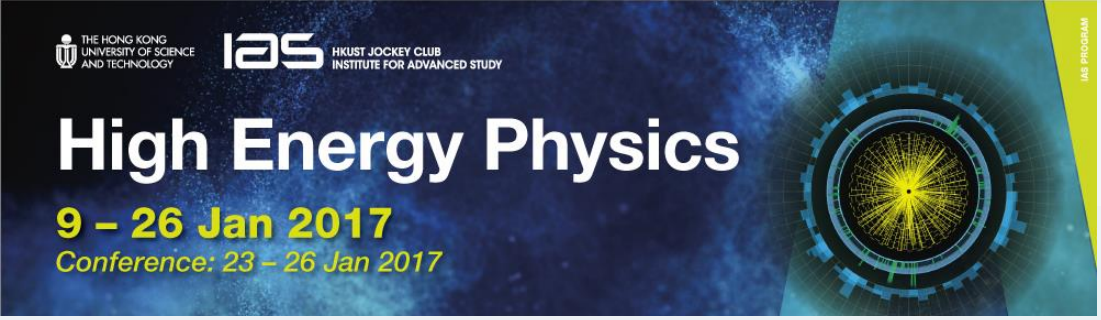

上海超导
Shanghai Superconductor

上海交通大學
SHANGHAI JIAO TONG UNIVERSITY

Progress in R&D for 2G HTS wires in Shanghai Superconductor

Yue Zhao[a,b], Linfei Liu[b] , Xiang Wu[a,b], Jiamin Zhu[a], Wei Wu[a,b], Zhiwei Zhang[a,b], Zhuyong Li[b], Zhen Huang[b], Zhiyong Hong[a,b], and Yijie Li[a,b]

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b, Shanghai Jiao Tong University, 200240 Shanghai, People's Republic of China

2017-01-19

Outline

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Shanghai Superconductor

- Introduction of Shanghai Superconductor
- Production Line
- R&D of HTS wires
- Summary

INTRODUCTION

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Shanghai Superconductor

Corporate Introduction

- Strategic High-tech Enterprise Established in 2011
- Started with R&D of 2G High Temperature Superconductors

Milestones

2007
Developed strategic blueprint for the commercialization of 2G HTS

2011
Shanghai Superconductor Technology Co., Ltd. established

Sep 2013
Successfully Fabricated the first 1000-metre 2G HTS wire in China

2010
Successfully fabricated the first 100-metre 2G HTS wire (193 A) in China

Jun 2013
Realized autonomous manufacturing of the entire production line of 2G HTS

Mar 2015
New headquarter at Zhangjiang Hi-tech Park put into service

INTRODUCTION

上海超导
Shanghai Superconductor

Research Centre & Facilities

Research Institute of Superconductivity @ Shanghai Jiaotong University

- An institute with independent personnel authority, financial authority and PhD enrollment quota
- Brought together a group of top-tier researchers from home and abroad
- Continuous R&D to guarantee the most advanced technologies and process world-wide for 2G HTS wire production

INTRODUCTION

上海超导
Shanghai Superconductor

Our People

- Over 30 Employees
- 40% with Master Degree or Above
- Graduate Profiles

University of Cambridge
University of Oxford
Imperial College London
Swiss Federal Institute of Technology
Technical University of Denmark
University of Michigan
Nanyang Technological University
Chinese Academy of Sciences
Tsinghua University
Shanghai Jiao Tong University
Fudan University
Zhejiang University

Key Scientists & Researchers

Prof. Yijie Li
Distinguished Professor
Chief Scientist

Prof. Zhijian Jin
IEEE Member
Ex-employee of CERN

Dr. Linpeng Yao
Research Fellow

Dr. Yue Zhao
Research Fellow

Dr. Wei Wu
Research Fellow

Dr. Zhiyong Hong
Associated Professor
Executive Director

Dr. Zhiwei Zhang
Research Fellow

Dr. Xiang Wu
Research Fellow

Dr. Wei Wu
Research Fellow

Dr. Guangyu Jiang
Research Fellow

Production Line

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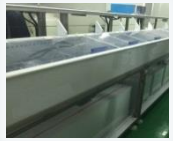
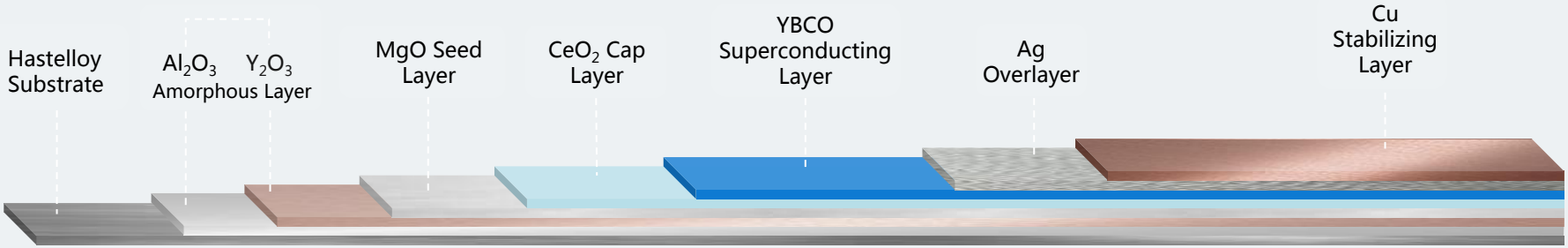
Shanghai Superconductor

Polishing	RF Sputtering Deposition	Ion Beam Assisted Deposition	High Temperature RF-Sputtering Deposition	Pulsed Laser Deposition	DC Sputtering Deposition	Slitting	Electroplating	Lamination
								



- From fabrication of sputtering targets to repair and maintenance
- The first 2G HTS wires production line in China
- Capable of mass-producing high quality 2G HTS wires

