deutsche nanoschicht

Chemistry meets Energy

Development of cost-effective chemical solution deposition YBCO superconductor tapes

R. Feenstra, B. Wojtyniak, J. Kunert, J. Bennewitz, M. Falter, M. Rikel, M. Baecker

Deutsche Nanoschicht GmbH
Heisenbergstr. 16
53359 Rheinbach
www.d-nano.com

Federal Ministry of Economics and Technology

Outline

Introduction
- Deutsche Nanoschicht, GmbH
- Process technology: Chemical Solution Deposition (CSD)

Performance/ YBCO properties
- CSD conductor architecture/ YBCO process
- Performance: 50-100 m long tapes
- Properties: incl. H-, T-, θ-dependences

Summary

Deutsche Nanoschicht GmbH

Part of BASF group since June 2013
- 63 employees, Rheinbach and Heidelberg, Germany

High Temperature Superconductor (HTS) wires
- ceramic functional layers, magneto-calorics, 3D-printing

Chemical Solution Deposition (CSD)
- unique and protected CSD-multi-layer technology

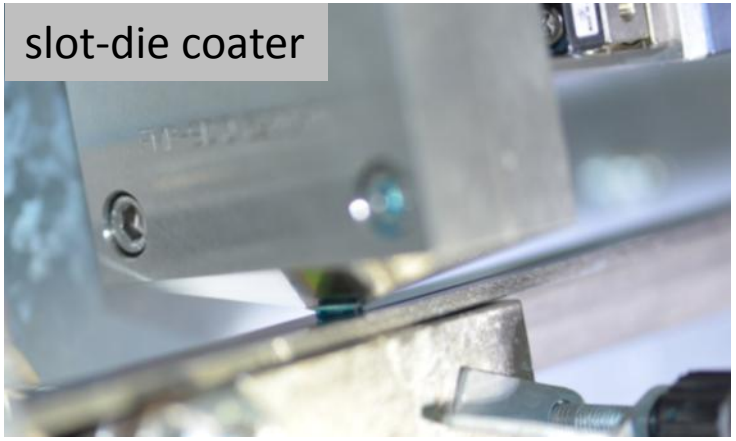
D-Nano process technology

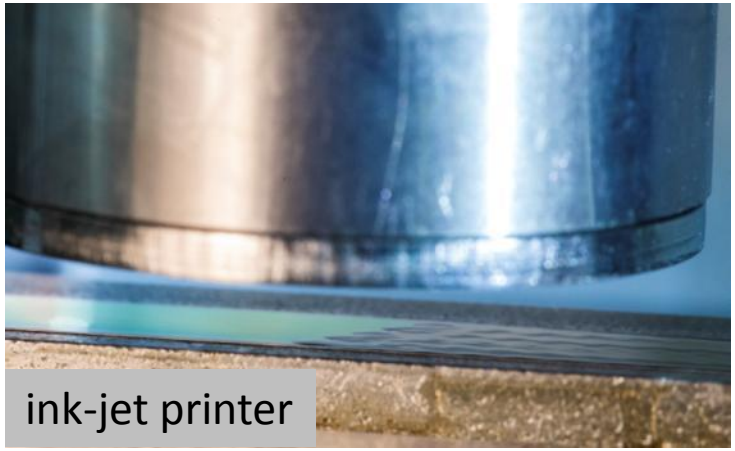
Chemical Solution Deposition

- All-CSD architecture: Buffer layers, HTS, Ag
  - reduced equipment cost
    - slot-die/ ink-jet deposition (1 atm operation)
    - furnaces (simplified design/ construction)
  - 95+% material usage
  - variable deposition width
    - production volume scales with tape width

➢ Competitive price/performance ratio (€/kA.m)

