chemistry meets energy

All-Chemical-Solution Coated Conductors at Deutsche Nanoschicht GmbH

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Federal Ministry
of Economics
and Technology

Outline

- Deutsche Nanoschicht GmbH
- Process technology
- Expanded pilot line
- Performance
- Technical HTS conductor
- Summary

Deutsche Nanoschicht GmbH

- Since June 2013 part of BASF group
- 63 employees , located in Rheinbach and Heidelberg, Germany
  - High Temperature Superconducting (HTS) wires,
    - chemical solution deposition, ceramic functional layers, ink-jet-printing, epitaxial growth
  - Additive manufacturing / 3D-printing

High Temperature Superconductors

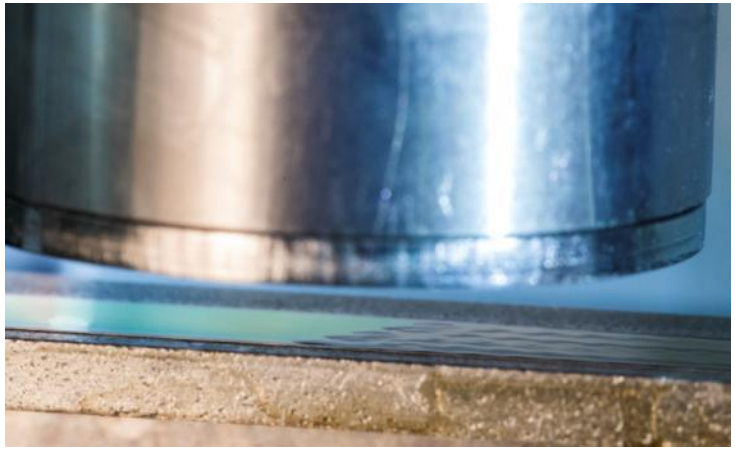
- Challenges for development and production
    - Best price performance ratio (€/kAm)
    - Scalable large volume production
    - Reliable and in-time supply
    - Flexible but mechanically and electrically stable

Process Technology

- Chemical solution deposition

  - Chemical solution deposition (CSD) for all layers is considered to be the „most promising and most challenging process“

  - Unique and protected CSD-multi-layer technology



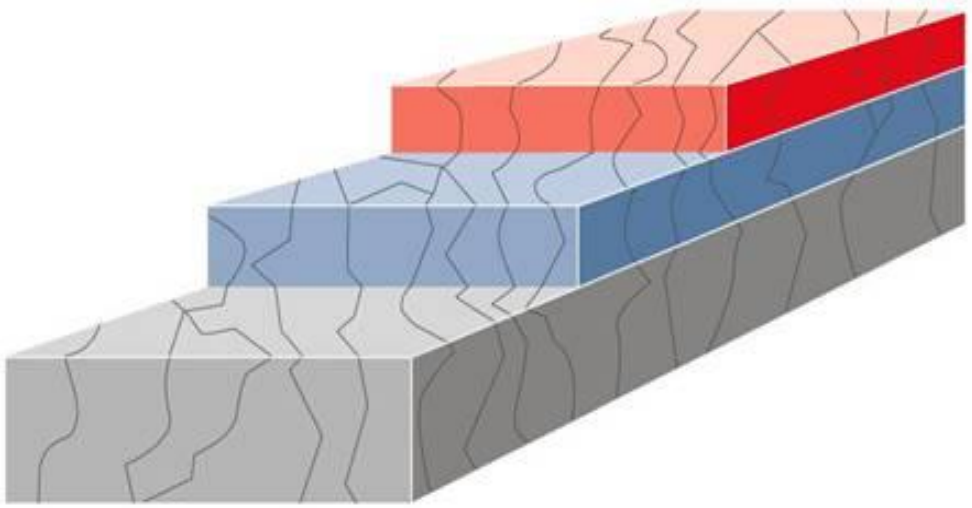
Process Technology

- HTS wire architecture – thin flexible ceramic coatings

Superconductor layer
$YBa_2Cu_3O_x$ (YBCO)

