Perspectives on IBAD Coated Conductors

Cost and Future

Follow up to the 2014 CCA presentation

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25 Years of Coated Conductors

- Yasuhiro Iijima at Fujikura, 1991
- Typically takes 20 years to bring new materials to marketplace

First CC
IBAD-MgO Stanford
ORNL RABiTS
LANL first 1 meter CC
AMSC first commercial CC
SuperPower 10km to Sumitomo
6 Companies producing CC

Price of superconductor wire is critical for applications

- In 2010 proposed cost target for CC: $5/kAm (LN2)
- Cost of embodied materials: about $0.10 per kAm (with 1000 A/cm, 5 MA/cm²)
- Performed a bottom up analysis for coevaporation showing <$5/kAm is possible (~50,000 km/yr)
- Top down: cost should decrease due to scale up from 100 km to 100,000 km (10x); performance (A/cm) should increase by at least 2x; yield increases
- Vibrant industry: 15 companies are producing or intending to produce coated conductors

<table>
<thead>
<tr>
<th>Layer</th>
<th>Materials cost/kAm</th>
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<tbody>
<tr>
<td>Ag (0.5 µm)</td>
<td>$ 0.06</td>
</tr>
<tr>
<td>YBCO (2 µm)</td>
<td>$ 0.02</td>
</tr>
<tr>
<td>IBAD+epi (MgO)</td>
<td>$ 0.0005</td>
</tr>
<tr>
<td>SDP layer (Y₂O₃)</td>
<td>$ 0.002</td>
</tr>
<tr>
<td>substrate (stainless)</td>
<td>$ 0.04</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>$ 0.12</strong></td>
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Coated Conductor Manufacturers

Tier I

AMSC, Mass. USA (RABiTS+MOD)
SuperPower, NY, USA/Japan (IBAD+MOCVD)
SuNAM Co. Ltd, Korea (IBAD+RCE)
SuperOx, Russia/Japan (IBAD+PLD)

Tier II

Fujikura, Japan (IBAD+PLD)
Bruker HTS, Germany (IBAD+PLD)
Theva, Germany (ISD+RCE)
STI, TX USA (IBAD+RCE)
Shanghai Superconductor, China (IBAD+PLD)

Tier III

d-nano (BASF), Germany (RABiTS+MOD)
Shanghai Creative Superc, China (IBAD+MOD)
SAMRI/CAS, Suzhou China (IBAD+MOCVD)
Oxolutia, Spain (IBAD+MOD)
Sumitomo, Japan (RABiTS+PLD)
Metox, TX USA (RABiTS+MOCVD)
Production and Price Trends

- Trend presented at last CCA
- Overcapacity in production
- At present CC Production volume is saturating; price is leveling off
- Companies are not profitable and price is too high for mass adoption
- Valley of Death?
- There is life after the Valley
- Only truly scalable approaches will win (need to scale 1000x)
WatterShed

- HTS-HVDC allows for multi-GW transmission over long distances
- Wattershed proposes connecting grids across oceans tracing shallow waters of continental shelves
- Phased approach with intermediate steps in building cables
Semiconductors using Iijima approach

  - Epi-Si on metal and glass
  - Demonstrated first solar cells using this approach
- Selvamanicakam et al (University of Houston): GaAs – 2009-2015
  - High quality GaAs on IBAD templates
  - Hall mobilities 60 - 300 cm²/ V-s (h, e)
25 Years of GaN LEDs

- Shuji Nakamura 1991: InGaN LED
- Solid State Lighting Revolution

First LED on sapphire
- Nichia starts selling HB LEDs
- p-doping
- First 1.5 mW HB LED

White Light LEDs
- 2nd gen LED GaN on GaN
- Sumitomo develops GaN substrate
- Flip chip LED


Nakamura, Akasaki, Amano win Nobel Prize

$20B LED Industry

Coated Conductors for Applications 2016, Aspen, CO, USA
Lessons from GaN

- Get product out to customers quickly
- Role of government funding and regulation:
  - Helped to obtain market adoption
- Chinese entry into market

EU Member States’ committee meeting of 8 December 2008: "Incandescent lamps will be phased out from the EU market starting 2009 and finishing in 2012"
Conclusions

- Technical progress on Coated Conductors for Applications has been amazing – we have come a long way in the last 25 years
- Clearly CC are here to stay – Magnet applications are validated
- However, still a long way to go for Electric grid applications
- The play is long term and companies need to survive the Valley of Death
- There is life through the Valley