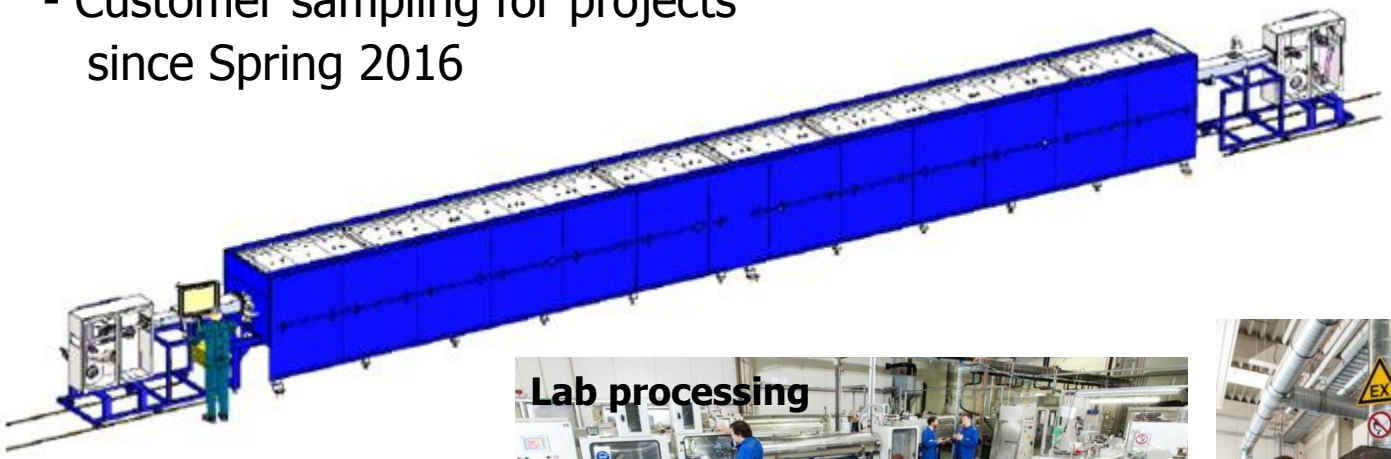
➢ Viable path to large volume (10^3-10^4 km/yr)

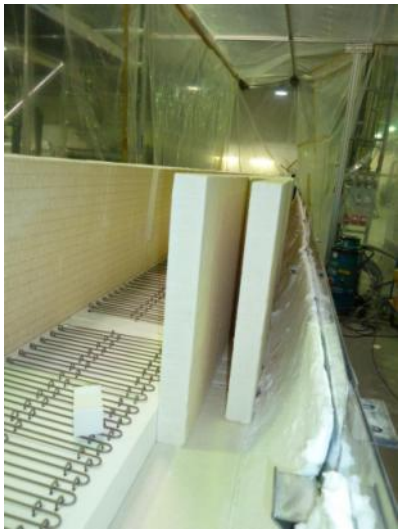

slot-die coater

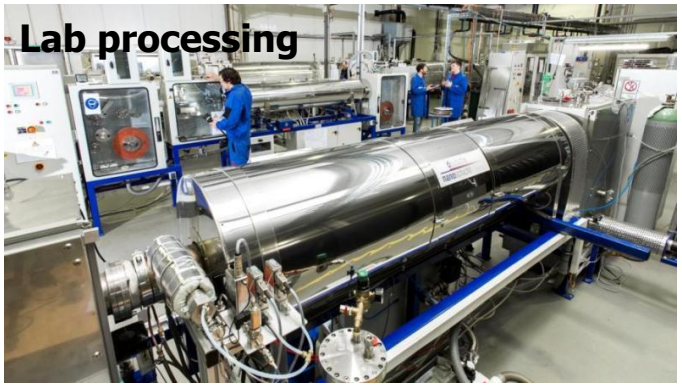

ink-jet printer

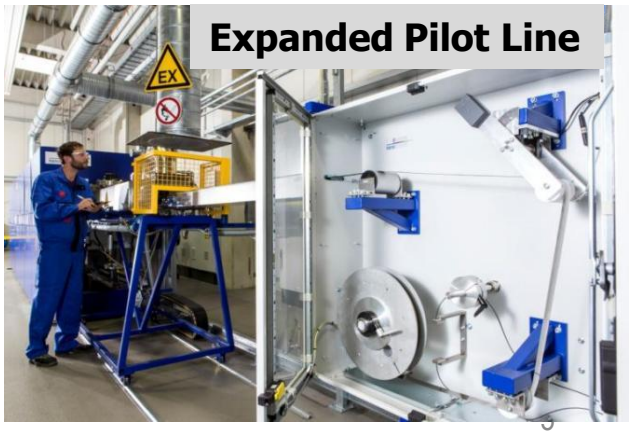
D-Nano Expanded Pilot Line (EPL)

- Production capacity: >200km/yr (HTS conductor)
- Commissioned in 2016, fully operational in 2017
- In-house design/ construction of key technology
- Customer sampling for projects since Spring 2016



