Influence of granularity on the local transport properties in pure and BaHfO$_3$ doped YBCO films on technical templates

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We thank A. Usoskin (Bruker HTS) and M. Falter (D-Nano) for the provision of the buffered substrates.
Coated conductor development

**Rolling Assisted Biaxially Textured Substrates (RABiTS)**
- Rolling
- Annealing
- Ni or Cu alloys
- Biaxially textured metal tape
- Epitaxial growth of buffer architecture

**Ion Beam Assisted Deposition (IBAD)**
- Ion beam
- PLD, e-beam, sputtering
- Texture evolves in buffer layer
- Based on biaxially textured buffer layers

**Inclined Substrate Deposition (ISD)**
- Inclined substrate deposition
- Texture evolves in buffer layer

**European development of Superconducting Tapes:** integrating novel materials and architectures into cost effective processes for power applications and magnets (EUROTAPES) (2012-2017)
Coated conductors: Local granularity

Influence of grain boundaries

High $J_c$ in polycrystalline materials require strong biaxial texture

RABiTS
- YBCO
- biaxially textured metal tape
- Based on biaxially textured substrates

IBAD/ABAD
- YBCO
- arbitrary textured metal tape
- Based on biaxially textured buffer layers

→ Differences in grain boundary network

Hilgenkamp et al., Rev. Mod. Phys. 74 (2002) 485
Growth of YBCO coated conductors

Pulsed laser deposition - PLD

- $f_{\text{Dep}} = 10$ Hz ($\sim 1.2$ nm/s)
- Film thickness $\sim 1 \ldots 2 \, \mu m$
- Substrate: industrial tape

Stainless steel / ABAD-YSZ / PLD-CeO$_2$
RABiT Ni-5 at.% W / CSD-La$_2$Zr$_2$O$_7$ / CSD-CeO$_2$
SrTiO$_3$ single crystal

Targets from stoichiometric powders:
- Pure YBCO
- YBCO + 5 mol% BaHfO$_3$ (BHO)
- Similar deposition conditions
Influence of granularity

Study of ~1 µm thick PLD-YBCO layers

SEM surface images of etched spots

- Homogeneous structure on STO and ABAD-YSZ
- Varying microstructure on NiW

P. Pahlke et al., IEEE-TAS 26 (2016) 7201505
Influence of granularity

**EBSD**

YBCO on SrTiO$_3$

YBCO on ABAD-YSZ

YBCO on Ni-5at.% W

**P. Pahlke et al., IEEE-TAS 26 (2016) 7201505**
Granularity of YBCO on Ni-W RABiTS

*EBSD of PLD-YBCO layers with different thickness*

400 nm YBCO

![REM - SE](image1.png)  
**a)** K1, K3, K4

![EBSD - Absolute MO](image2.png)  
**b)**

![EBSD - Out-of-plane MO](image3.png)  
**c)**

1200 nm YBCO

![REM - SE](image4.png)  
**d)** K3, K2, K4

![EBSD - Absolute MO](image5.png)  
**e)**

![EBSD - Out-of-plane MO](image6.png)  
**f)**

Higher roughness but improved intragrain texture
Influence of granularity

**EBSD**

- YBCO on SrTiO$_3$
- YBCO on ABAD-YSZ
- YBCO on Ni-5at.% W

*P. Pahlke et al., IEEE-TAS 26 (2016) 7201505*
Influence of granularity – local scale

**SHPM mappings (Hall scan of trapped field profile at 4.2 K)**

YBCO on STO

YBCO on ABAD-YSZ

Influence of granularity – local scale

SHPM mappings (Line scans)

- Granularity is visible in the SHPM map
- Changes with magnetic field \( \rightarrow \) reduced influence of the grain boundaries

Influence of granularity – local scale

Correlation

SHPM/EBSD

SEM/EBSD

- Good match between different types of local analysis
- Regions with low (negative) remanent field: magnetic field can penetrate
  → No/weak superconductivity although MO<6°
  → Possible reason: connectivity between two grains (precipitates, pores, non-coalesced YBCO islands)

Not only total MO but also microstructure of GB need to be considered!
Influence of granularity – local scale

*CSD-YBCO on Ni-5at.%W*

Remanent field profile at 4 K

- Some signature of granularity + envelope of global $J_c$
- Result of meandering grain boundaries
Influence of granularity – global scale

**SHPM mappings (Hall scan of trapped field profile at 77 K)**

1.3 µm YBCO on ABAD-YSZ

1.2 µm BHO:YBCO on STO

1.7 µm YBCO on NiW

Granularity is still an issue for RABiTS-based coated conductors!
Thick BaHfO$_3$ doped YBCO films on Ni-W

*Hall scan measurements at 77 K*

- Similar maximum $J_c$-values, but reduced granularity and homogeneity for BHO doping
- Reduced granularity for thicker films

*M. Sieger et al., IEEE TAS 25 (2015) 6602604
M. Sieger et al., IEEE TAS 26 (2016) 7500305

*M. Sieger et al., IEEE TAS (EUCAS 2017) submitted*
Summary

- Granularity of ABAD-YSZ films almost similar to films on STO single crystals
- **Granularity** has an influence on local $J_c$ in particular for RABiTS based coated conductors
- Intergrain $J_c$ on RABiTS is influenced by grain boundary angle and by local microstructure of the grain boundary
- YBCO layers with artificial pinning centers show reduced granularity
- Influence of granularity is further reduced in thick YBCO films
Thanks for your attention!