Simulation for equipment design

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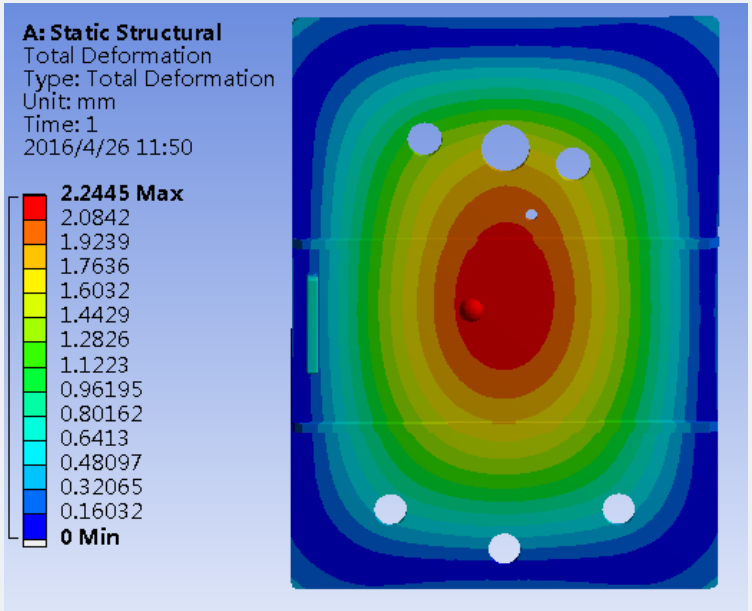
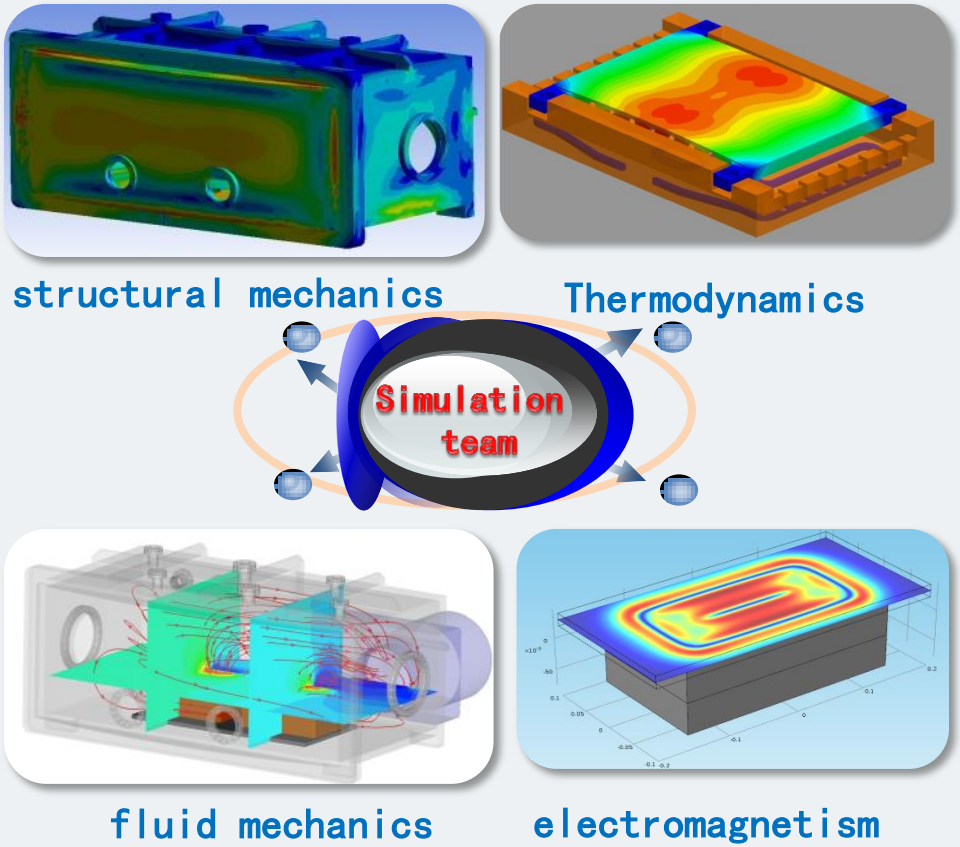
Case I :
Optimization of the setup





Design of the door for the chamber：
Total weight in the previous design: 580 Kg
Low stability and poor operability

Simulation for equipment design

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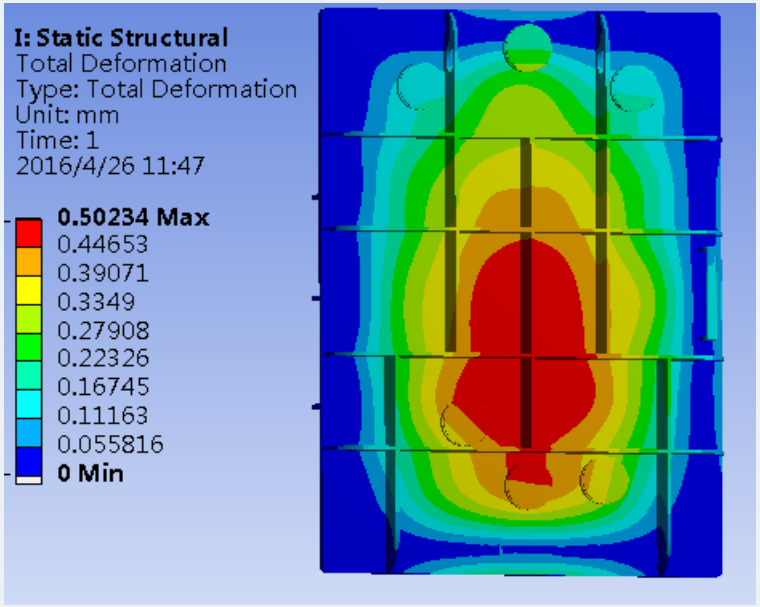
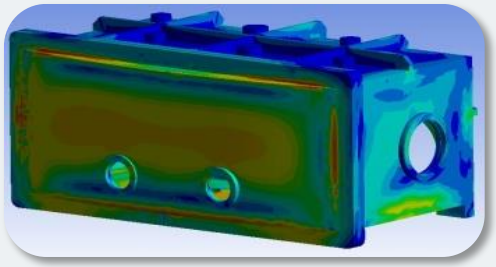
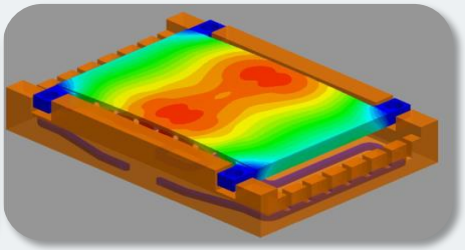
Shanghai Superconductor