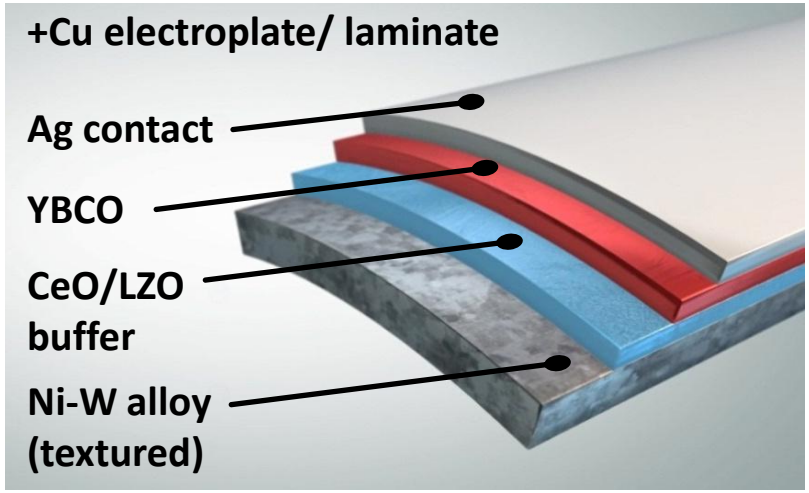




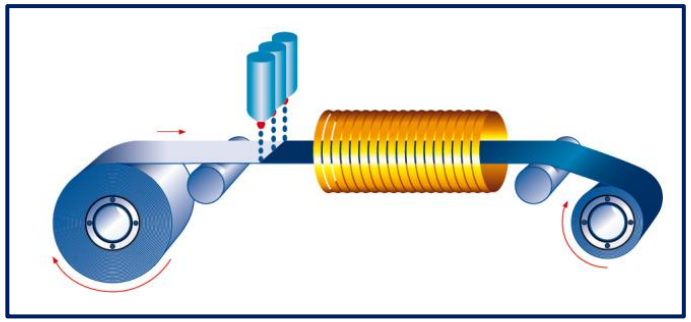


D-nano CSD conductor

- **Architecture**
  - biaxially textured substrate Ni-W5/Ni-W9
  - LZO+CeO buffers: CSD (300 nm)
  - YBCO: TFA-CSD
  - Ag contact: CSD (1000 nm)
  - coating width: 10 mm -> 40 -> 100 mm
  - protection: electro-plated Cu lamination



- **YBCO process/ properties**
  - slot-die coating, in-line pyrolysis (2-3x 500 nm)
  - sub-atmospheric crystallization furnace (full-thickness)
  - c-axis epitaxial laminar growth (GB meandering)
  - J_c = 1.8-2.5 MA/cm^2 (77 K, 0 T)
  - T_c = 88-91 K (over-doped)
  - pinning: growth-induced defects