Buffer layer
$La_2Zr_2O_7$ (LZO), CeO_2

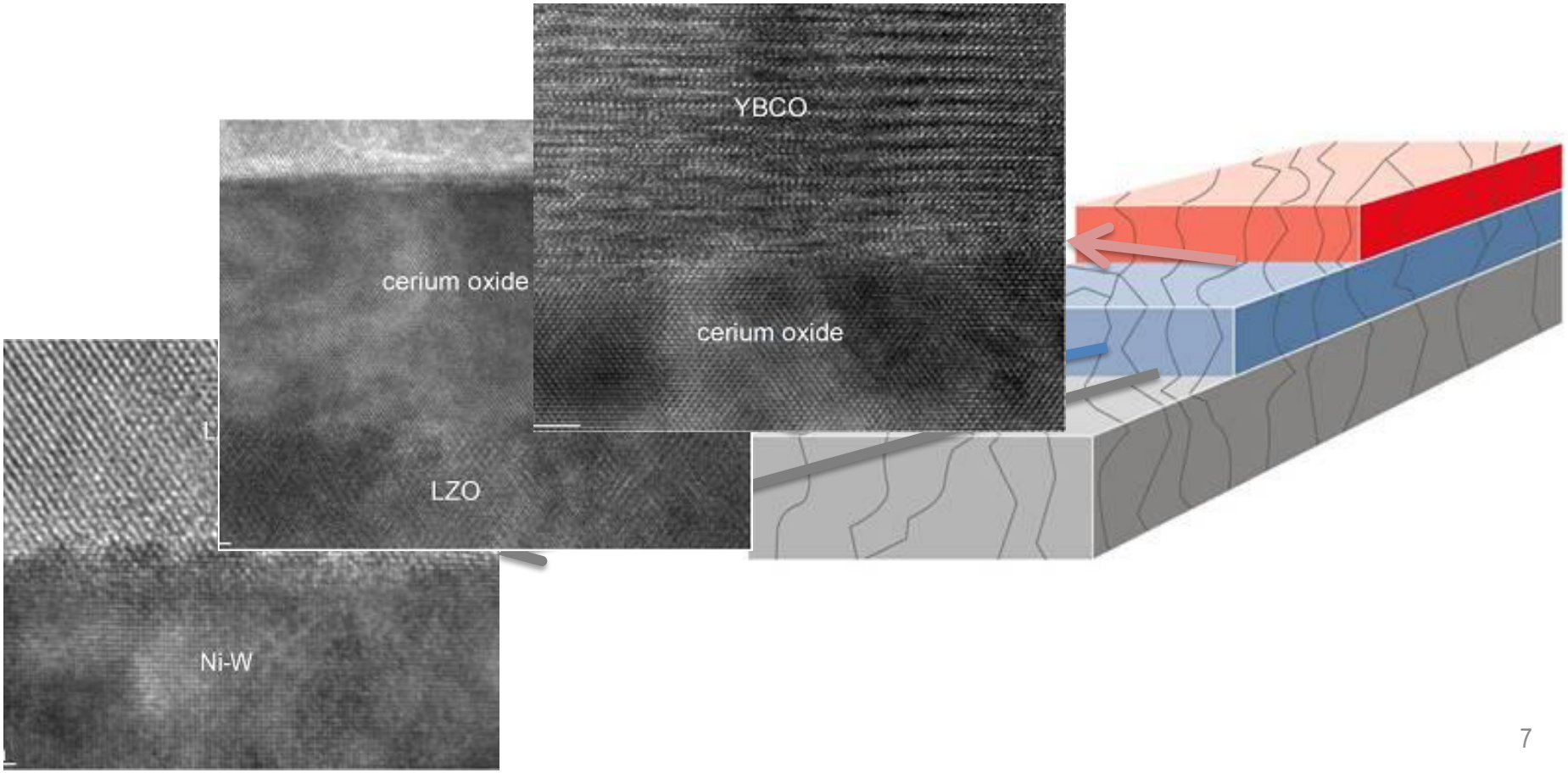
Metal alloy substrate
NiW-alloy



Process Technology

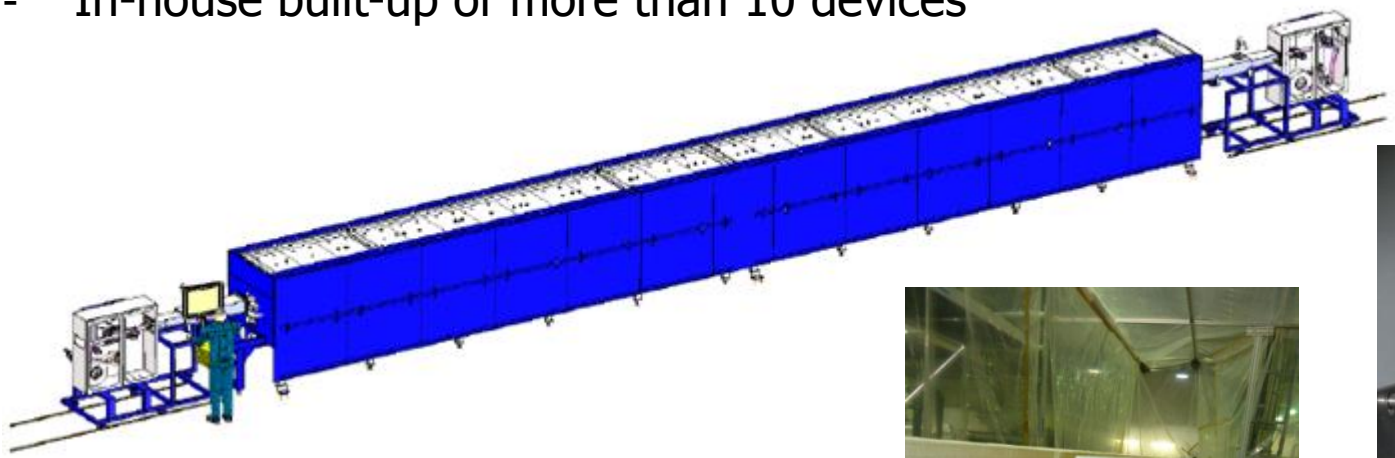
universitätbonn
Rheinische Friedrich-Wilhelms-Universität Bonn

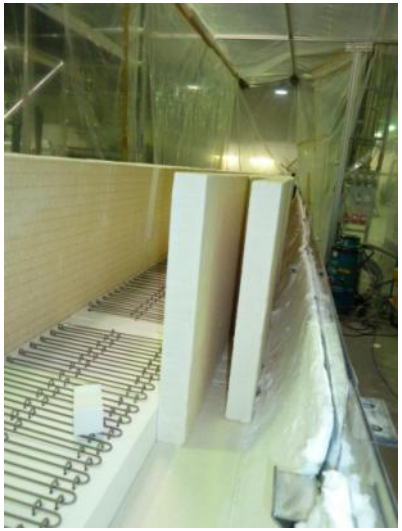
- HTS wire architecture – thin flexible ceramic coatings

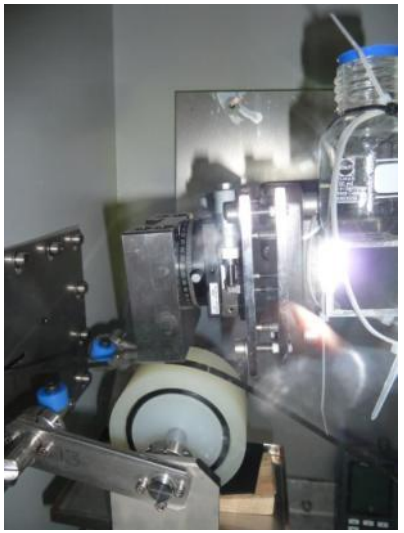


Expanded pilot line

- Construction of key process devices in house
- In-house built-up of more than 10 devices







