SuperOx

Production and integration of 2G HTS wire into HTS devices
Outline

- The SuperOx group of companies
- The material: 2G HTS wire
- Further integration
• The SuperOx group of companies
On the market, quick and efficient

• The material: 2G HTS wire

• Further integration
SuperOx founded in Moscow in 2006. SuperOx Japan LLC was founded in Tokyo in 2011. In 2012, joint production of 2G HTS wire began in Russia and Japan. In 2014, SuperOx delivered 2G HTS wire to customers worldwide.
SuperOx (Moscow)

- Electropolishing
- Silver DC sputtering
- Copper electroplating
- Solution deposition (MOD & SDP)
- MOCVD (R&D)
- Polyimide insulation
- Solder plating & lamination
- Quality testing, etc.

850 sqm / 20 employees

Focus on customisation and applications
Focus on PVD technology

- RF sputtering: buffer layers
- IBAD-MgO
- PLD: CeO$_2$ & HTS
- DC sputtering: silver
- $I_c$ measurements

220 sqm / 5 employees

SuperOx Japan LLC (Tokyo)
• The SuperOx group of companies

• The material: 2G HTS wire
  Good for all applications

• Further integration
2G HTS wire: basic structure

Customisation
(silver/copper/solder/lamination/insulation)

HTS layer

Substrate
- electropolishing or planarisation
- buffer layers

30.06.2015
2G HTS wire: layer architecture

- Hastelloy C276
- \( \text{Al}_2\text{O}_3 \) or \( \text{LaMnO}_3 \)
- \( \text{Y}_2\text{O}_3 \) or \( \text{LaMnO}_3 \)
- IBAD - MgO
- \( \text{CeO}_2:\text{RE} \)
- \( \text{GdBSCO} \)
- Ag
- Finish

**Customised finish tailored to application**

**DC sputtering (custom thickness)**

- PLD-2 (1-3 microns)
- PLD-1 (100-200 nm)
- RF sputtering (30-50 nm)
- IBAD with RF sputtering (5-7 nm)
- RF sputtering (30-50 nm)
- RF sputtering (50 nm)
- Cold rolled & electro polished (60-100 microns)

**Dual-Chamber:**
- PLD system

**Single Chamber:**
- RF sputter + IBAD
### Present status: 2011-2015

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<th>Substrate</th>
<th>Buffer</th>
<th>HTS</th>
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### Coming: 2015

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### Next step: 2016-…

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</table>
2G HTS wire: progress in production

March 2014

July 2014

September 2013
2G HTS wire: 12 mm width

Long lengths with $I_c$ up to 500 A/12 mm available
2G HTS wire: 4 mm width

Long lengths with \( I_c \) up to 150 A/4 mm available
2G HTS wire: performance in magnetic field

Low angular anisotropy

Reproducible lift factors
2G HTS wire: consistent HTS composition

Consistent composition of the PLD-GdBaCO layer over years of production results in consistent wire performance.
# 2G HTS Wire: Customisation

<table>
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<tr>
<th>Manufacturer</th>
<th>Customisation options</th>
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<td>Copper plating</td>
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<td>Surround polyimide</td>
<td>Polyimide wrapping</td>
<td>Solder plating</td>
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**Polyimide deposition**

**Custom copper plating**

**Custom solder plating**

30.06.2015
Customisation: surround polyimide coating

Polyimide coating
(5 \mu m)

- Copper
  (10 \mu m)
- Silver
  (1 \mu m)
- Buffers + HTS
  (2 \mu m)
- Substrate
  (60 \mu m)

Thin PI layer: keeps \( J_e \) high

1 kV dielectric strength

Complete edge coverage
## 2G HTS wire: specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tr>
<td>Production Length</td>
<td>up to 500 meters</td>
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<tr>
<td>Substrate Thickness</td>
<td>60–100 µm</td>
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<tr>
<td>Tape width</td>
<td>4 mm</td>
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<tr>
<td>Critical Current @ 77K, s.f.</td>
<td>100-150 A</td>
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<tr>
<td>J\textsubscript{e} at 4.2 K, 20 T</td>
<td>&gt; 400 A/mm\textsuperscript{2}</td>
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<tr>
<td>Current Uniformity</td>
<td>±10%</td>
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**Customisation:**

- Variable silver thickness
- Variable copper thickness
- Lamination
- Insulation
- Artificial pinning centres
- Solder plating
- Low resistance splices
- ... just ask
• The SuperOx group of companies

• The material: 2G HTS wire

• Further integration
We want to deliver HTS solutions, not just the material
Integration: Roebel cables

Collaboration with Karlsruhe Institute of Technology, Dr. Anna Kario et al.

Standard way: coat-and-punch

Smooth cross-section of the punched edge

Cu gets smeared over HTS layer

Well, most times ...
Integration: Roebel cables

Collaboration with Karlsruhe Institute of Technology, Dr. Anna Kario et al.

Standard way: coat-and-punch

S. Otten et al., SUST 28 (2015) 065014

... But sometimes delamination occurs
Integration: Roebel cables

Collaboration with Karlsruhe Institute of Technology, Dr. Anna Kario et al.

Novel alternative: punch-and-coat

Cu-plating of a punched strand

HTS layer fully enclosed Sharp punch burr smoothed
Integration: Roebel cables

Collaboration with Karlsruhe Institute of Technology, Dr. Anna Kario et al.

Coat-and-punch results

- CCA-2014, 300 A-class wire
- Recent, 400 A-class wire

30.06.2015
Integration: Roebel cables

SuperOx is acquiring own machinery for Roebel cable fabrication

Will provide advanced punch-and-coat cable
Filamentisation for AC loss reduction

Collaboration with KIT

Finish-and-striate:
- SuperOx provides wire with different finish: 0-5-10-20 μm Cu
- KIT makes up to 120 laser striations and AC measurements

Striate and finish:
- KIT striates Ag-coated wire
- SuperOx electroplates 5-7-10 μm Cu

At SuperOx (new):
- Develop reel-to-reel chemical etching 100 μm grooves, 1 mm filaments

Graph from Anna Kario’s talk on Monday M1OrC-01
Current leads for LTS magnets

SuperOx’s custom 100 A HTS current lead for a corrector coil of an LTS magnet

Nuclotron LTS magnets
NICA collider, Dubna JINR
2G HTS coaxial cables

Cooperation with Russian cable Institute (VNIIKP), Dr. Vitaly Vysotsky

Low level of AC losses confirmed
HTS Fault Current Limiter (FCL)

- FCL is extremely needed equipment for power utilities, as well as for electric infrastructure of railways, large industry, ships, etc.

Operation of FCL

SuperOx know how

Main features

- up to 220 kV
- up to 5 kA
- no inductance
- low losses
- 3 ms switching time
- self-recovery

Three FCL machines are being built with SuperOx 2G HTS tape: two in Russia and one in France
Double pancake coil

- Made of polyimide coated Cu plated tape
- Magnetic field 1 T at 77 K without core
- Operation current up to 120 A
- 84 000 Amps*Turns.
By now, SuperOx has built 2G HTS blocks with levitating force of over 200 kg
Tape stacks, composite bulk blocks, magnetic field shields
2G HTS composite bulk

Collaboration with University of Cambridge, Dr. Anup Patel et al.

A. Patel et al.

A. Baskis et al.
• The SuperOx group of companies
On the market, quick and efficient

• The material: 2G HTS wire
Good for all applications

• Further integration
We want to deliver HTS solutions, not just the material