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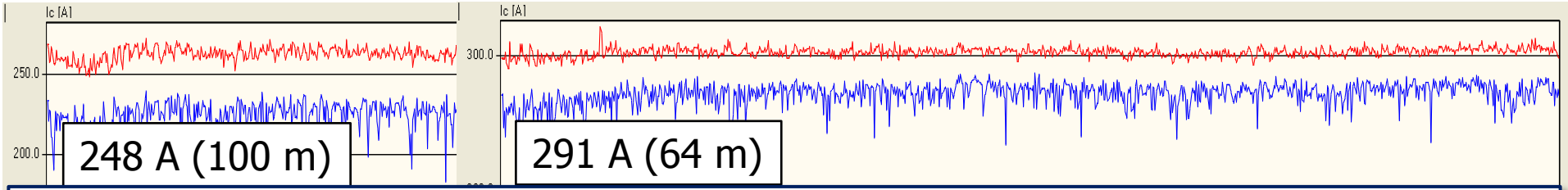
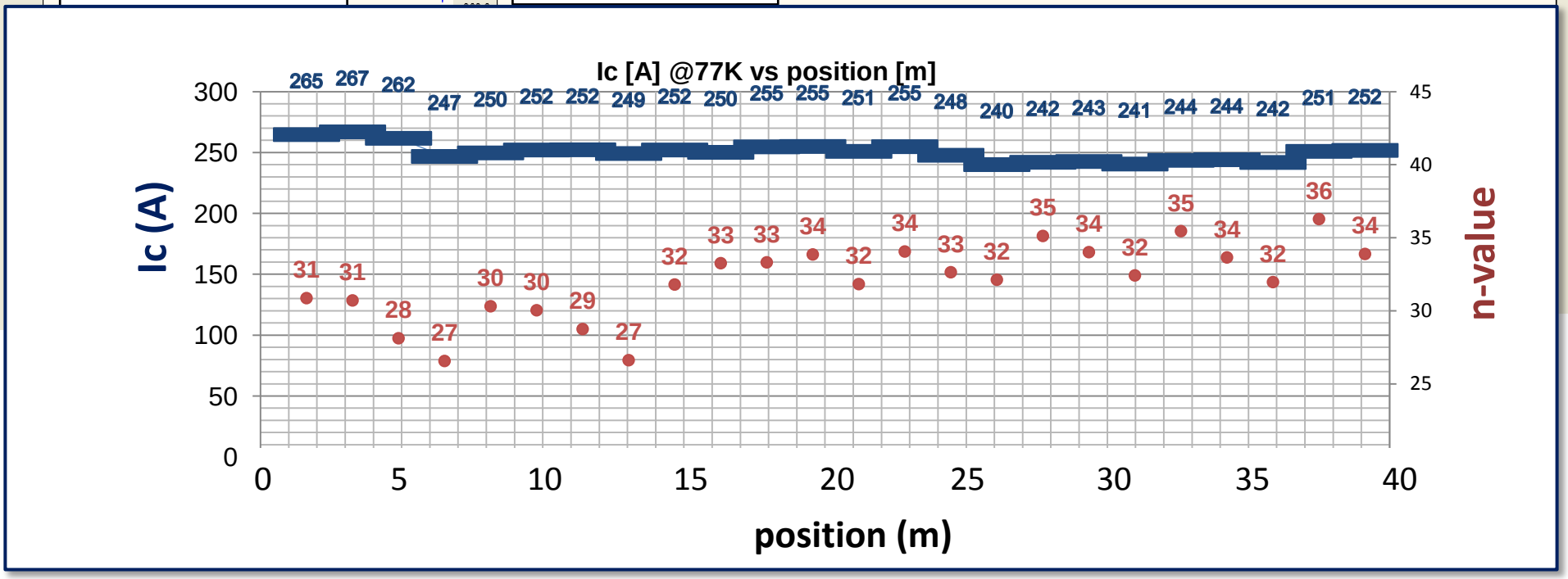
EPL produces 50-100 m tapes with $I_c \cong$ 250-300 A/cm

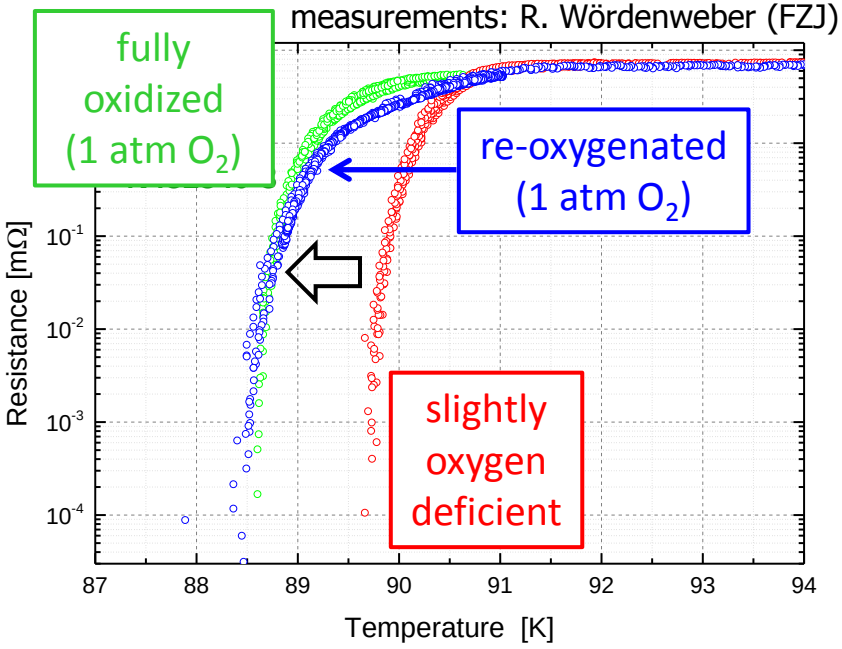
- Tapestar calibrated against transport I_c (homogenous tapes)