Expanded pilot line

- Opening of expanded pilot line in Rheinbach at 10th May 2016

Expanded pilot line

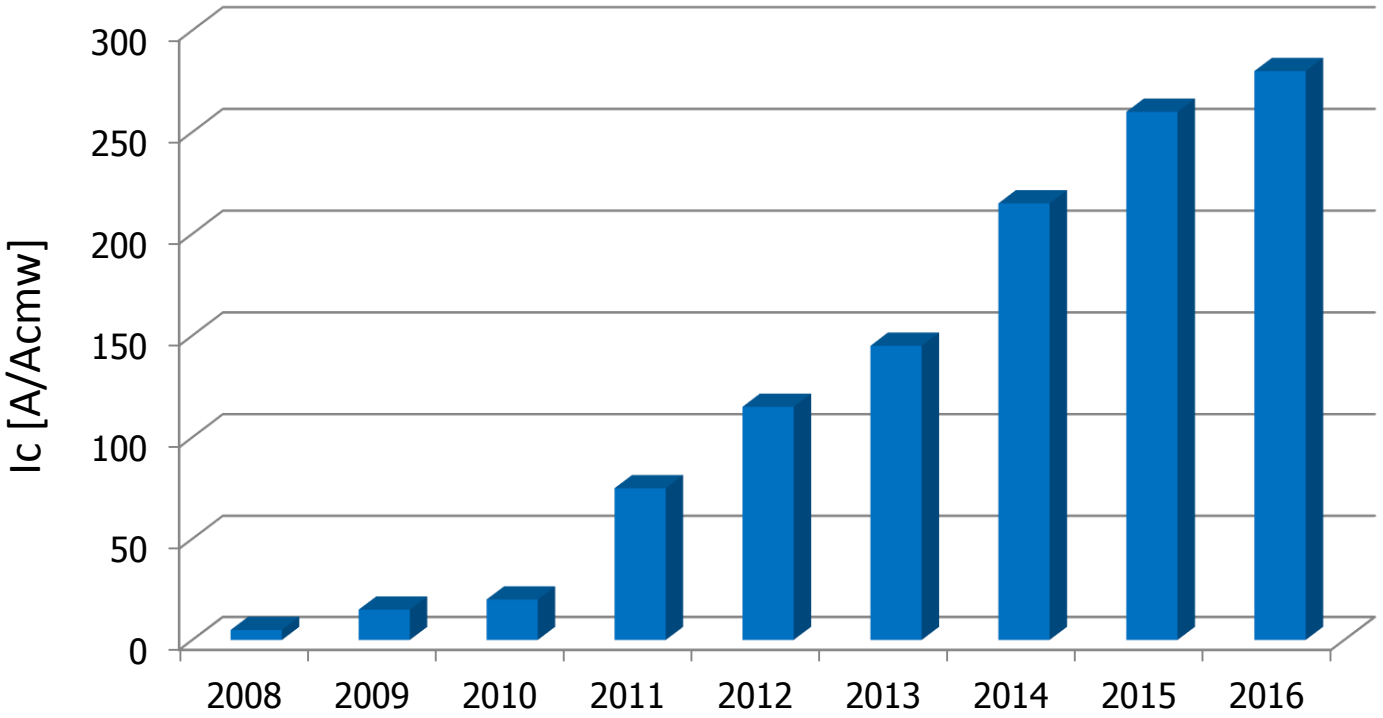
- EPL construction until mid 2016 completed
- EPL capacity ramp-up completed. Increasing the yield is ongoing.
- Theoretical capacity > 200km technical HTS wire
- Started sampling for projects in 2016

Lab processing

Expanded Pilot Line

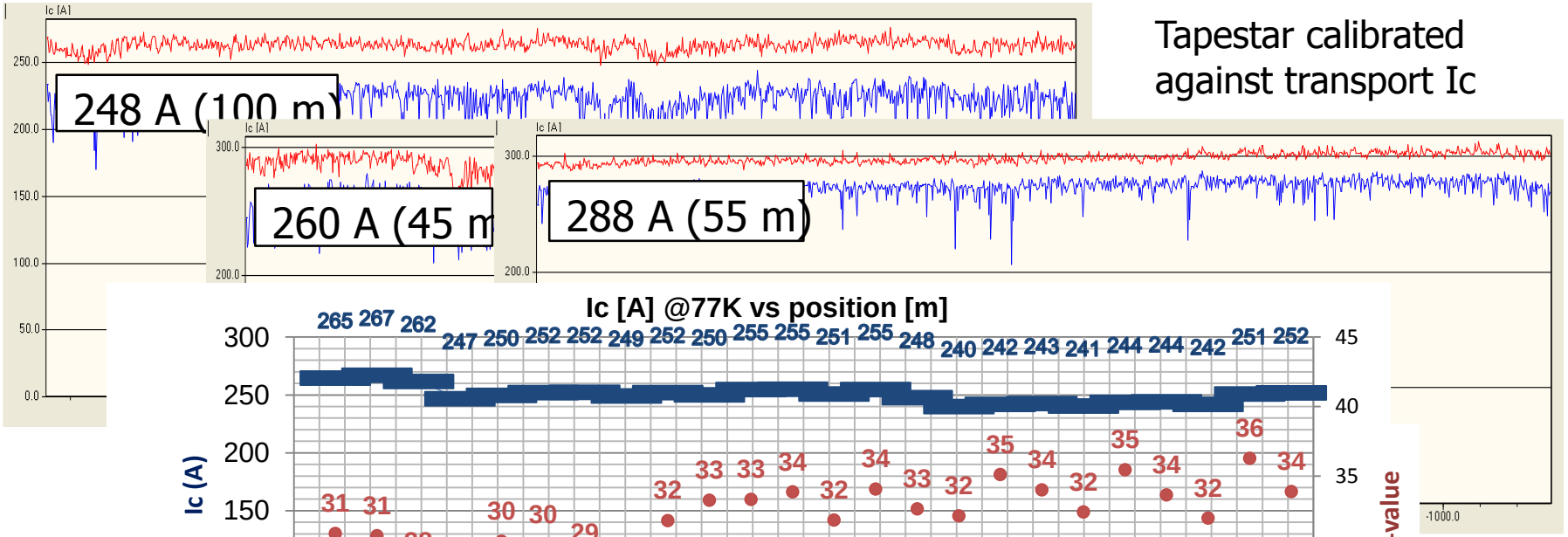
Performance

- Development with industrial partners over nearly 10 years
  - Long lengths samples >20m



