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ASC 2016 paper 1MOr2C-05. ASC Best Student Paper Contest (Materials) Third Prize Winner.

TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

Grain boundaries in coated conductors: still an issue at low temperatures?

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5 September 2016

ASC 2016, Denver, Colorado, USA

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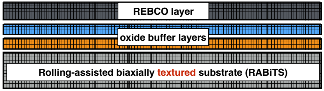
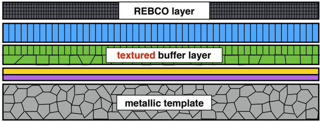
Introduction

- Grain boundaries (GBs) have been known to inhibit the current-carrying capacity of HTSCs.

$$J_c(\theta_{GB}) = J_c(0)\exp(-\frac{\theta_{GB}}{\theta_c}); \theta_{GB} \geq 4^\circ$$





- Biaxially textured metallic substrates and textured buffer layers has prompted production of long-length coated conductors (CCs) **with high J_c**.

[1]D. T. Verelbeyi, et al. APL 76, 13, pp. 1755-1757, 2000

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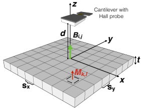
Motivation

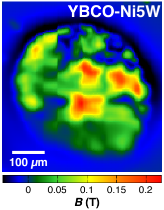
- The growing demand of large magnetic fields has called for operation of CCs to 4.2 K $\rightarrow$ **effects of GBs become more pronounced as temperature decreases.**
- We aim to investigate the collective effects of the GBs to the percolative current flow in CCs and its significance at low temperatures ($T < 77$ K).

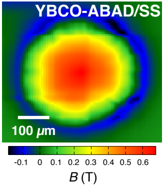
Magnetic field profile

Scanning Hall probe microscopy



- He gas flow cryostat
- T: 4 K – 300 K
- $\mu_0 H_{app}$: -5 T ... 5 T
- min s_x, s_y: 1 μm
- min d: 1 μm





- **Remanent field profile at 4 K**
- Pulsed laser deposited (PLD) YBCO on two types of metallic templates (IFW)
- Patterned by wet chemical etching (IFW).

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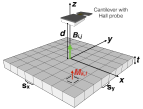

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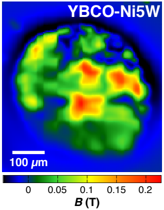
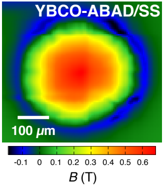


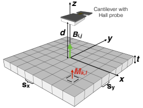
- 1.5 µm-thick YBCO
- Buffer layers:
  - CSD-$LaZrO_7$
  - CSD-CeO_2
- Substrate: **RABiT Ni-5at%W (Ni5W)**



- 1.5 µm-thick YBCO
- Buffer layers:
  - PLD-CeO_2
  - **ABAD-Yttria stabilized Zirconia (YSZ)**
- Substrate: stainless steel

Magnetic field profile

Scanning Hall probe microscopy



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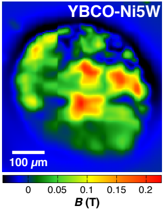
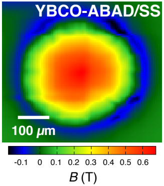
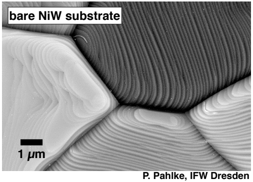


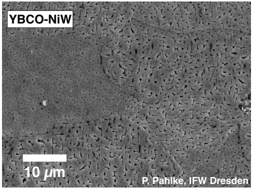


Striking difference: Formation of magnetic clusters in YBCO-Ni5W tape → directly related to granularity
It persists:

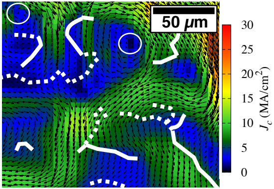
- under applied magnetic fields
- different temperatures
- with a **Ni-9at%W** template
- with a 10×20 mm^2-sized sample

Microstructure





- Each grain of RABiT Ni5W substrate is faceted at different angles (vicinal angle $< 10°$).
- The deposited YBCO layer reproduces the misorientation.
- Aside from percolative current flow, the spatial distribution of J_c is also inhomogeous.



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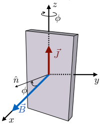
Transport J_c

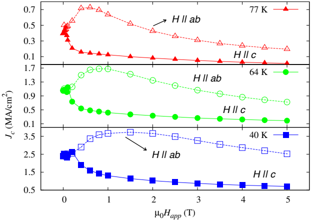
Transport J_c measurement



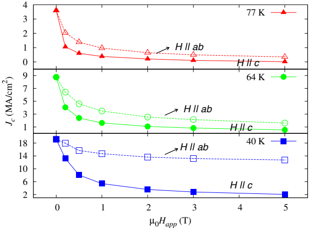
- $\mu_0 H_{app}$: -5 T – 5 T, split coil magnet
- T: 40-77 K
- ϕ: 0 – 360°

- Maximum Lorentz force
- $E = E_c \left(\frac{J}{J_c}\right)^N$, $E_c = 1\,\mu\text{V/cm}$
- 300 μm-width bridges - laser structured