Case I :
Optimization of the setup

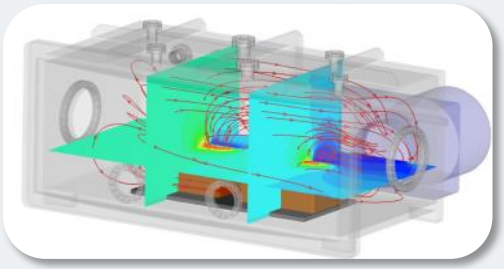




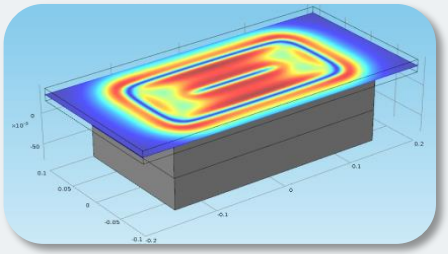
structural mechanics



Thermodynamics



fluid mechanics



electromagnetism

Design of the door for the chamber：
Total weight in the new design: 330 Kg

Simulation for equipment design

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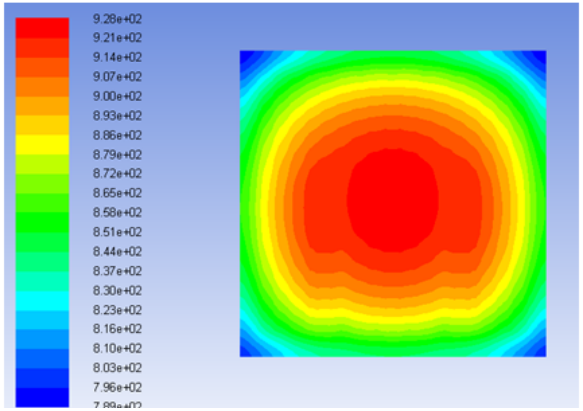
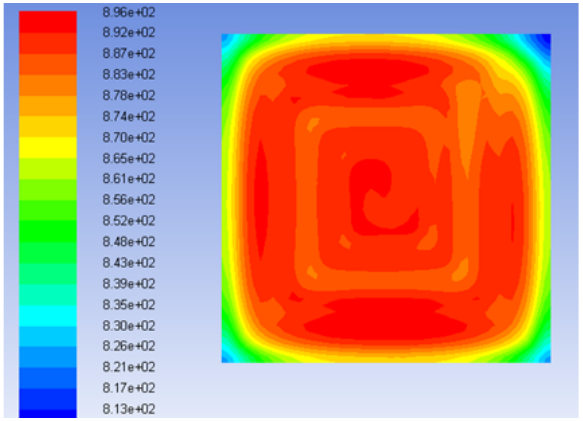
Case II :

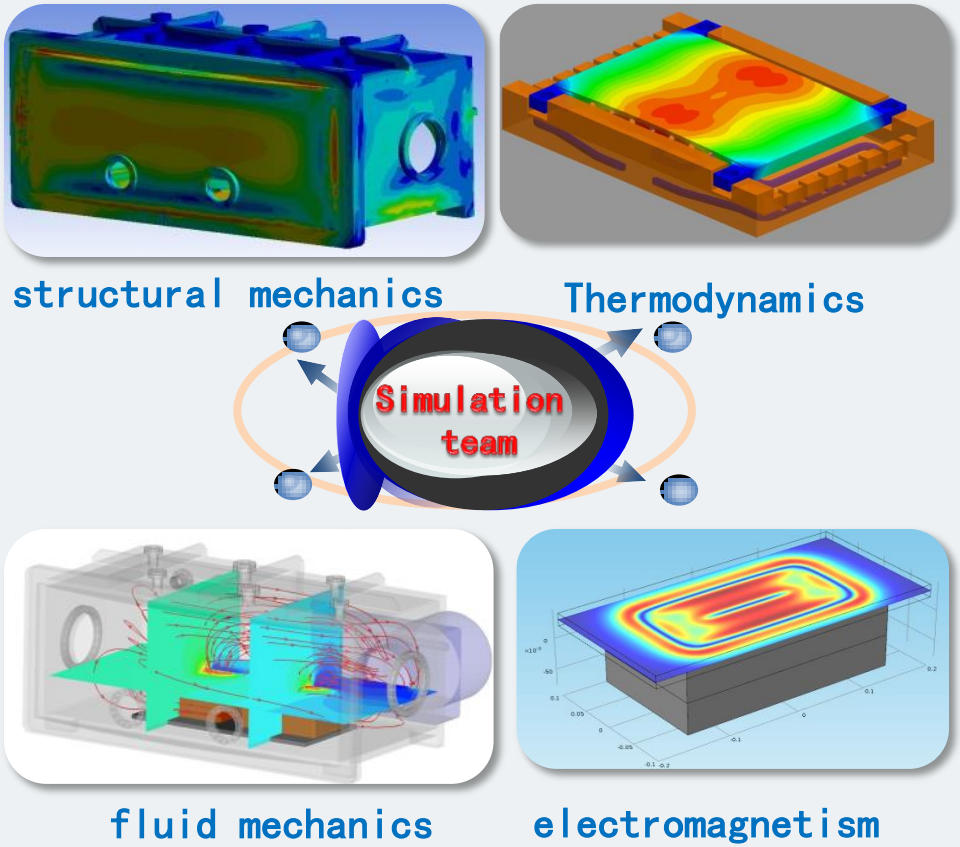
Enhance homogeneity of the heating zone



Temperature variation 138°C



Temperature variation 78°C



Upgrade of the facilities:

Reduced temperature variation: <60°C;

Errors to target temperatures: from ±2.6% to ±0.9%

Simulation for HTS wind generator

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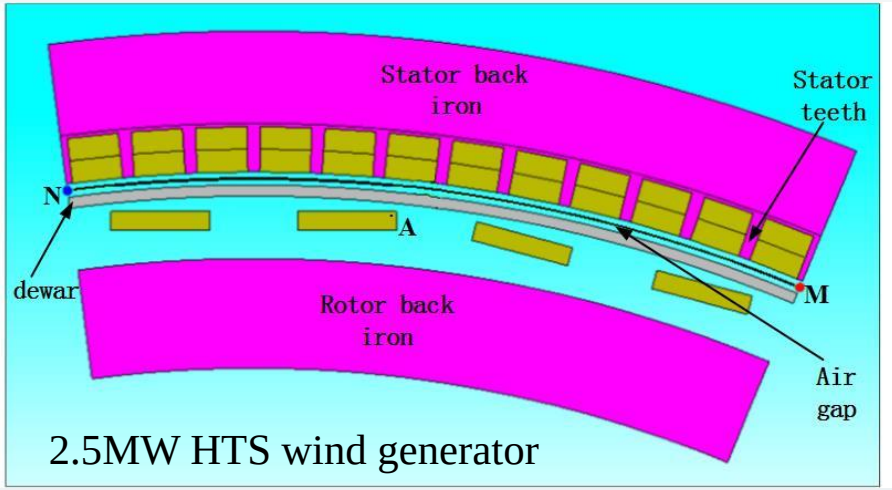
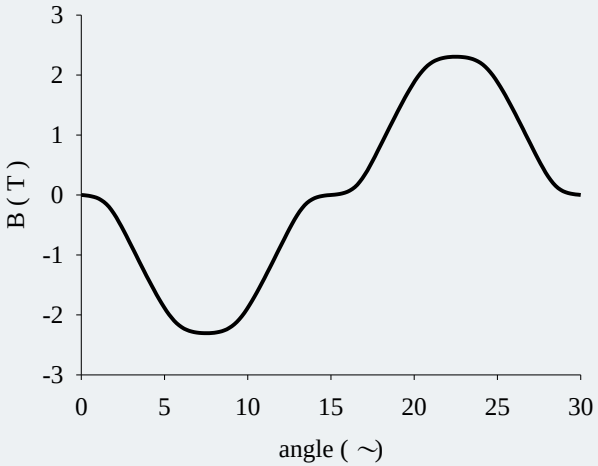
Parameter	Value
Rated power	2500 kW
Frequency	2.9 Hz
Phase number	3
Slot number	144
Pole number	24

