Scale-up of coated conductor substrate process by reel-to-reel planarization of amorphous oxide layers

Yunfei Qiao¹, Yimin Chen¹, Xuming Xiong¹, Sungjin Kim¹, Vladimir Matias², Chris Sheehan², Yue Zhang³ and Venkat Selvamanickam³

¹ SuperPower Inc., 450 Duane Ave., Schenectady, NY 12304 USA
² Superconductivity Technology Center, Los Alamos National Laboratory, Los Alamos, NM USA
³ Dept. of Mechanical Engineering, Texas Center for Superconductivity at the Univ. of Houston, Houston, TX 77024, USA

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IBAD-MgO texture and surface smoothness studied by LANL

- IBAD texture degrades rapidly with increasing roughness
- Need smooth surface to 1-2 nm RMS roughness (5 x 5 μm)
2 mil as received raw tape
20x20µm scan

Ra = 9.8nm
Peak to Valley: 20 ~ 41 nm
Slope: 1~6 degree
2 mil as received raw tape
5x5µm scan

Ra = 2.5nm
Peak to Valley: 8 ~ 23 nm
Slope: 1~5 degree
Electropolished 2mil substrate
20x20µm scan

20x20µm scan
Ra = 2.6 nm
Peak to Valley: 0.2 ~ 16 nm
Slope: ~ 2 degree
Grain boundary
Height:1.2 nm
Slope: 0.8 degree
Electropolished 2mil substrate
5x5µm scan

5µmx5µm scan
Ra = 0.5 nm
Study of planarization by LANL in 2008

Still need many coatings (18)

Paul Clem is working on reducing the number of coatings

AFM data, after 18 coatings

<table>
<thead>
<tr>
<th>Sample name</th>
<th>5 x 5 um</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG026,SS,a</td>
<td>1.4</td>
</tr>
<tr>
<td>SG026,SS,b</td>
<td>2.3</td>
</tr>
<tr>
<td>SG026,SS,c</td>
<td>0.8</td>
</tr>
<tr>
<td>average</td>
<td>1.5</td>
</tr>
</tbody>
</table>

IBAD data, MgO texture

\[ \Delta \Omega = 2.57^\circ \]
\[ \Delta \phi = 4.7^\circ \]

In previous years we showed on sol-gel:
MgO: \( \Delta \phi = 4.8^\circ \) \( \Delta \omega = 1.0^\circ \)

PLD YBCO: 1.2\,\mu m
\( J_c > 1.5 \, \text{MA/cm}^2 \)

This year (FY08)
SS304 substrate, mechanically polished

RCE YBCO: 1.2\,\mu m
\( J_c = 2.4 \, \text{MA/cm}^2 \)
Objective: Eliminate electropolishing and restriction of substrate material in coated conductor manufacturing process

Approaches:
- Optimize on planarized Hastelloy
  - Doubles Pilot buffer production by eliminating diffusion barrier sputtering process
- Planarization process can be used for any substrate material driven by customers
  - Thinner, fewer buffers with Ni-Cr
  - Inexpensive substrate
Smooth YO films directly on unpolished Hastelloy substrates by reel-to-reel planarization.
After 1 layer planarization with YO

- Ra = 5.8nm, 20X20µm, Slope: 6 degree, PV: 59nm

- Ra = 2.7nm, 5X5µm, Slope: 4 degree, PV: 15nm

- Ra = 1nm, 1X1µm, Slope: 3 degree, PV: 7nm
After 2 layers planarization with YO

- 20X20µm: Ra = 5.3nm, PV: 35nm, Slope: 3 degree
- 5X5µm: Ra = 2.0nm, PV: 6nm, Slope: 3 degree
- 1X1µm: Ra = 0.4nm
After 3 layers planarization with YO

- **20X20µm**
  - Ra = 4.2nm
  - PV: 38nm
  - Slope: 2 degree

- **5X5µm**
  - Ra = 1.4nm
  - PV: 4nm
  - Slope: 1 degree

- **1X1µm**
  - Ra = 0.4nm
  - PV: 2nm
  - Slope: 4 degree
After 4 layers planarization with YO:

- 20X20µm: Ra = 2.2nm
  PV: 14nm  Slope: 0.3 degree

- 5X5µm: Ra = 0.6nm
  PV: 2nm  Slope: 0.3 degree

- 1X1µm: Ra = 0.12nm
Ra vs. number of planarization layers
YO and YALO planarized substrate on as received 2mil Hastelloy tapes
High quality buffers and HTS films demonstrated on fewer planarized layers

- Planarized yttria, no alumina; Out-of-plane texture = 4.5° FWHM, In-plane texture = 7° FWHM
- $I_c = 140 \text{ A/cm}$ achieved in 0.4 mm MOCVD film with no alumina and only 3 vapor deposited layers ($J_c = 3.5 \text{ MA/cm}^2$)
High quality buffers demonstrated on long length planarized substrates with 3 layers
High quality HTS films demonstrated on long length planarized substrates