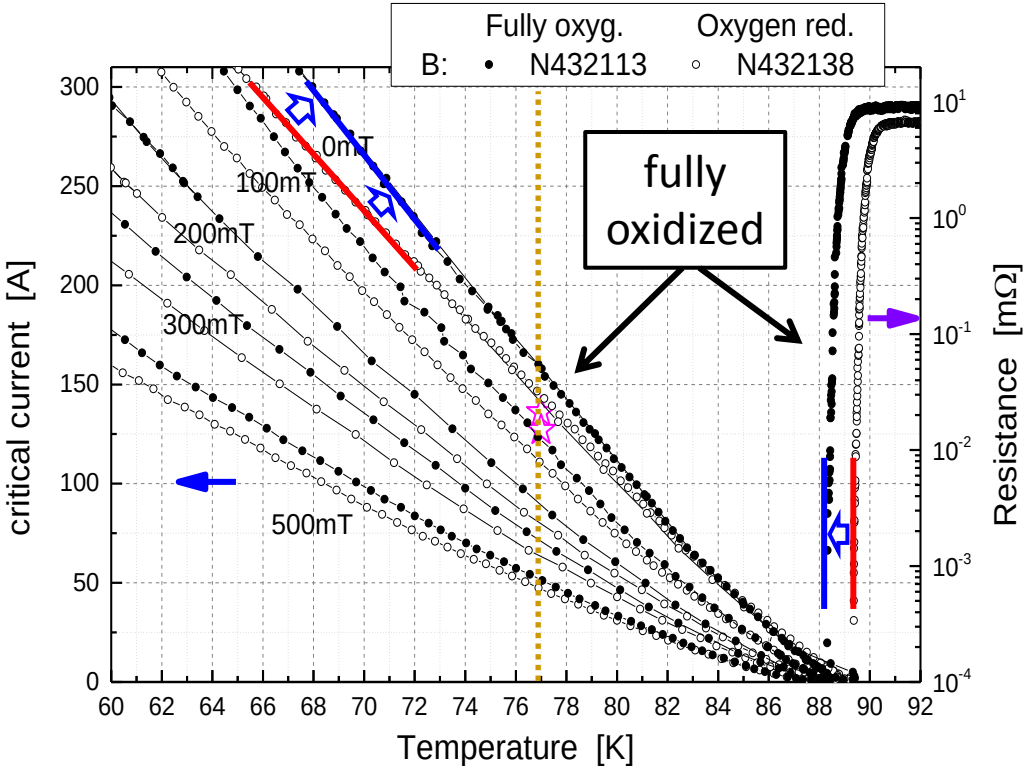




Hole-overdoped YBCO: strong low-T and in-field performance

- overdoping: T_c decreases (slightly) after full oxygenation

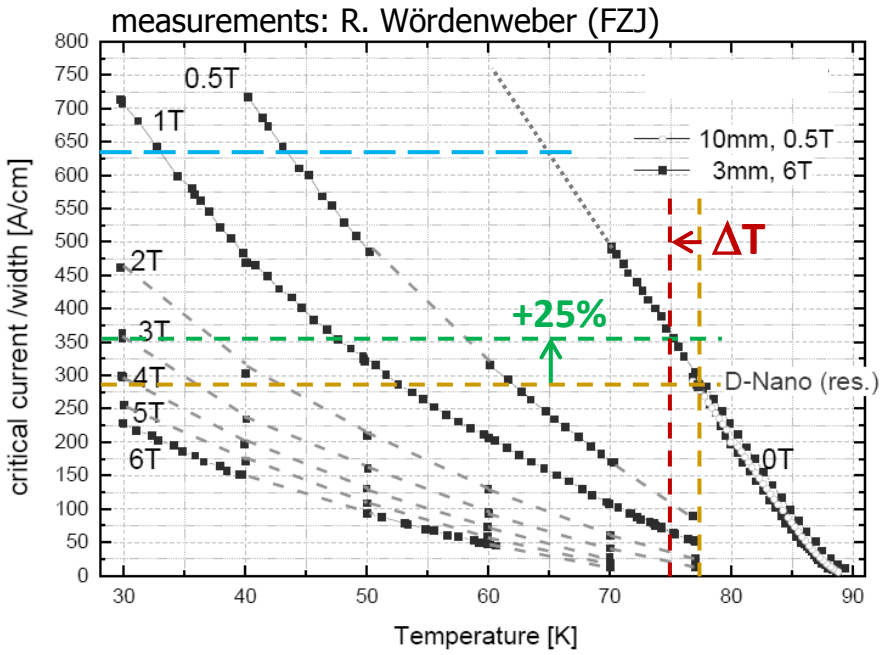




Phys. Rev. B **45** (1991) 7555
Physica C **416** (2004) 1
Appl. Phys. Lett. **104** (2014) 242601-1