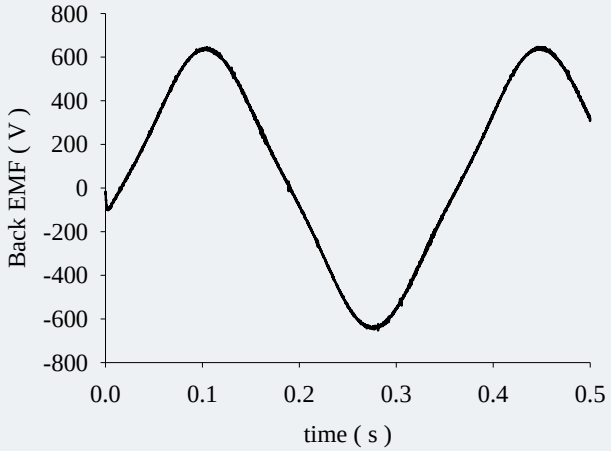


2.5MW HTS wind generator

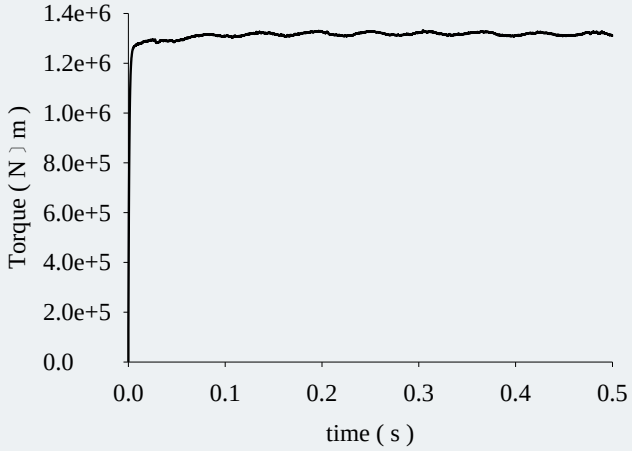
DEC 东方电气 DONGFANG ELECTRIC



(a) Radial magnetic flux density

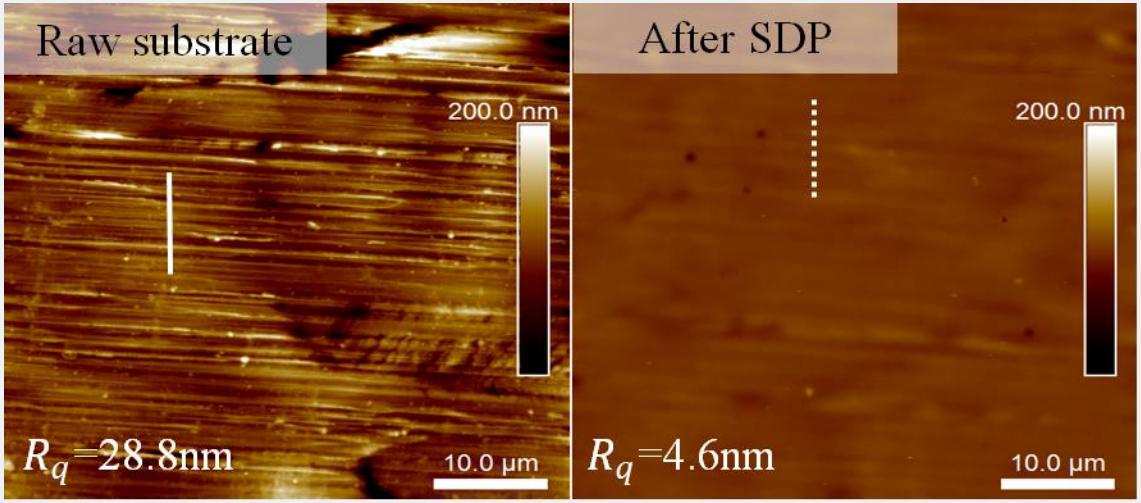


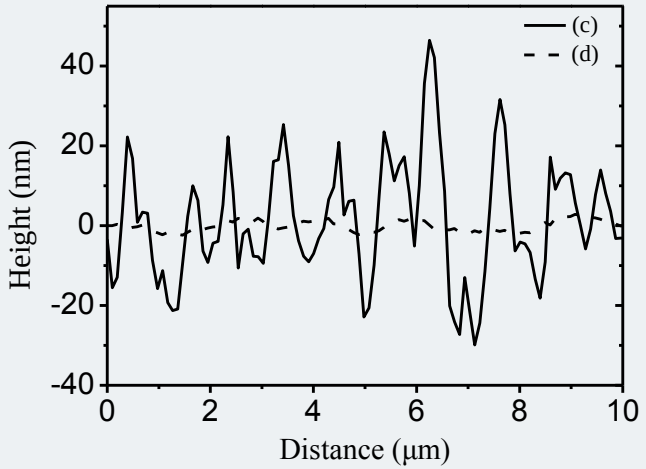
(b) Back EMF of phase A

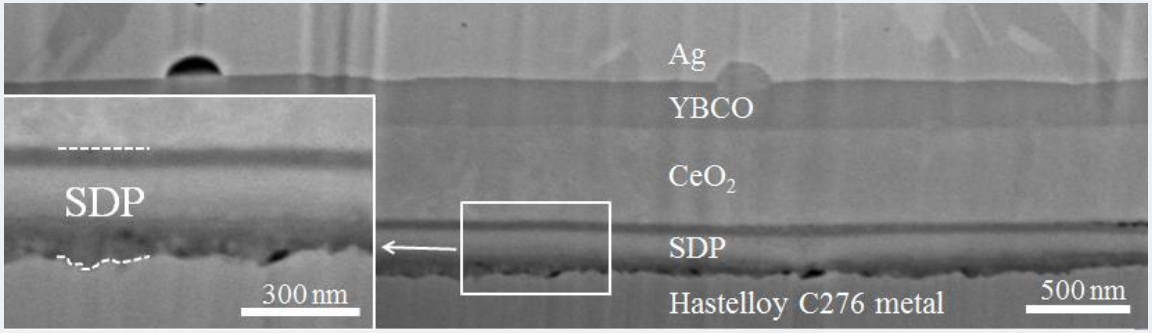


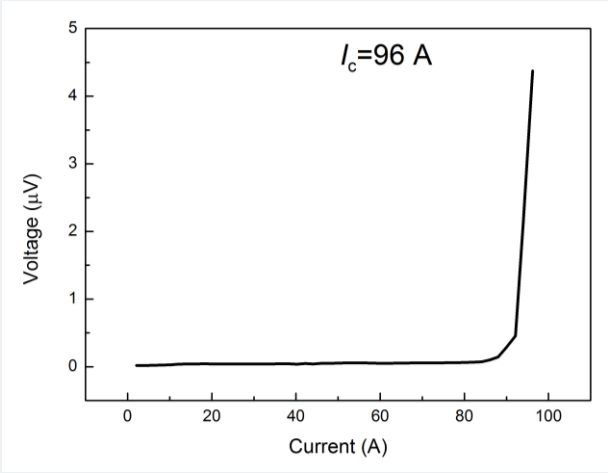
(c) torque