Performance

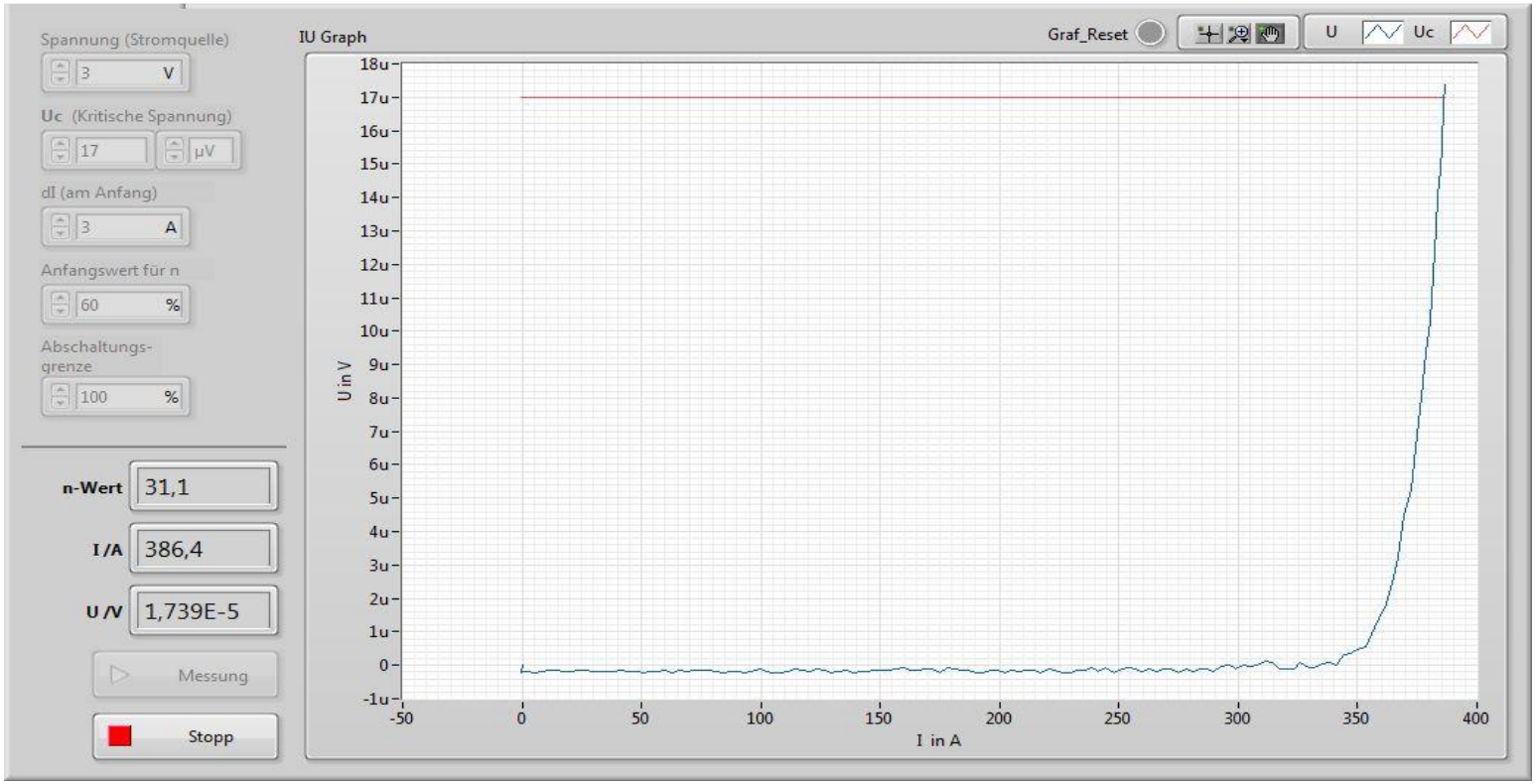
- D-nano has produced in 2016 1cm wide 50-100m tapes with Ic ≅ 250 A/cm



Tapestar calibrated against transport Ic

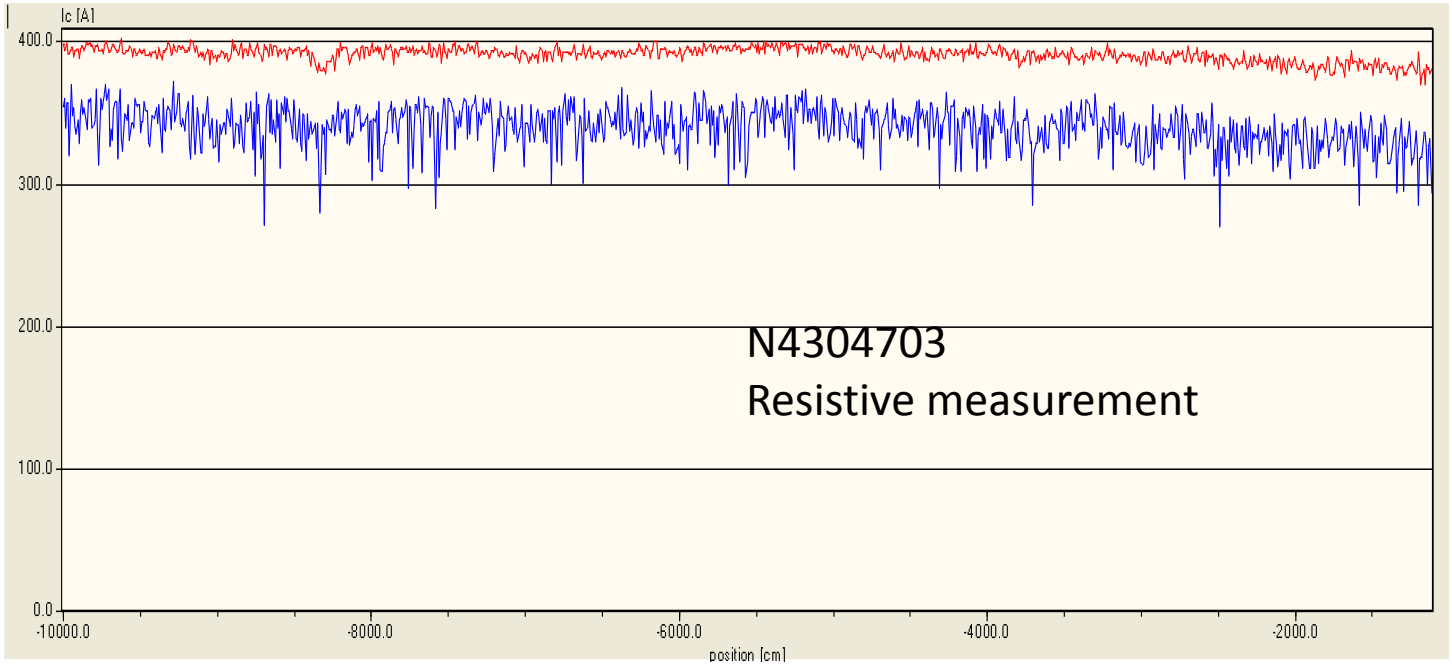
Performance

- Recent record value on EPL with length >20m (10mm width uncut)



