Karlsruhe Institute of Technology

KC^4 :
The KIT-CERN REBCO laboratory

Bernhard Holzapfel, Institute for Technical Physics, Karlsruhe Institute of Technology,
1st HiTAT workshop, 09.03.2023

Institute for Technical Physics

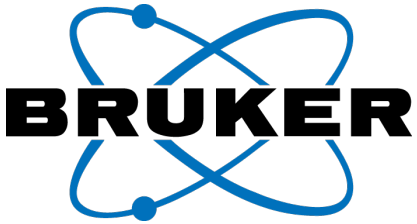
Content

KC^4 project for Coated Conductor development

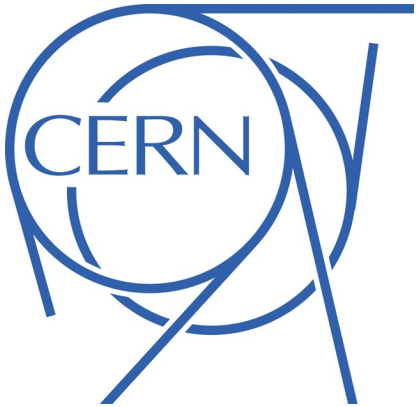
- Motivation and concept
- Technical background
- Timeline and R&D topics
- Current Status

Acknowledment

- Input from ITEP-Material, ITEP-Magnet and ITEP-Energy groups

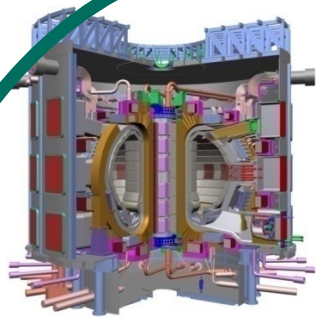


A. Usoskin, U. Betz, K. Schlenga

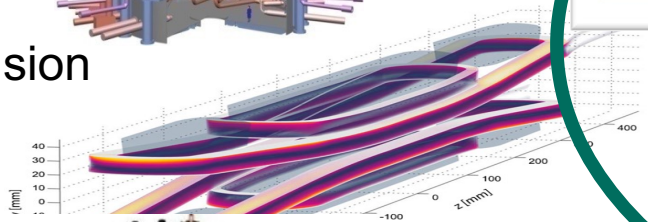


Christian Barth, Amalia Ballarino,
Andrzej Siemko, Luca Bottura

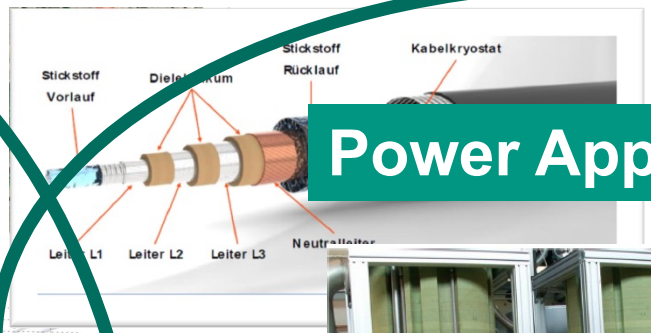
REBCO Coated Conductor Application Areas



Fusion

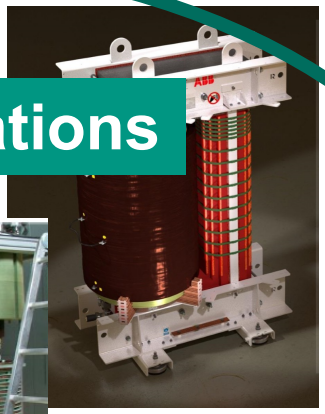


FCC



AC/DC cables

Power Applications



Transformer

FCL

Magnets

NMR/MRI

Rotating Machines

Current Status and Challenges of Coated Conductors

- Coated Conductors are available on an industrial scale, but costs remain an issue
- Beyond J_c there exist a number of open development areas, which need to be improved (yield, mechanical issues, thin conductors, electromechanical properties of full conductor, ac losses) and combined
- Each application requires different and specific CC properties/architectures (e.g. magnetic field, temperature, ac-properties, stabilization, mechanical properties, insulation)
- New scientific ideas often require just a few 100m of very specific CC, not easily available from commercial vendors, since industry needs to focus on just a few CC variants to enable economic production
- There exists currently no company independent public research institution in Europe, which is able to bridge the gap between small scale basic materials research on PLD-based CC and larger scale industrial synthesis, being able to deliver 100m+ class, tailored, high quality Coated Conductors on demand

KC^4: KIT-CERN Collaboration on Coated Conductor

KIT and CERN will establish a **joint, open HTS CC synthesis Lab**, which will bridge the gap between small scale materials research on CC and larger scale component requirement of **tailored, high quality full Coated Conductor architectures** in sufficiently long length