R&D——low-cost solution deposition planarization process



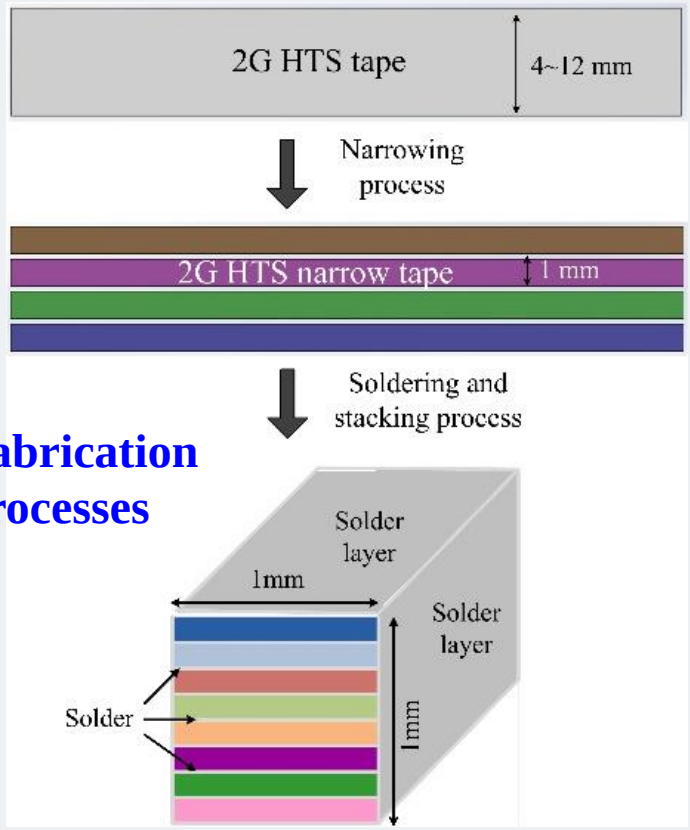


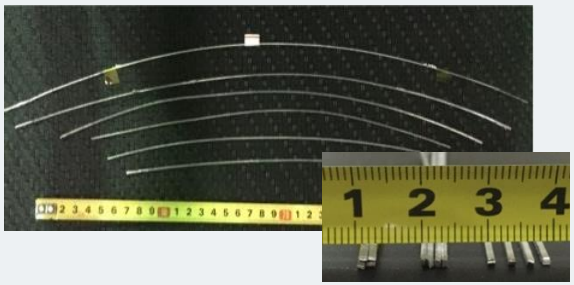


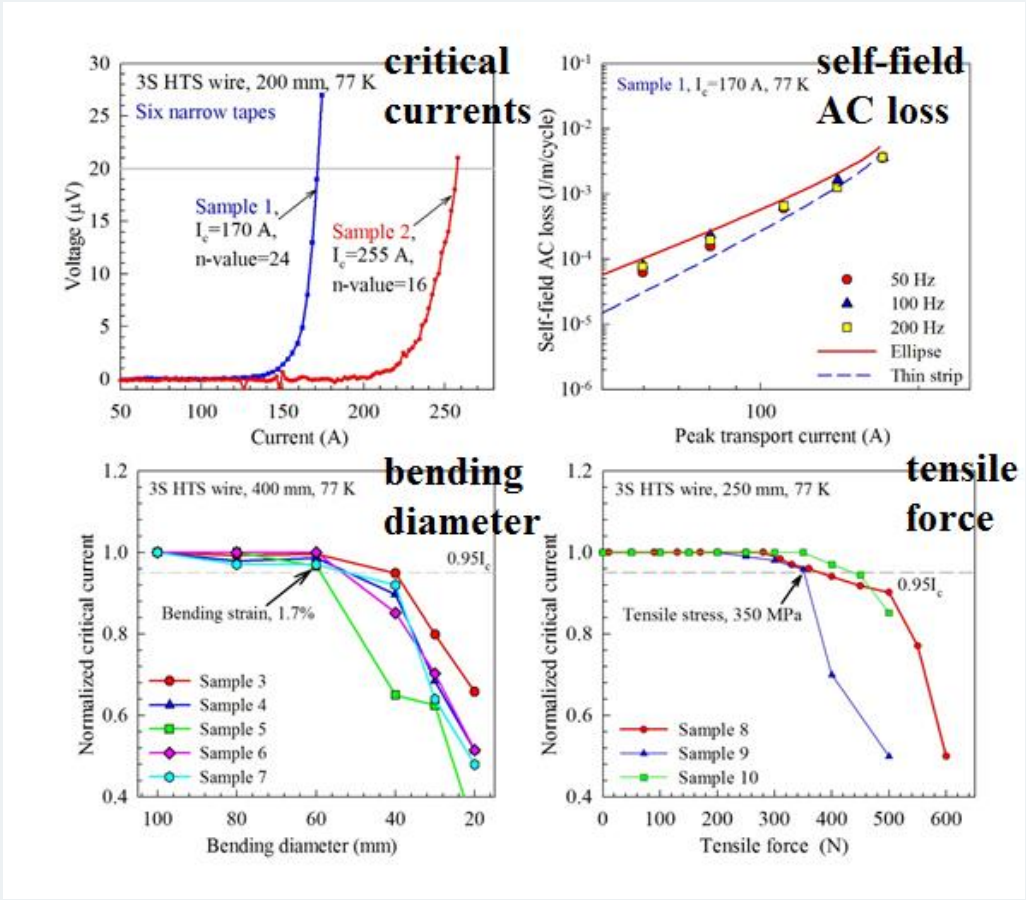


R&D——a Novel Soldered-Stacked-Square (3S) HTS Wire

Fabrication processes







Z.Y. Li, et.al, IEEE Trans. Appl. Supercond., Vol. 26, No. 4, 8201104, 2016.
Z.Y. Li, et.al, IEEE Trans. Appl. Supercond., Vol. 27, No. 4, 6600904, 2017.

