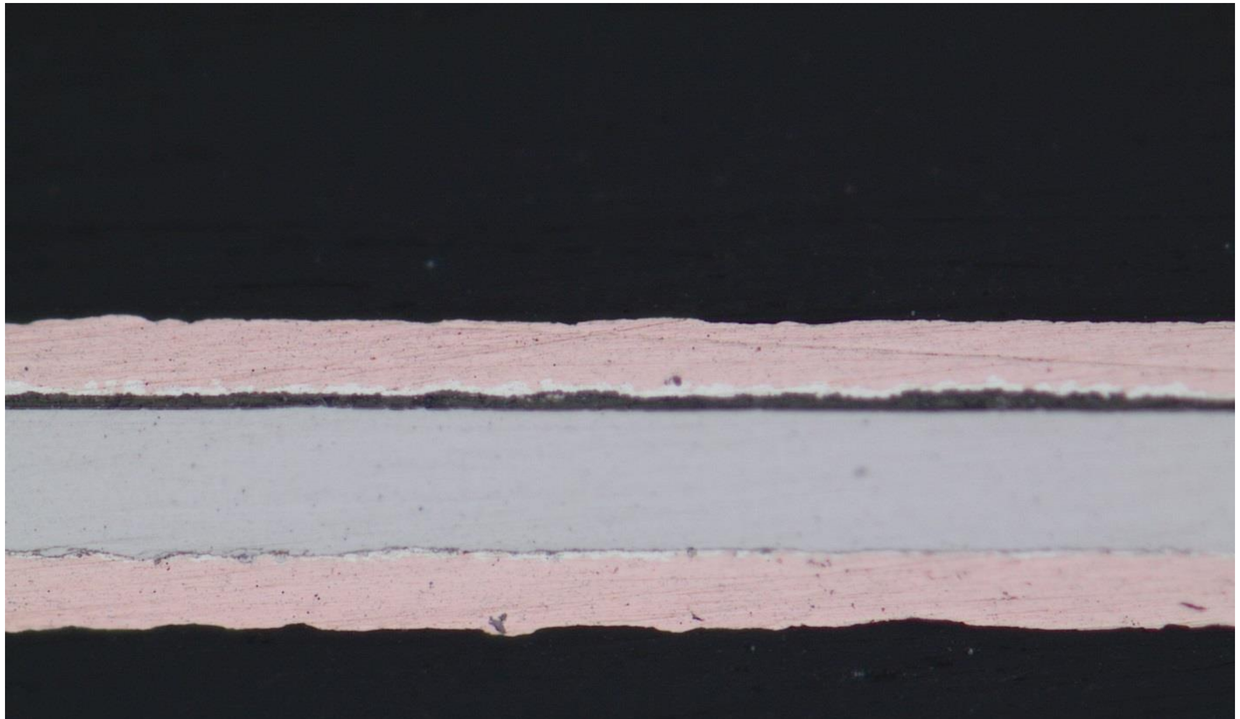


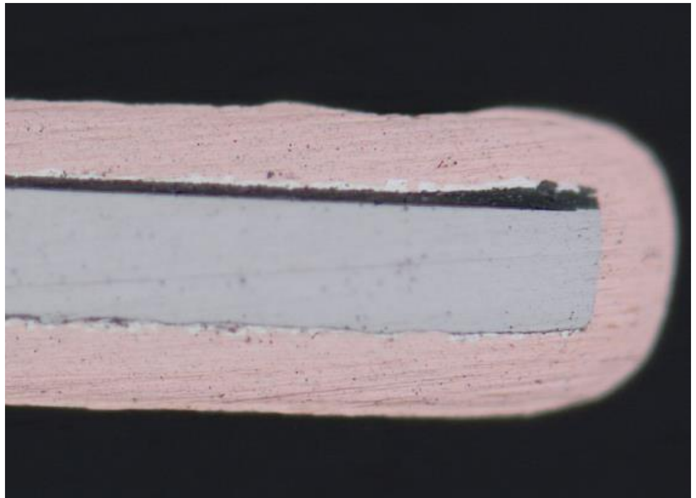
检测数值：

测试样品号	77K，0MPa Ic	77k，拉伸至 450MPa Strain	77K，拉伸至 450MPa Ic at 450MPa
1	691A	2854×10^{-6}	674A
2	699A	2826×10^{-6}	682A

30μm thick Hastelloy for High J_e Conductor







I_c=170A/4mm@77K, 0T

Cu15μm each side
Je=671A/mm2 at 77K, 0T
Cu5μm each side
J_e=988A/mm^2 at 77K, 0T

Ag 1μm each
SC 2μm
Others ~0.3μm

assumed ~560A/4mm@4K, 10T

CC for Applications begin to be broadly used in China

Summary

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✓ 2G HTS wires at SST:

- 77K, s.f. I_c (100-200 A/4mm-w) and 4.2K, 10T I_c (>400 A/4mm-w)
- 30μm Hastelloy high Je tape
- Advanced lamination and jointing processes
- Strong R&D cooperation with the university

✓Outlooks:

- Higher Performance & Lower Price
- Stable supply
- High in-field I_c , High J_e, composite conductors, advanced jointing techniques

Production Capability

2018 S1	2019
1 PLDs 15km/month 70% yield	3 PLDs or more >50 km/month 80% yield
>120 km/year	>500 km/year

END