- Both **power applications** as well as **magnet applications** will be targeted
- Focus on R&D CC issues, **not on low cost CC productio**n
- KC^4 is part of the Helmholtz R&D Programm „Materials and Technologies for the Energy Transition“ at KIT
- KC^4 is part of the High Field Accelerator Magnets R&D Programm at CERN
- Third party R&D projects towards tailored CC synthesis for specific applications will be become possible based on an HTS CC open foundry concept
- KC^4 is based on established Bruker CC-technology for long CC and wide tapes, but Bruker is not involved in KC^4- contract/operation
- Long length filamentization and ROEBEL cable fabrication will be feasible

Content

Short intro to ITEP activities in superconductivity

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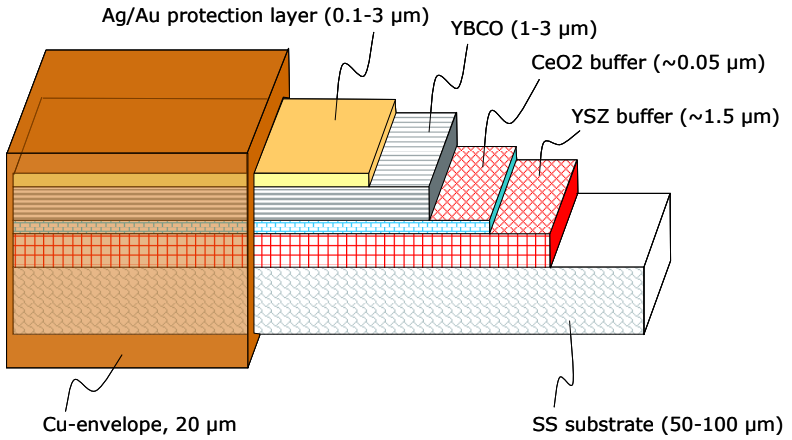
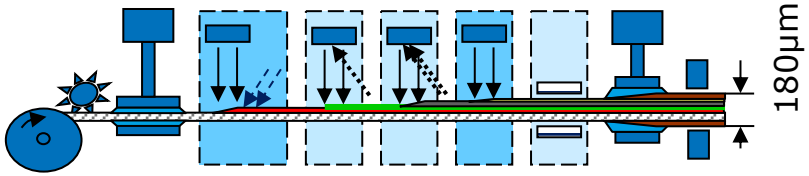
BHTS's process chain

- The standard processing route for the BHTS coated conductors consists of …
  - … stainless steel substrate polishing and cleaning
  - … YSZ buffer layer coating by vacuum deposition (ABAD)
  - … Ceria and YBCO layer coating by vacuum deposition (PLD)
  - … Ag shunt layer coating by vacuum deposition (evaporation) and Ag layer annealing in O2 atmosphere
  - … Cu encapsulation by plating
  - … final inspection and quality check of the HTS tapes

Typical HTS layer stack



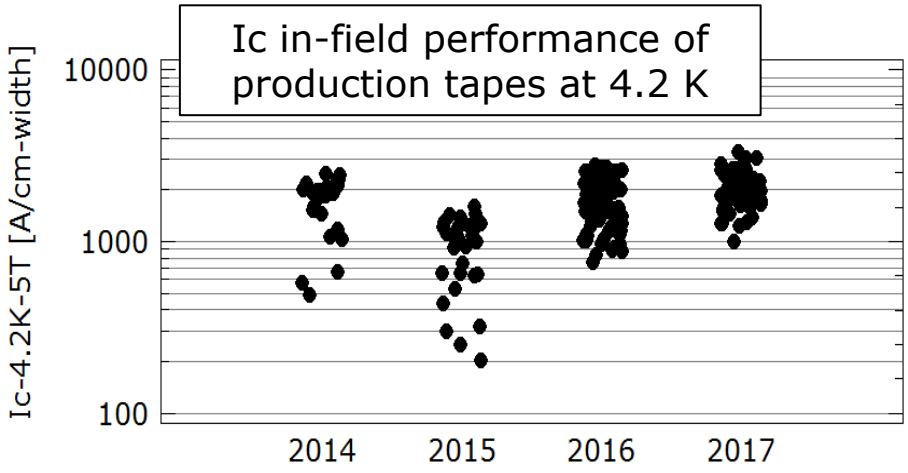
Idealized sketch of the BHTS process chain