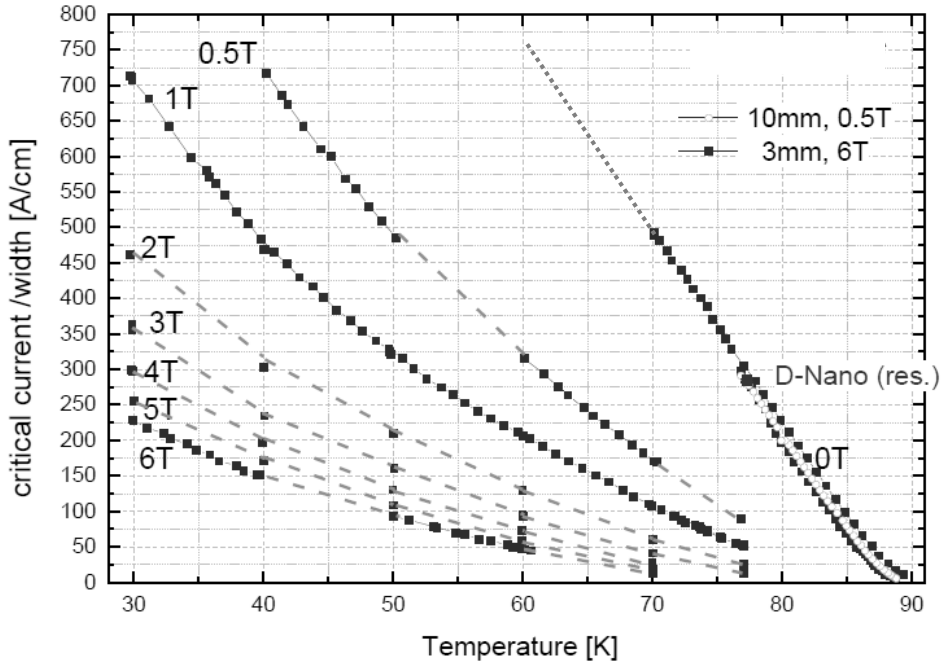
Performance

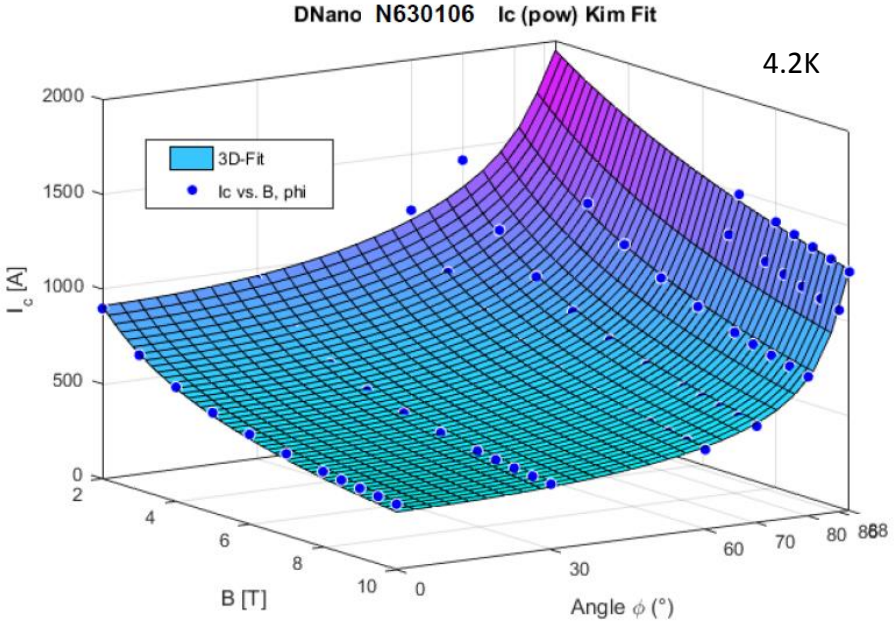
- EPL at 6 month after opening: 90 m long / 10 width uncut



Performance

- Typical behavior in magnetic fields

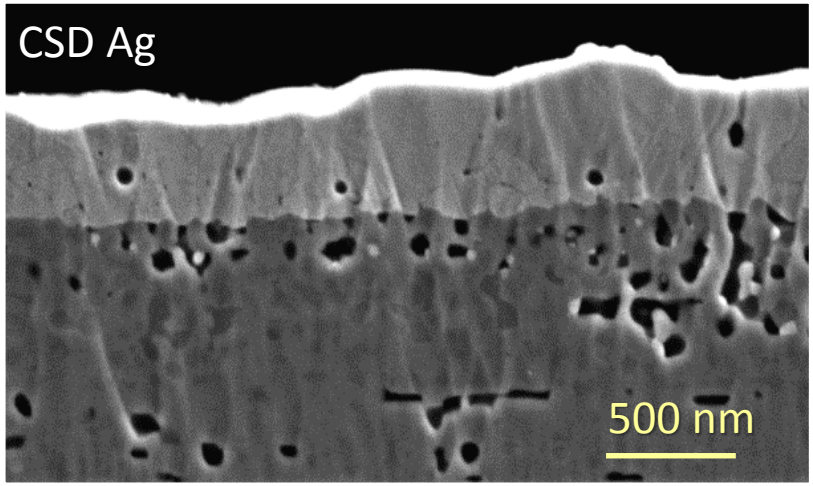




Technical HTS conductor

- Silver coating
  - Unique chemical solution deposition process
  - Fast and vacuum-free processing
  - Thin and dense coating

Sample	T_c (K)	ρ contact ($\mu\Omega cm^2$)
N433460	90.1	< 0.45
N432135	88.2	< 0.68
N432161	88.2	< 0.38
N432162	86.4	< 0.45
N433507	89.9	< 0.60
N433508	89.4	< 0.35
N433509	89.3	< 0.30



Technical HTS conductor

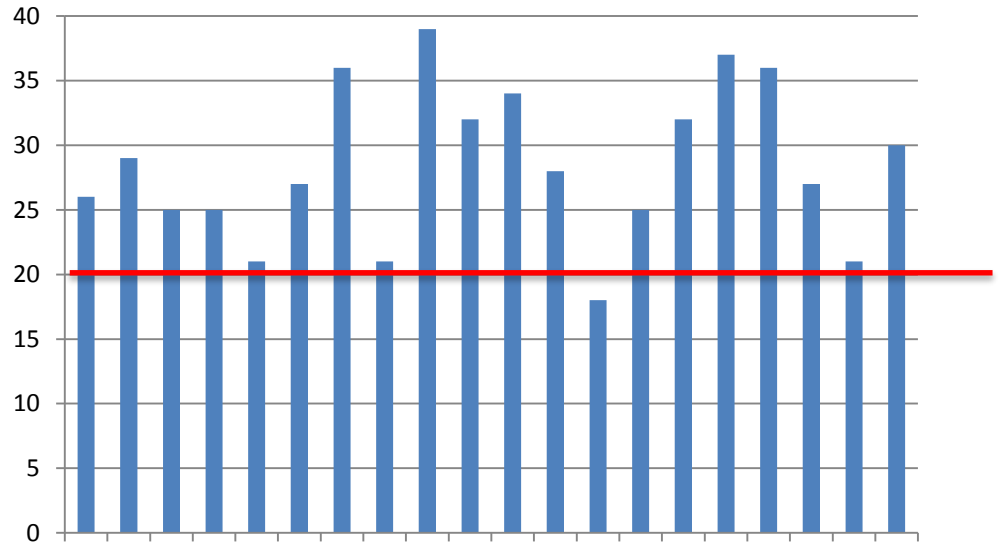
- Copper electro-plating
  - Homogeneous coating
  - Variable copper layer thickness
  - Low contact resistance

