Progress of REBCO Coated Conductor Program at SJTU and SSTC

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Outline

- Introduction to REBCO CC program at SJTU & SSTC
- Research activities at SJTU
- Scale-up processes for fabrication at SSTC
- Summary
Introduction

CC Project Background at SJTU & SSTC

- Key National Project from Ministry of Science and Technology of China (2009-2012) (PLD+RABiTS, 3.5 million US$, SJTU+Northwest Institute for Non-ferrous Metal Research)
- China’s domestic ITER (International Thermonuclear Experimental Reactor) matched project (2012-2014, 1 million US$, SJTU)
- Major industrialization project from Shanghai Municipal Science and Technology Commission (2012-2016) (PLD+IBAD; 8 million US$, SJTU+Shanghai Superconductor Tech. Co.)

Lab Research Goal: 3 μm thick REBCO layer, $J_c > 3.5 \text{ MA/cm}^2, I_c > 1000 \text{A/cm}$

Pilot-line Goal: $L > 1000 \text{m}, I_c = 300-500 \text{A/cm}$, $J_c > 3.0 \text{ MA/cm}^2$
Lab Research Activities @ SJTU
High Jc REBCO CC Process Development
Lab Research Facilities

Proto-PLD System

Sputter System

Research Facilities

TapeStar Hall Probe System

Bruker Area-Detector XRD

1000A Four-Probe I-V Measurement System
AFM

Ion Beam Assisted Deposition System

Reel-to-Reel Electropolishing System
Reel-to-reel Research PLD System

Maximum Tape Length: 200m,
LPX Pro 220 Laser: 90W, 200Hz, 248nm
- **Hastelloy C276 substrate**
- **IBAD-MgO**
  - IBAD-MgO with Y$_2$O$_3$/Al$_2$O$_3$ barrier layer
- **Buffer layer**
  - Sputtering – single CeO$_2$ layer
- **Superconducting layer**
  - PLD-REBCO layer
- **Ag and Cu stabilization**
  - Sputtering Ag layer
**Electropolishing Process**

As-processed metal tapes
Rq>50nm (10x10 μm²)

After electropolishing
Rq<2nm (10x10 μm²)

PLD-IBAD processed YBCO superconducting tape architecture

First Home-made Reel-to-Reel Electropolishing System in China

Hastelloy alloy
IBAD Process

GIXRD profile by Shanghai Synchrotron Radiation Facility

RHEED image of IBAD MgO film

- IBAD-MgO film had pure c-axis orientation.
- IBAD-MgO film had smooth surface.
  - RMS < 1nm (5μm × 5μm)

AFM image of IBAD MgO film
Sputter-deposited CeO$_2$ layers on IBAD-MgO have smooth surface and high texture.

RMS $<1$ nm, (5$\mu$m $\times$ 5$\mu$m); $\Delta\phi<4.0^\circ$, $\Delta\omega<1.5^\circ$
Optimized CeO$_2$ layer texture: $\Delta \Phi = 2.91^\circ$
XRD from YBCO layer; in-plane texture is smaller than 2 degree
YBCO film microstructure evolution as the increase of thickness on IBAD tapes
YBCO film microstructure evolution as the Increase of thickness on RABiTS tapes
Thick and thinner films have similar surface morphology

0.4 µm

2.0 µm
Deviated lower Ts caused a-axis orientation
REBCO films deposited at deviated higher Ts

(123)+(211) phase

RE-rich REBCO films deposited at higher Ts on IBAD-MgO
Thick YBCO films on RABiTS tapes

Different surface morphology on different grain.

>1.0μm thick YBCO films, Ic~300A; Jc<3×10^6 A/cm²
On IBAD tapes, when REBCO thickness increased to 2.0μm, Ic is still nearly linearly increasing with thickness. So far, we have achieved Ic of 780A. Further research work on increasing REBCO layer thickness is ongoing.
100m long coated conductor

- Magnetic, non-contact measurement
- Reel to reel measurement
- Ic is about 500A/cm and uniform along the length. (77K)
Scale-up processes for fabrication at SSTC
Fabrication Line @ SSTC
Long tape fabrication process development and results
Pilot Electro-polishing Process

Original Tape

Polished tape

Roughness: 5μm X 5μm, Rq=0.7nm

Tape speed >200m/h
Pilot IBAD-MgO Process

IBAD-MgO on-line in-situ RHEED pattern.

ϕ-scan XRD pattern from PLD-CeO₂ film grown on IBAD-MgO template, Δϕ=4.0°
CeO$_2$ single Cap-layer Process

CeO$_2$ film has very smooth surface
RMS = 0.908nm (5μm × 5μm)

XRD θ-2θ scan of CeO$_2$ films deposited on IBAD-MgO
Km class CeO$_2$ long tape has high texture, $\Delta \Phi < 4.0^\circ$, $\Delta \omega < 1.5^\circ$
REBCO Process

REBCO film deposited by PLD

- The surface of REBCO films is smooth
- RMS=2.2 nm (5μm × 5μm)
- Pure c-axis orientation

XRD θ-2θ scan

Intensity

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2theta
$T_c = 92.6$ K
In August 2014, first kilometer long REBCO tapes was fabricated.
In October 2014, the third kilometer long REBCO tapes, $I_C > 200\text{A.}$
Improvement of uniformity along length
Ic Profile Over km Long Tapes
SSTC standard REBCO tape: $I_c=1020\,\text{A/cm}$, at 4.2K and 12T, $H//c$. $I_c$ measured at Institute of Plasma Physics, Chinese Academy of Sciences.

**Goal:** $I_c>2000\,\text{A/cm}$, at 4.2K and $H>10\,\text{T}$, $H//c$, $J_c>2\times10^7/\text{cm}^2$
SJTU successfully developed hundred meter long class CC tapes with over 500 A/cm (at 77 K, self field) based on PLD deposition processes.

A pilot PLD/IBAD-MgO process CC fabrication line was set up at SSTC in 2013.

Reel-to-reel PLD process with high deposition rate was already scaled up to >100 m/h tape speed.

Kilometer long coated conductor tapes with over 300A/cm performance have been routinely fabricated at SSTC.

Next step will be focused on REBCO tape fabrication for high-field applications.
Thanks
For Your Attention