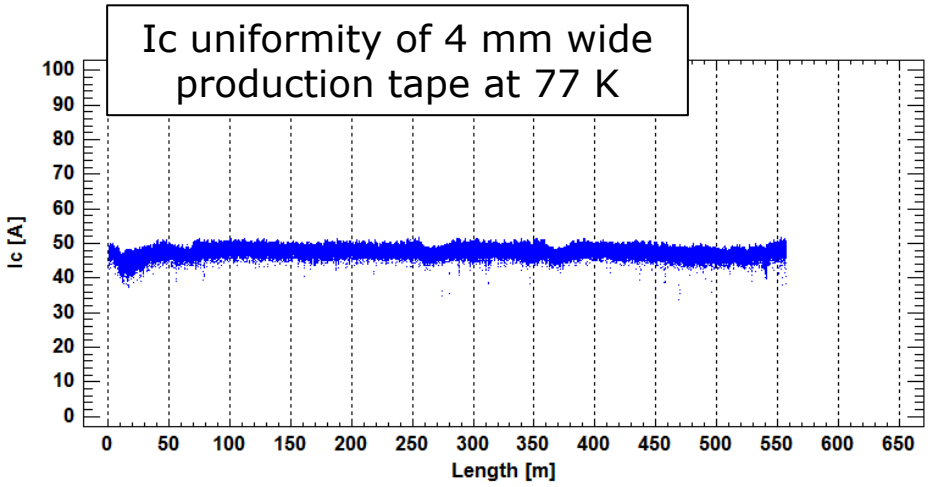


Bruker Energy & Supercon Technologies (BEST)

BRUKER HTS at a glance

- BHTS pilot-line plant (about 2000 sqm operation area), max. capacity 25 km p.a. (further ramp-up to 100 km p.a. possible within the plant)
- HTS tapes for ultra-high magnetic field application at intermediate and low temperatures, Ic at 4.2 K, 30 T, B//c exceeding 750 A/cm-width
- Tape width 4 mm and 12 mm (optionally 40 mm), the max. actual batch size for 4 mm is 600 m (max. tape length in 2014 was 200 m, production capability ramp-up to 600m started in 2015)





BRUKER HTS R&D-line equipment

To be transferred to KIT….

- Tape processing equipment with different substrate handling concepts (batch and reel-to-reel R2R processes) including stabilization

PLD600
Batch vacuum coating

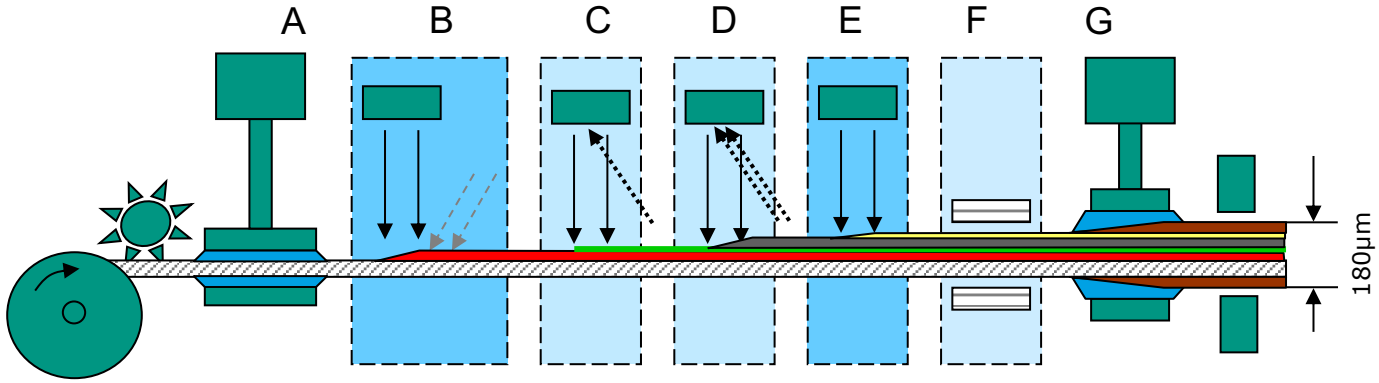
R2R electroplating

ABAD vacuum coater

PLD600
substrate drum

PLD

KC⁴ Coated Conductor Synthesis Steps



b > 12mm (Folien)