Cu-plated HTS conductor, 45µm single Cu-layer

Sample	Cu layer thickness	T_c (K)	ρ contact ($\mu\Omega cm^2$)
N630078	9µm	89.8	7.5
N630095	40µm	89.8	3.7
N630102	9µm	89.8	2.3
N630106Z	45µm	88.7	4.2

Technical HTS conductor

- Delamination strength
  - c-axis tensile av. 28(6) MPa (bare insert, non-laminated)
  - Architecture suitable for most energy applications



Threshold for cable applications

Specimen geometry: 12.8 x 6.4 mm² (soldered on 10 x 20 mm² sample)

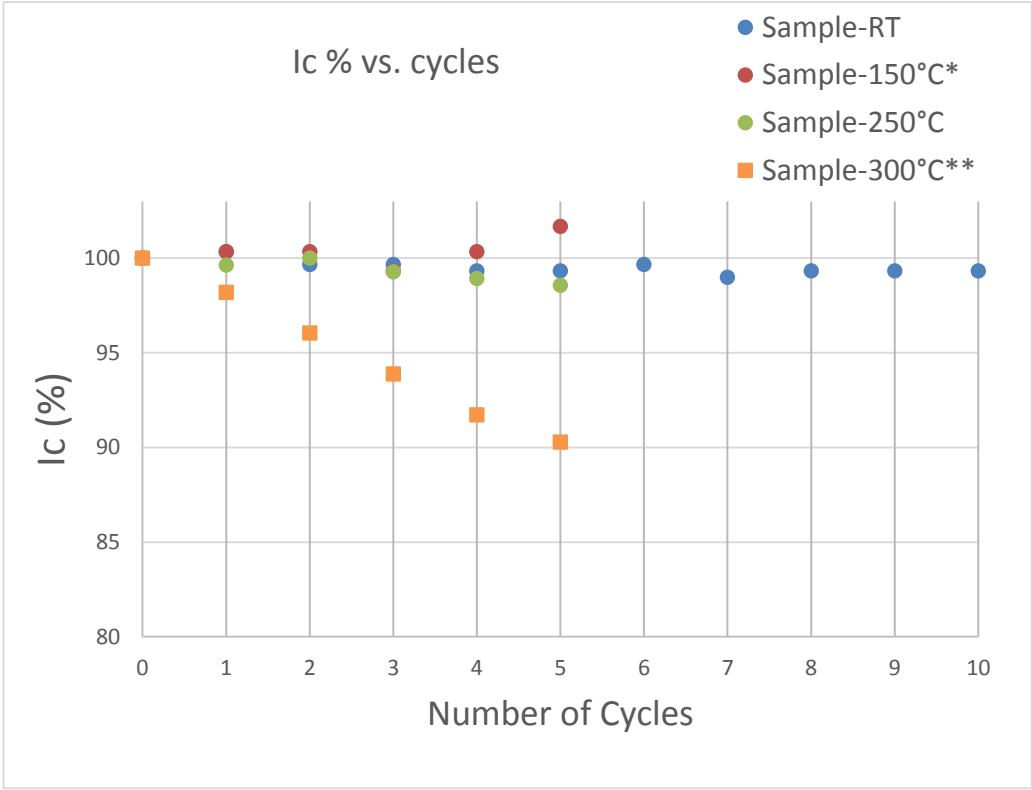
Technical HTS conductor

Temperature Stability

Tested CC with copper coating

- 250 deg C for >1 hour
- 300 deg C for 30 min

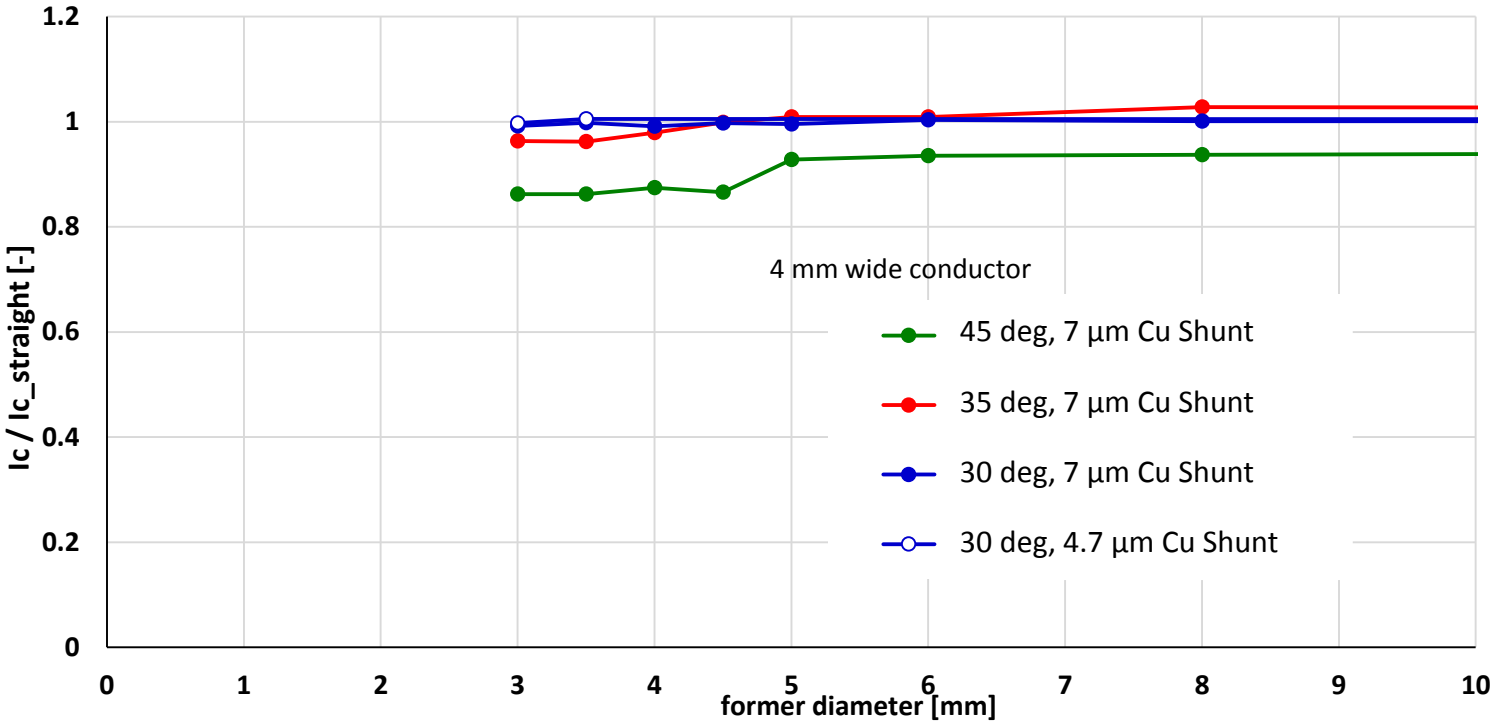
Material suitable for welding or soldering