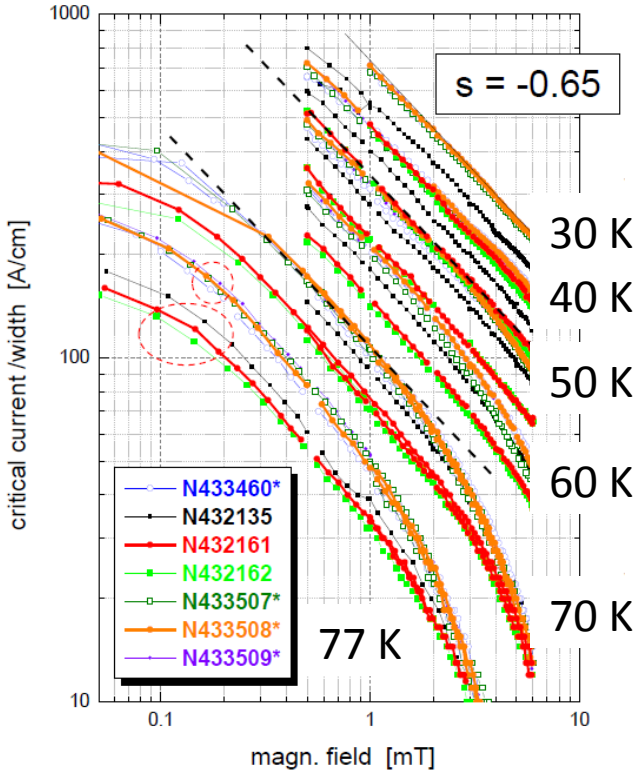
I_c depends strongly on operating temperature in LN2 regime

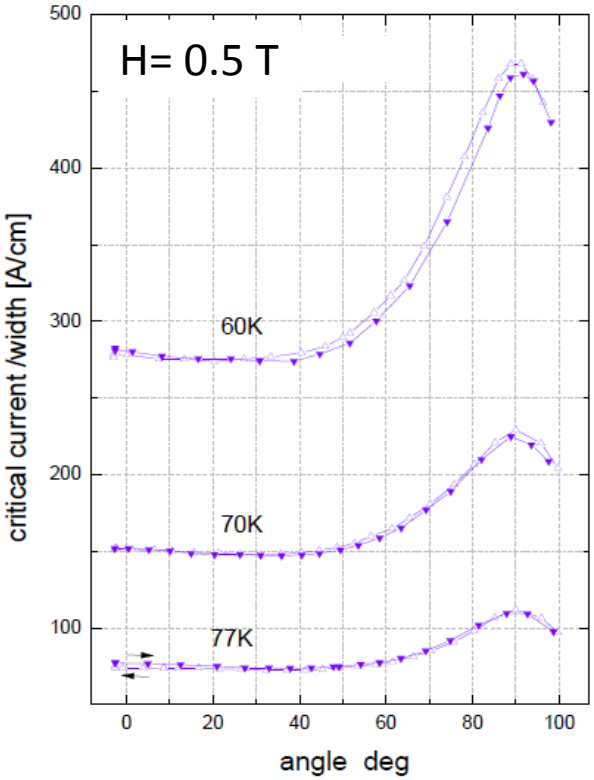
- I_c increase with cooling below 77.3 K: ΔI_c = +25% -> $|\Delta T| < 3$ K
  - similar after Cu-plating, Ni-W5at%, Ni-W9at% substrates
- Lift factor Ic(65K, 0T)/Ic(77K, 0T) = 2.5
- Lift factor Ic(30K, 1T)/Ic(77K, 0T) = 2.5-2.9



H-field strength and orientation dependence of I_c (typical)