YBCO-Ni5W

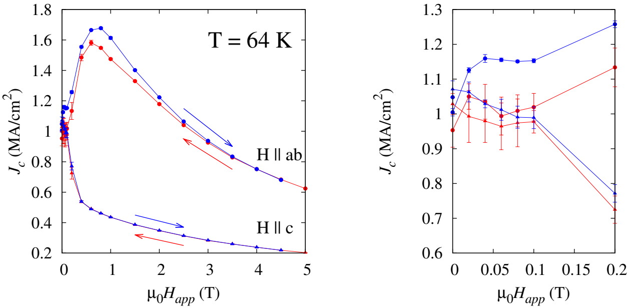


YBCO-ABAD/SS



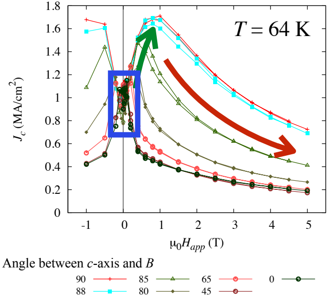
- Non-monotonic magnetic field dependence of J_c in the YBCO-Ni5W sample

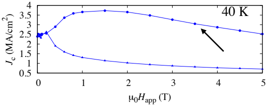
Transport J_c

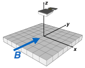


- $J_c(B)$ has a peak when $H \parallel ab$.
- Stochastic behavior at low fields, i. e. < 0.1 T.

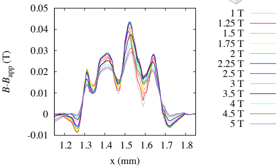
Transport J_c







H_{app} || *ab*-planes



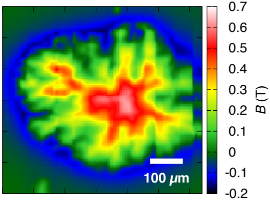
- **Grain boundary limited regime.**
- **Pinning limited regime.**
- **Cross-over.**

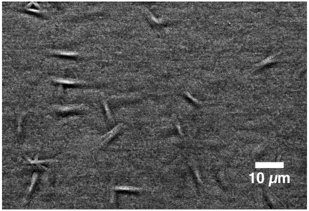
- **Cross-over** - Abrikosov vortices providing a periodic potential to pin vortices in GBs[3]

$$J_c = J_\circ \sqrt{1 + H/H_s} \qquad (1)$$

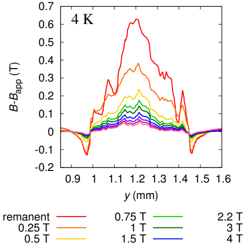
[3] A. Gurevich and L. D. Cooley, *PRB* **50** 13563 1994.

CSD grown-YBCO film





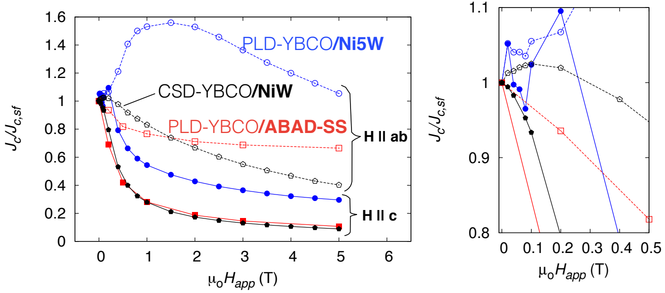
M. Sieger, IFW-Dresden



- Chemical solution deposited (CSD) YBCO on Ni-5at%W produced by Deutsche Nanoschicht (d-nano).
- No visible boundaries in the SEM image of the surface → meandering structure of GBs.
- The granular behavior in the field profile at T=4 K is significantly reduced.

CSD grown-YBCO film

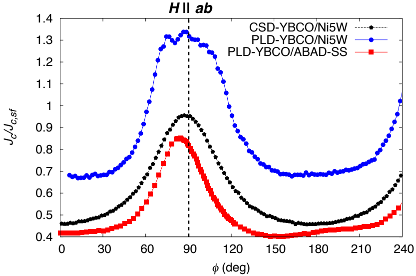
$J_c(B)$ at 40 K



- The peak in $J_c(B)$ at $H \parallel ab$ is reduced and shifted to low fields in CSD-YBCO sample.

CSD grown-YBCO film

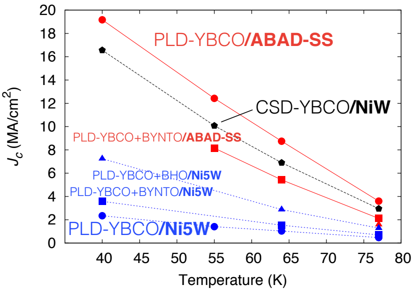
$J_c(\phi)$ at T =40 K and $\mu_\circ H_{app}$ =0.5 T



- The ϕ-independent region is not observed.
- Although, $J_{c,H\|ab}$ increases to a value close to its self-field.

Self-field J_c

Self-field J_c



- The PLD-YBCO on NiW sample has lower J_c compared with PLD-YBCO on ABAD/SS substrate. Both CCs are short lab samples.
- The CSD-YBCO on NiW, a piece from a long length commercially produced tape, has competitive J_c value. It's performance is optimized at 77 K.

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Conclusions

- Granularity effects are still found to be strongest in PLD-YBCO films on RABiTS NiW.
- A clear transition from grain boundary limited to pinning limited J_c was shown in transport measurements.
- The grain boundary limited regime including the cross-over region occurs up to 2 T at 40 K and will span a larger range in field as temperature decreases.
- CSD-YBCO is a promising route to minimize the effects of granularity due to the meandering formation of the boundaries compared to the planar form in PLD-grown films.

Acknowledgments

- Dr. Johannes Hecher, TUW
- Dr. Michael Eisterer, TUW
- Dr. Ruben Hühne, IFW
- Patrick Pahlke, IFW
- Max Sieger, IFW
- Dr. Martina Falter, Deutsche Nanoschicht
- Dr. Alexander Usoskin, Bruker

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Conclusions

Thank you!