Development and Production of Second Generation High-Tc Superconducting Tapes in SuperOx and First Tests of Model Devices

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SuperOx is a 100% privately owned company with about 30 employees.

The R&D core of the company graduated from Chemistry and Material Science Departments of Moscow State University and had the experience in HTS since late 80’s - early 90’s.
SuperOx (Moscow)

MSU → Technopark “Slava”

Chemical processes
- solution deposition (MOD & SDP),
- MOCVD,
- electropolishing,
- copper deposition,
- quality testing,
- customization

> 850 sqm
➢ 20 employees
SuperOx coated conductor status in 2012:
Non-magnetic Ni-Cr-W RABiTS;
Chemically deposited buffer architectures.

Buffer architectures: CeO$_2$/SrF$_2$/MgO, BaZrO$_3$/MgO, La$_2$Zr$_2$O$_7$
SuperOx coated conductor status in 2012: MOCVD YBCO results
11 March 2011 – Decision to start the new Company in Japan

July 2011 - application of documents for Company registration

Sept 2011 – first employment contract

Oct. 2011 – design and placing purchase order for manufacturing equipment

Dec. 2011 – enter Sagamihara Incubation Center (new building SIC-3)

April 2012 – completed installation of main equipment
SuperOx Japan LLC (Tokyo)
*Sagamihara Incubation Center SIC-3 (Kanagawa)*

Physical vapor deposition processes
- RF & pulsed DC magnetron sputtering
- Ion Beam Assisted Deposition (IBAD)
- Pulsed Laser Deposition (PLD)
- DC Magnetron Ag sputtering
- Critical current measurements
  (reel-to-reel contactless, transport Ic)

> 220 sqm
5 employees
Ion Beam Assisted Deposition + magnetrons

IBAD-MgO

RF and pulsed DC 2 kW sputtering
ex-situ RHEED and QCM control
22x6 cm ion gun
Reels capacity >1.5 km
T up to 900°C
Speed up to 200 m/h

The same machine was used for deposition of all buffer layers with very short maintain time in between different processing stages
(Overall processing speed 20m/h)

IBAD-MgO
epi-MgO
Pulsed Laser Deposition of LMO, epi-MgO, RE-CeO2 & RE-123

Dual chamber PLD system with 130 W LEAP excimer laser

200 Hz, 650 mJ
Best price/pulse ratio

Reel capacity over 1 km

Processing speed of buffers 50-100m/h
HTS films 15-50m/h
Operation time 20h/day
Typical example of buffers and 2G HTS wire architecture

- **Epitaxial layers**
  - CeO$_2$:RE
  - LaMnO$_3$
  - epi - MgO
  - IBAD - MgO

- **Amorphous layers**
  - Y$_2$O$_3$
  - Al$_2$O$_3$
  - Hastelloy

[Graph showing normalized intensities over time]
SuperOx 2G wire Architecture

1. Hastelloy
2. Al₂O₃
3. LaMnO₃
4. IBAD - MgO
5. CeO₂:RE
6. High - Tc superconductor
7. Ag

Deposition Methods:
- RF reactive or nonreactive sputtering (50 nm)
- Cold rolled, annealed, electro polished (60-100 microns)
- Dual PLD Chamber system
- Single Chamber
- DC sputtering (1-2 microns)
- PLD-2 (1-3 microns) at T2
- PLD-1 (100-200 nm) at T1
- RF sputtering-2 (30-50 nm) at T1
- Ion beam assisted deposition with RF sputtering 5-7 nm
- RF sputtering-2 (30-50 nm) at T1
SuperOx Buffer Architecture

RE-doping in CeO2, suppression <111>
Growth, very wide processing window
Speed of 50m/h at a 50% laser power
SuperOx:
Hastelloy C276 Electropolishing

Present operation: 25 m/h
Possible throughput upgrade: 100 m/h

Original
RMS (40x40 um): 22 nm
RMS (5x5 um): 15 nm

Electropolished
RMS (5x5 um): 0.7 nm
Superox 2G HTS wires on electropolished substrates from different Hastelloy suppliers
Solution Deposition Planarization (SDP) of Hastelloy tapes

Nanocrystalline $\text{Y}_2\text{O}_3$ layer particle size: 10-15 nm

Smoothing out of major roughness after the fourth coat

Hastelloy
RMS:
16 nm (5x5 um)
22 nm (40x40 um)

SDP layer
RMS:
1.0 nm (5x5 um)
4.5 nm (40x40 um)

Currents up to 350 A demonstrated

More details on Wednesday at Poster 3P-WT1-02
Overcoming 300 A/cm on 100 m

Single piece length >200 m

Ic >120 A on 4 mm

Overcoming 300 A/cm on 100 m

Ic =550 A/12mm

Ic >120 A on 4 mm
# Product

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Production Length</td>
<td>50 – 200 meters</td>
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<tr>
<td>Tape 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></td>
<td>12mm</td>
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<tr>
<td>Critical Current @ 77K, s.f.</td>
<td>100-150 A</td>
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<tr>
<td></td>
<td>250-500 A</td>
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<tr>
<td>Current Uniformity</td>
<td>±10%</td>
</tr>
<tr>
<td></td>
<td>±10%</td>
</tr>
</tbody>
</table>

**Customization:**
- Variable silver thickness
- Variable copper thickness
- Lamination
- Insulation
- Artificial pinning centers
- Joints
**Power Cables**

4 mm copper-plated ~80-120 A HTS wire

2013: First two prototype **3 kA-4.5kA** cable are built and tested by leading Russian Cable Institute (VNIIKP)

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**Graph 1:**
- **Outer layer**: \( I_c = 4.36 \text{ kA}, n = 18.6 \)
- **Inner layer**: \( I_c = 4.45 \text{ kA}, n = 11.6 \)

**Graph 2:**
- **Total current, kA**
- **Electrical field, \( \mu \text{V/cm} \)**

**Graph 3:**
- **Losses (W/m/tape)**
  - **SuperOx cables**
    - **first**
    - **second**

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