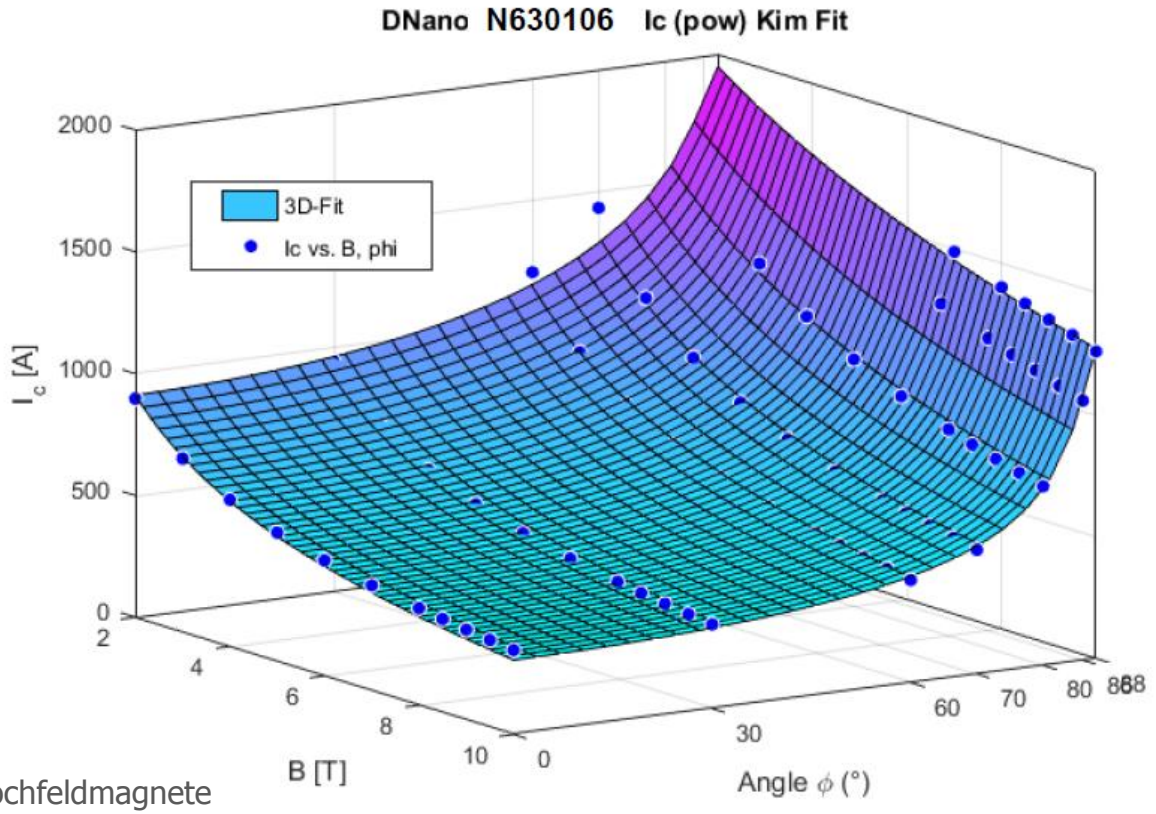
- log-log $I_c(H)$ coefficient $|\alpha| = 0.65$
- semi-isotropic at 77 K -> stronger angular dependence at reduced T





D-nano conductor exhibits strong behavior at 4.2 K

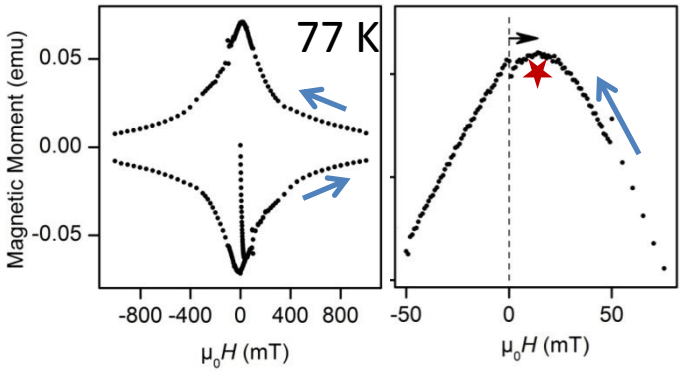
- High-current transport measurements at KIT
- I_c(77K, 0T)= 247 A leads to I_c(4.2K, 10T)= **350 A** (H||c) and **900 A** (H||ab)