long-length 2G HTS tape

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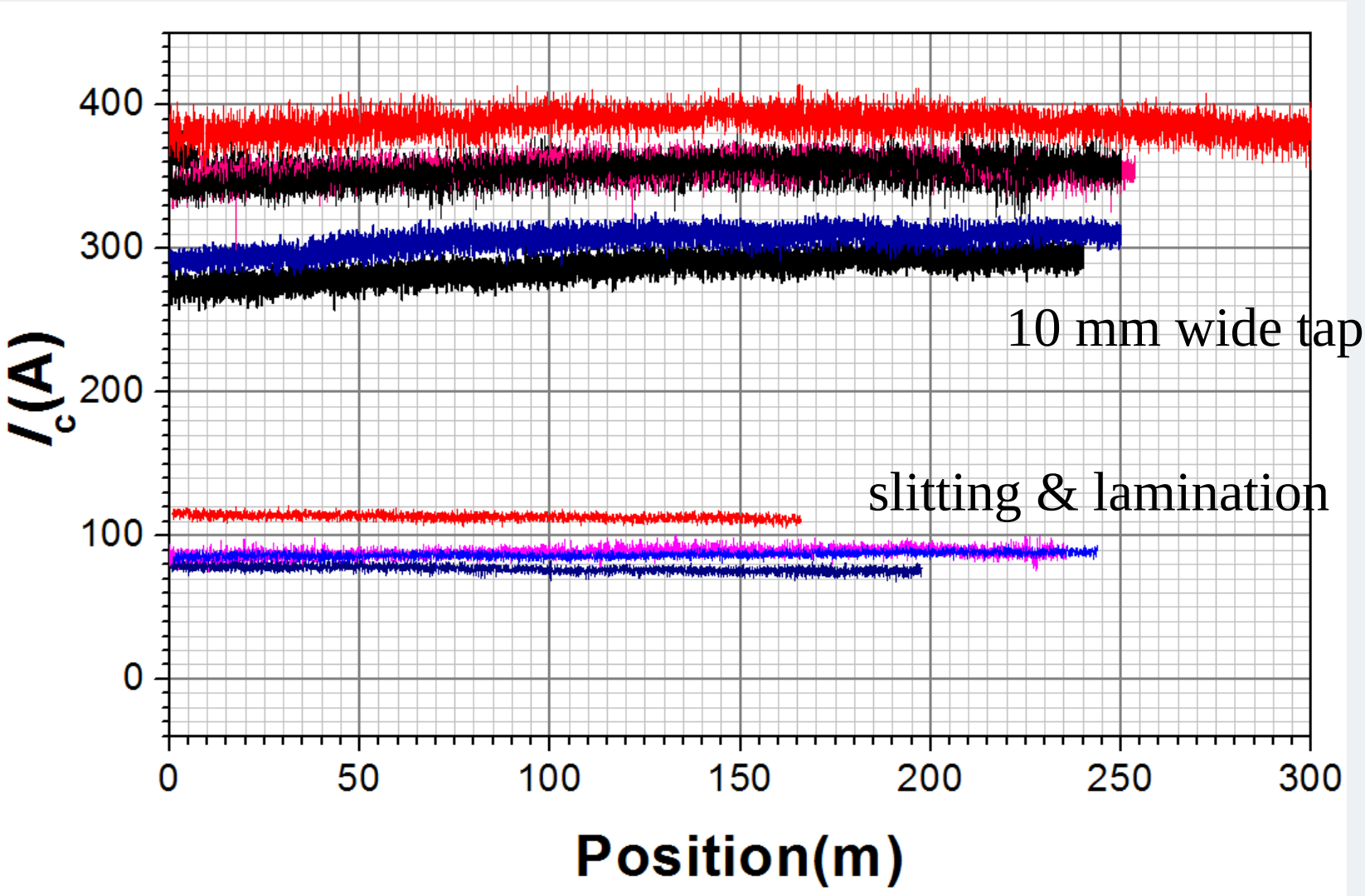

Performance of 2G HTS wires

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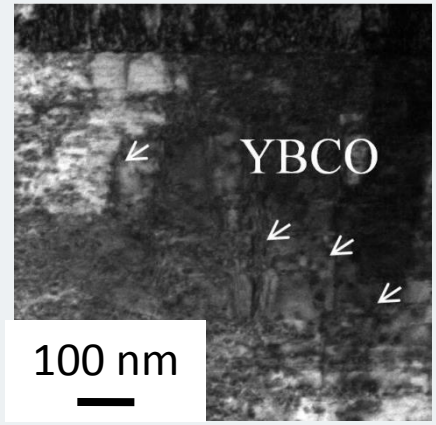
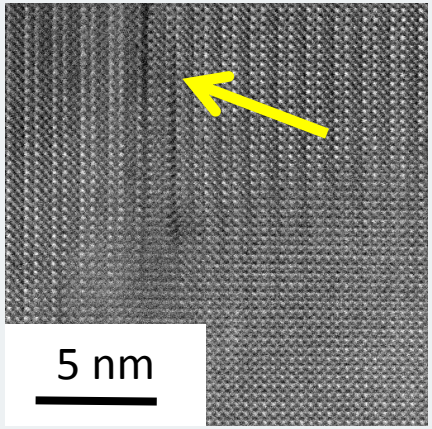
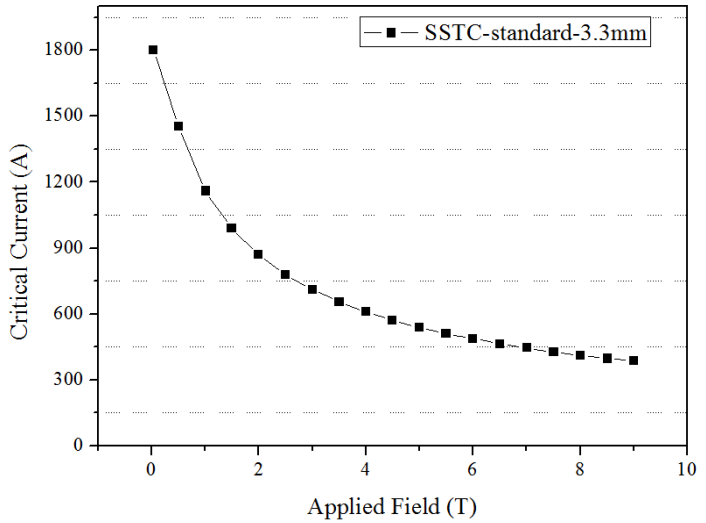
I

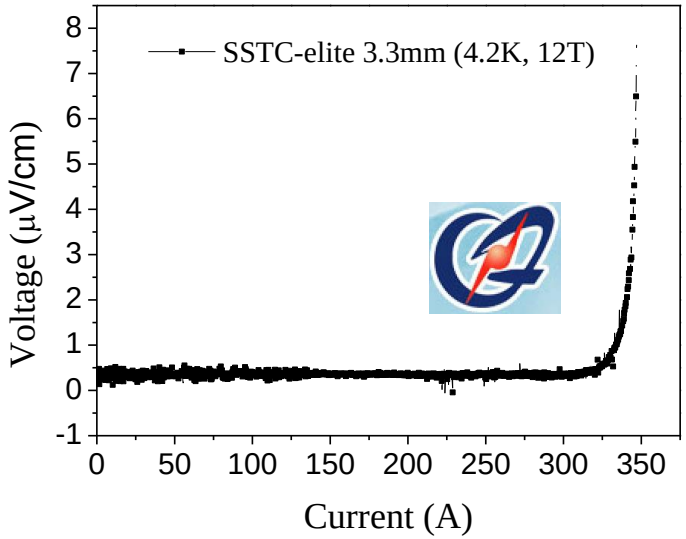
Excellent High Field Performance at Low Temperatures