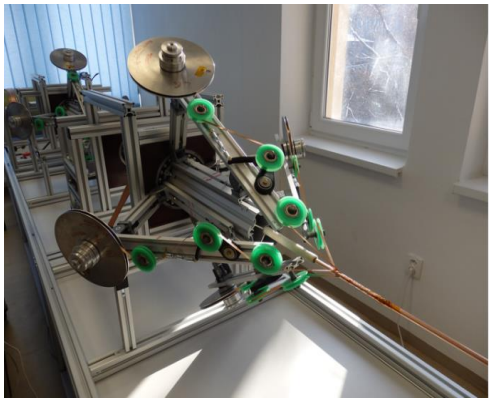
Duration per cycle : 30 minutes @ peak T

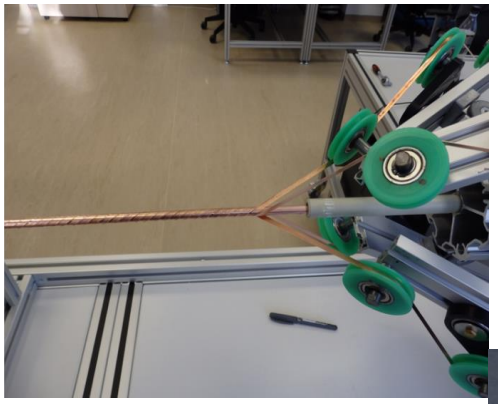
Technical HTS conductor

Bending tests (e.g. for CORT geometry)

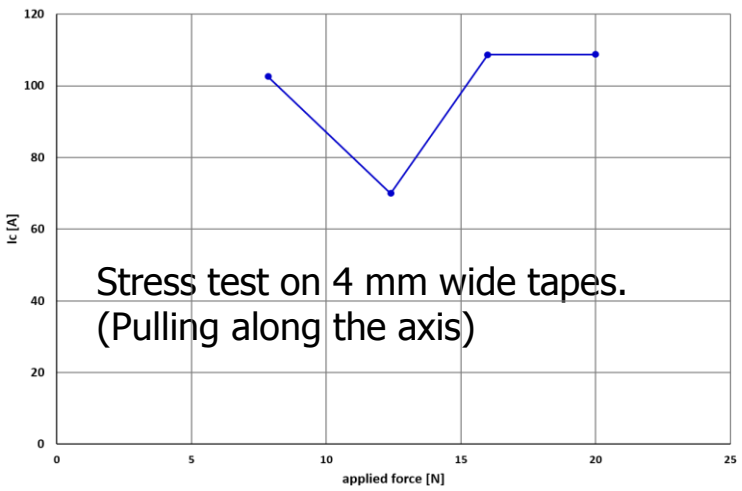


CORT Cable





- about 9 m long
- 2 layers
- 4 tapes in each layer
- lay angle about 33°
- tension during winding 20 N

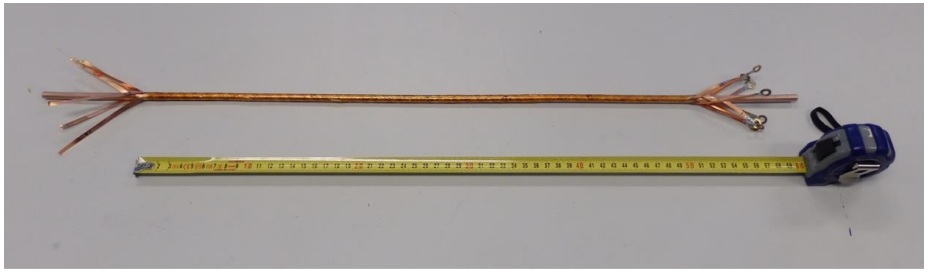


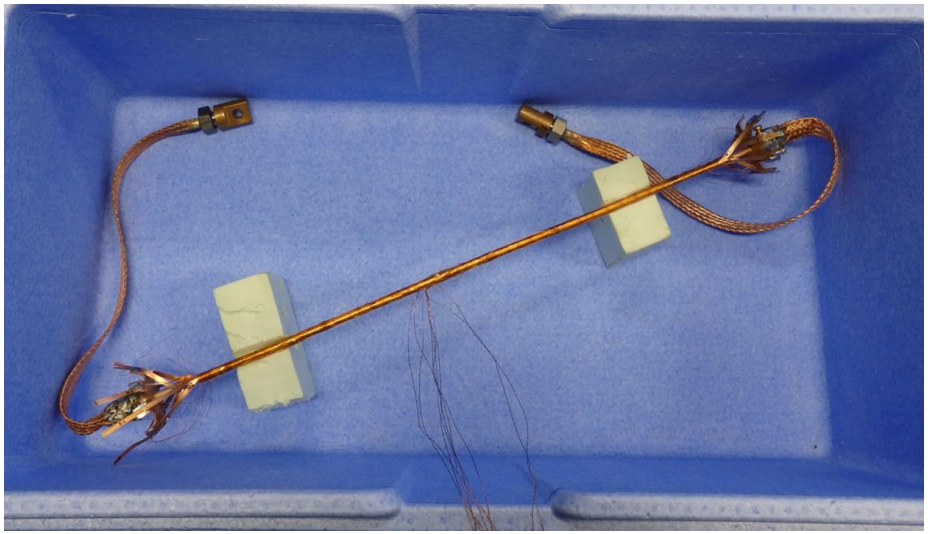
Stress test on 4 mm wide tapes.
(Pulling along the axis)

Technical HTS conductor

CORT cable, IEE Bratislava:

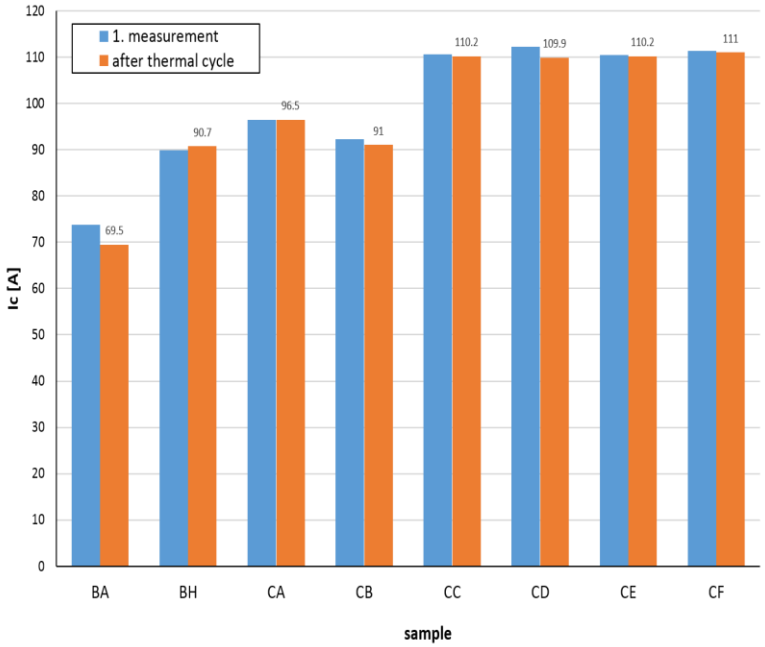
- 4mm copper coated tape
- 2 layers, 4 filaments each
- 6.35 mm tube
- 32° lay angle

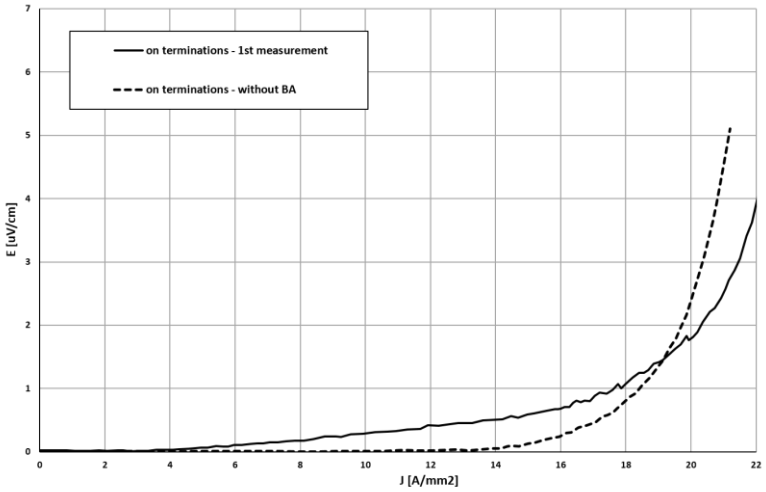




CORT cable

8 individual 4 mm filaments in 2 layers

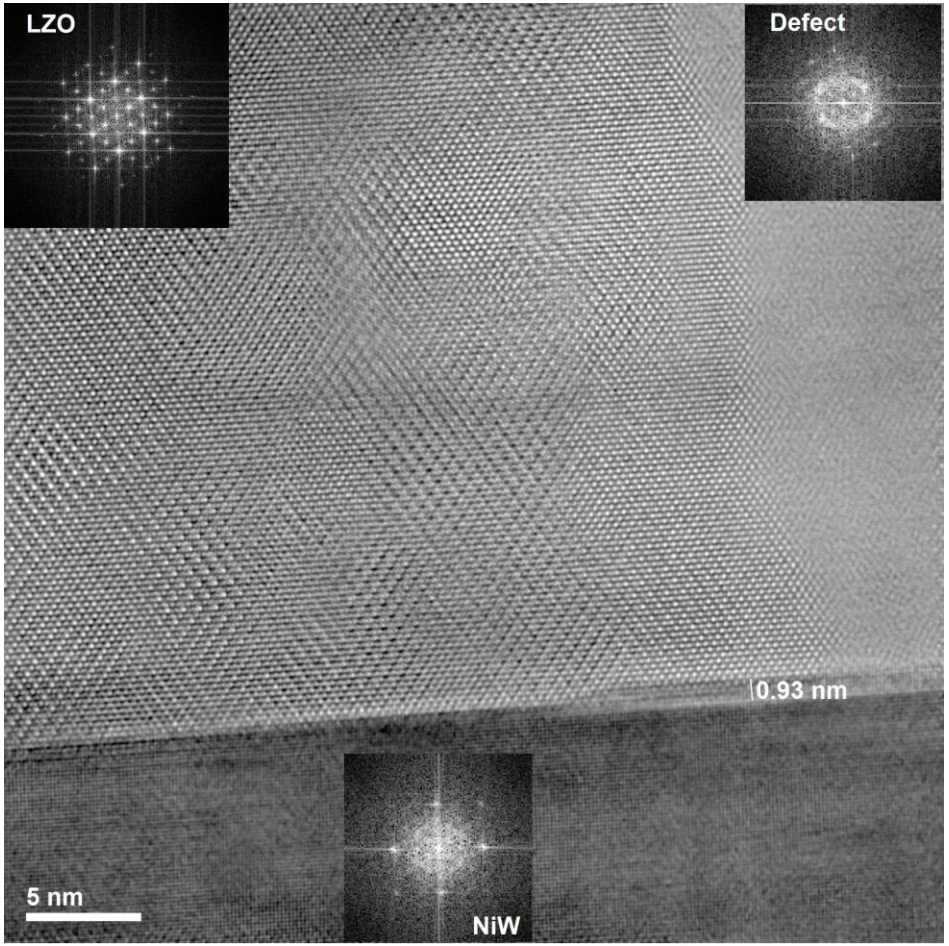




Total current in the CORT: >600 A
Technical current density: 18 A/cm^2

Process challenges

- Process stabilization
- Large area processing
- High throughput
- Local dropouts
  - Interface defects
  - Handling
  - Raw materials
- customization



Interface defect: loss of orientation

Summary

- Chemical solution deposition enables economic mass production of high temperature superconducting tapes
- Deutsche Nanoschicht reached significant performance increase over last years and starts pilot production in 2016/17
- HTS conductor successfully customized for applications
- First samples provided to customers

… but challenges remain in product and process development

chemistry meets energy

Thanks for your attention

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SEVENTH FRAMEWORK PROGRAMME

Federal Ministry of Economics and Technology