CSD template enables efficient current transport

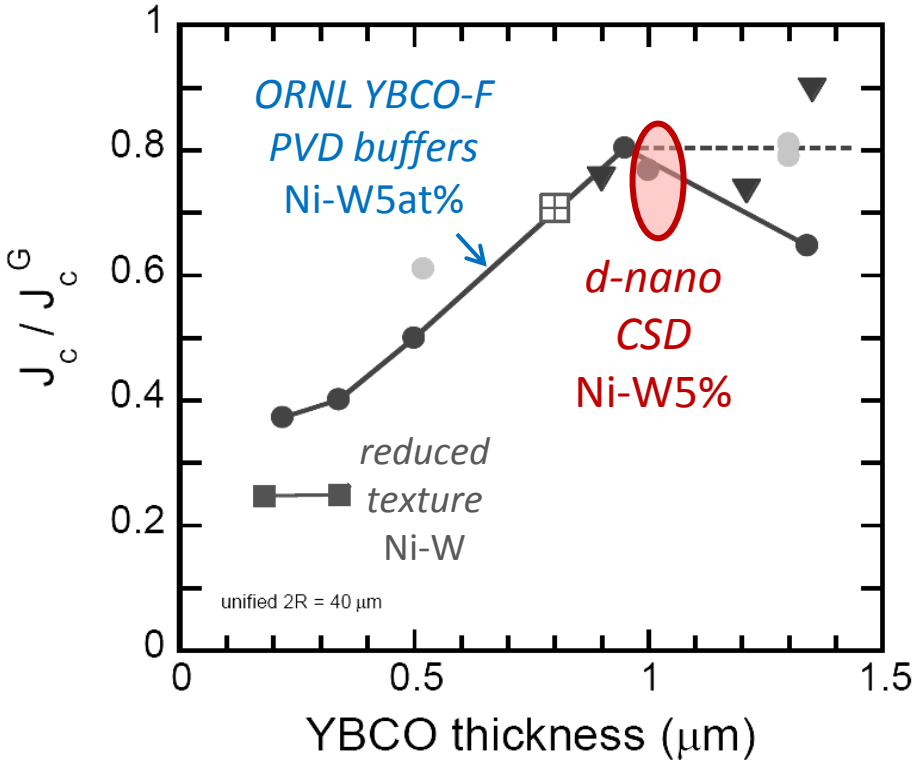
- 75-80% of maximum (intra-grain) J_c^G reached (1000 nm YBCO)
  - good metal/ buffer layer texture, grain boundary meandering

measurements: J. Hänisch (2014-IFW/ KIT)



Intra-grain J_c^G derived from magnetic granularity effect (SQUID)

- J_c^G = 2.3 MA/cm^2
- J_c = 1.8 MA/cm^2



Supercond. Sci. Technol. **24** (2011) 062001
J. Mater. Res. **20** (2005) 2012
Phys. Rev. B **75** (2007) 054517

Summary

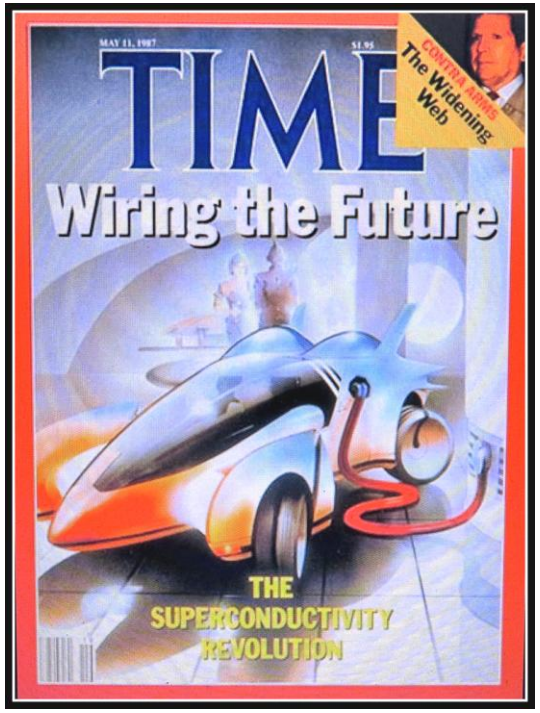
- D-Nano developed all-CSD technology for YBCO wires
  - textured Ni-W substrate
  - CSD: LZO+CeO buffer layers, YBCO, Ag

- Extended Pilot Line: commissioned in 2016; fully operational in 2017
  - planned capacity: >200km/yr HTS conductor wire
  - presently: 1 cm tape width
  - scaling to 4 (10) cm-w in progress

- 50-100 m YBCO tapes with $I_c \geq 250$ A/cm-w (77 K)
  - HTS conductor with electro-plated Cu (lamination)
  - back-to-back lamination doubles I_c (2x250 = 500 A)

- Sample tapes supplied to customers/ projects

Thank you for your attention!



May 11, 1987