@4.2K, 12T, I_c exceed 1000A/cm(width)









Measured by: Institute of plasma physics Chinese academy of sciences

Performance of 2G HTS wires

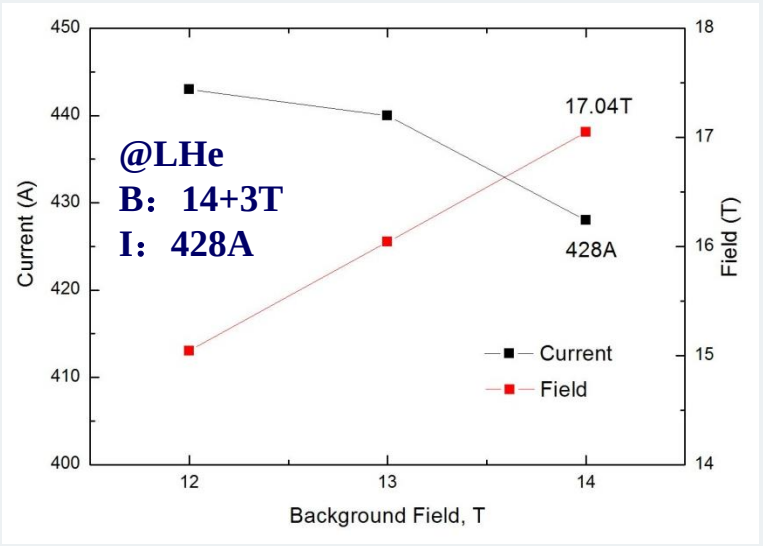
上海超导
Shanghai Superconductor

I

Excellent High Field Performance at Low Temperatures

Case study: 17 T insert coils

B (T)	3
Inner D(mm)	30
Outer D(mm)	57
Length(m)	~50
Layers	45
Turns total	360
I (A@77K)	100



Courtesy by: Institute of plasma physics Chinese academy of sciences

Performance of 2G HTS wires

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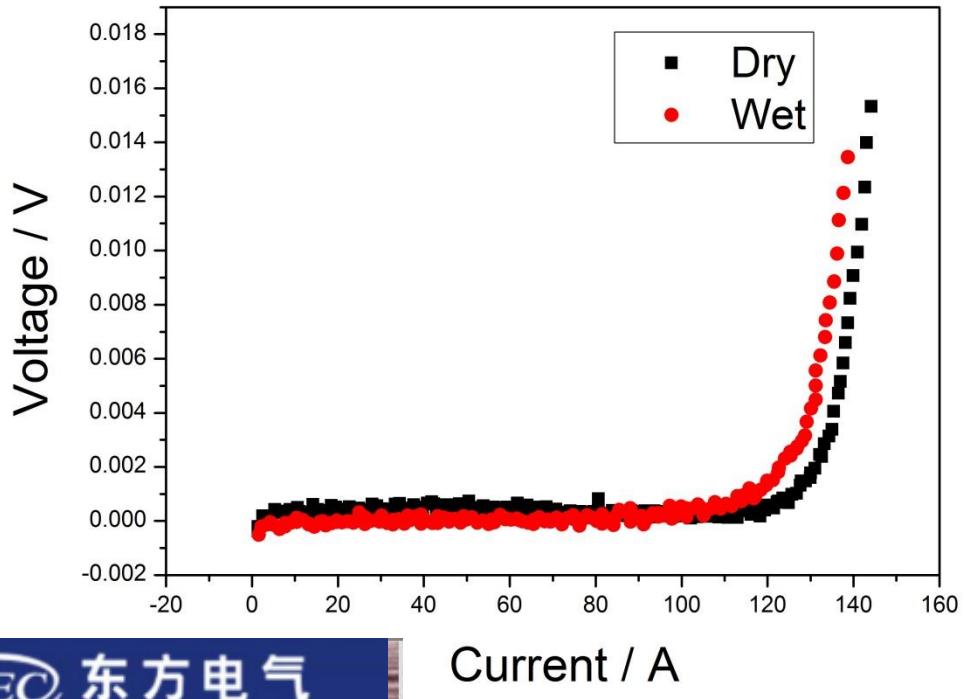
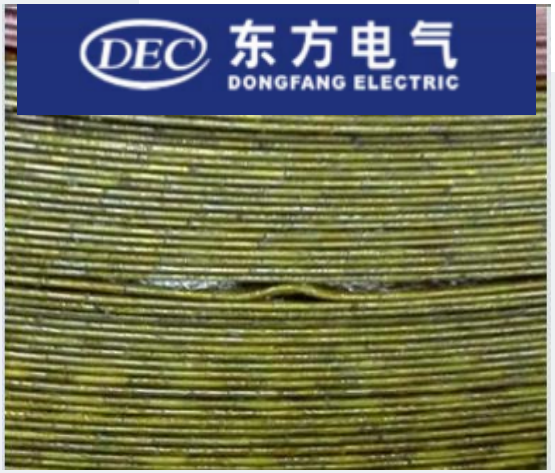
II
Advanced lamination technique

✓Superior delamination resistance

✓I_c loss after epoxy impregnation 10% in the worst case, no deterioration in most cases





Performance of 2G HTS wires

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Ⅱ
Advanced lamination technique

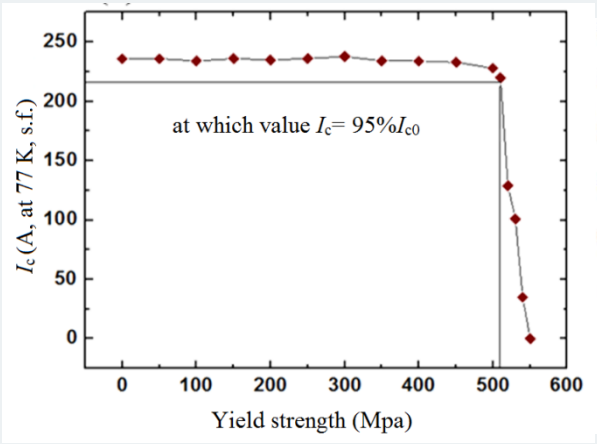
✓Superior delamination resistance

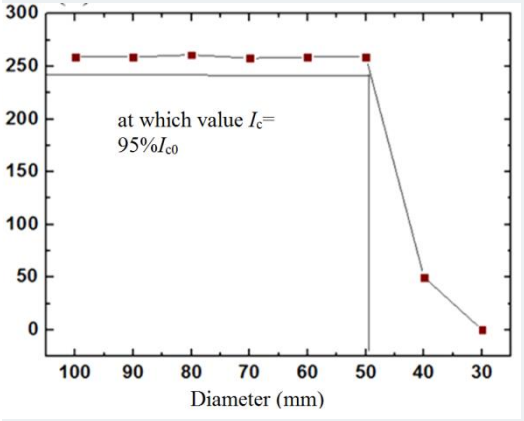
✓I_c loss after epoxy impregnation 10% in the worst case, no deterioration in most cases

✓Enhanced electro- mechanical performance

Critical tensile stress (77K)
>500 MPa

Critical bending diameter (77K)
<50 mm





Performance of 2G HTS wires

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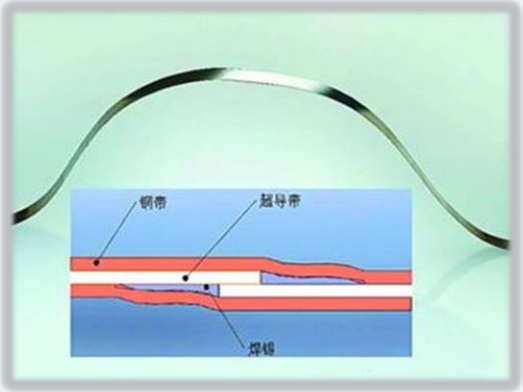
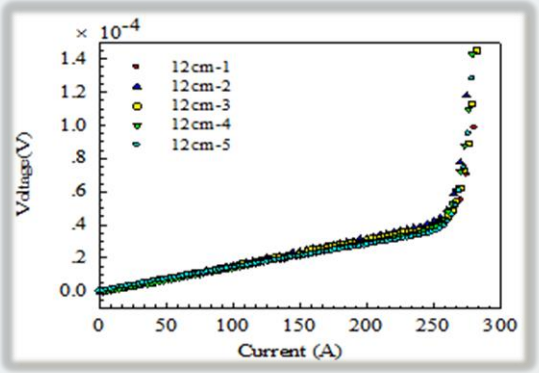
Shanghai Superconductor

Ⅲ

Various techniques developed for joints

Based on lamination technique





- ✓Superior performance of the joint (resistance <2.3 nΩ)
- ✓Adjustable of joint resistance
- ✓No reduction of critical tension strength

Joint length Joints overlaps (cm)	12	22	32	51	103	200	300	400	600	800
Joints resistance (nΩ)	150.30	77.73	50.01	36.49	16.19	8.81	6.13	4.55	2.91	2.25

Performance of 2G HTS wires

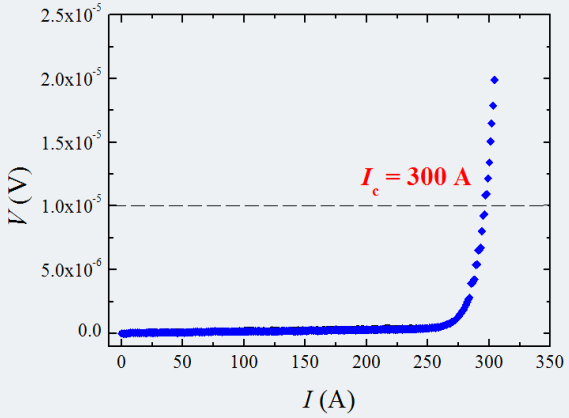
上海超导
Shanghai Superconductor

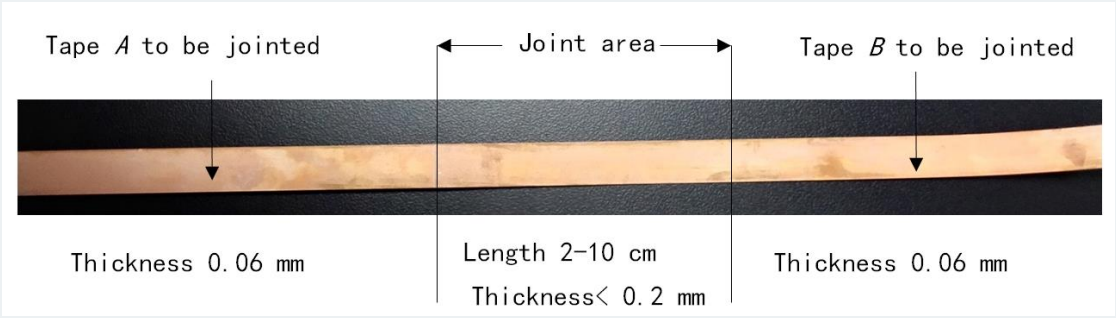
Ⅲ

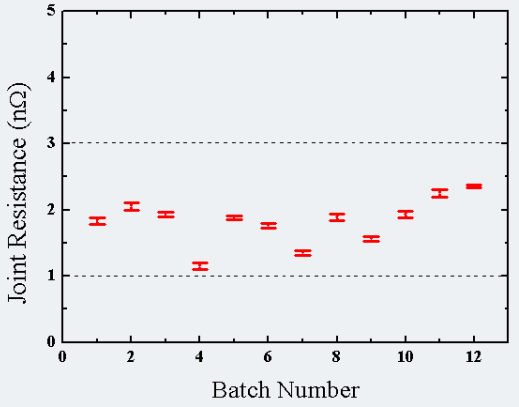
Various techniques developed for joints

Based on diffusion technique

- ✓small joint resistance 1-3 nΩ
- ✓Less overlap length (around 10 cm)
- ✓Applicable for closed-loop







2G HTS wires in SSTC

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Shanghai Superconductor

Product Specifications (As of Apr. 2016)

	ST-04-E Series	ST-05-L Series	ST-05-E Series	ST-06-L Series	ST-10-E Series	ST-12-L Series
Wire Structure	Copper Electroplated	Laminated*	Copper Electroplated	Laminated*	Copper Electroplated	Laminated*
Width	4 mm	4.8 mm	4.8 mm	5.8 mm	10 mm	12 mm
Critical Current	80-200 A	80-200 A	80-200 A	80-200 A	200-300 A	200-300 A
Thickness	60-130 μm	170-350 μm	60-130 μm	170-350 μm	60-130 μm	170-350 μm
Critical Tensile Stress	>600 Mpa	>400 Mpa	>600 Mpa	>400 Mpa	>600 Mpa	>400 Mpa
Critical Tensile Strain	0.4 %	0.4 %	0.4 %	0.4 %	0.4 %	0.4 %
Current Uniformity	±15 %	±15 %	±15 %	±15 %	±15 %	±15 %
Minimal Bending Diameter	11-15 mm	15-20 mm	11-15 mm	15-20 mm	11-15 mm	15-20 mm

*Choice of Materials: Copper, Brass or Stainless Steel (welding material being PbSn)

For details please visit our homepage
http://www.shsctec.com/

Summary

上海超导
Shanghai Superconductor

◆ Performance of 2G HTS wires in SSTC：

- Strong R&D backup from the university
- Homogeneity for the tapes up to 500 m；
- High performance at low temperature high magnetic field ；
- Advanced lamination processes ；
- Various of joint techniques

◆ Outlooks：

Higher Performance

Lower Price

Thanks for your attention !