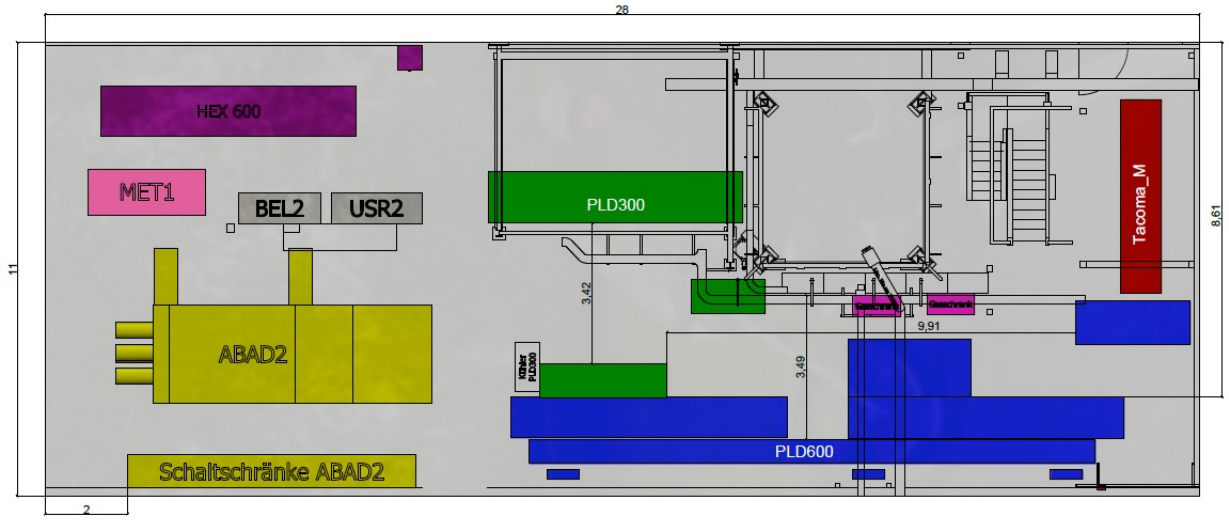
b < 12mm (Bänder)

A : substrate cleaning/polishing	USP/USR-F/USR-B/POL
B : IBAD Puffer deposition	ABAD
C : PLD Puffer deposition	HEX600+PLD300/600
D : PLD SC deposition	HEX600+PLD300/600
E : Ag- coating	Tacoma–M/MET-F
F : O_2- loading	Tacoma-O/BEL-F
G : Cu-plating	PLA

+ characterization
(structural, electrical, mechanical)

e.g. TapeStar

Core KC^4 Lab space



Transfered Bruker equipment list

USR-F*	substrate cleaning
USP*	tape spooling
USR-B*	reel-to-reel substrate cleaning
POL*	substrate polishing
ABAD	IBAD deposition
HEX 600	tape handling
PLD300	PLD
PLD600	long length PLD
Takoma-M	Ag-coating
Takoma-O	O-loading
MET-F	Ag-coating
BEL-F	O-loading
PLA*	Cu-plating
TapeStar*	J_c-characterization

*: equipment located in other ITEP labs

ITEP wide > 500 m^2 lab space dedicated to KC^4

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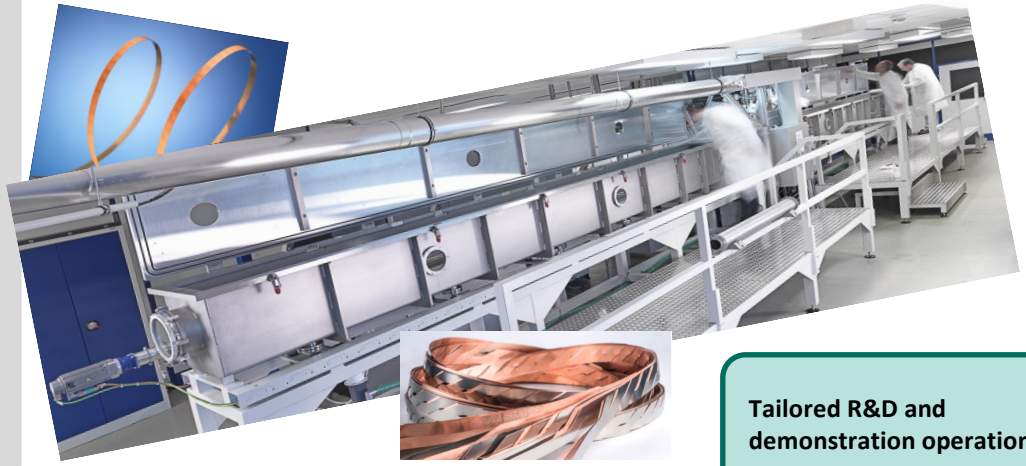
Timeline of KIT-CERN Collaboration



HTS CC Open Lab/Foundry

KIT ITEP | CERN | Third Parties

Tailored R&D and demonstration operation — CERN | KIT/ITEP

KIT/ITEP — Baseline R&D Operation (< 25% capacity use) — CERN

I-A Installation | I-B Commissioning | I-C Performance demonstration | I-D Baseline R&D operation

t.b.c

Intermediate 20m length scale

Extension to 100m+ length scale

2022 2023 2024 2027

KC^4: Baseline R&D Topics

- Investigate scaling laws to transfer small scale PLD materials development results towards larger scale Coated Conductor production systems
- Address specific Coated Conductor architectures needed for the R&D program at CERN and KIT
- Investigate and improve electromechanical properties of full coated conductor architectures (mechanical stability, interface resistance, thermal properties,….)
- Evaluate in-line quality control systems
- Establish accelerated materials development concepts
- ….

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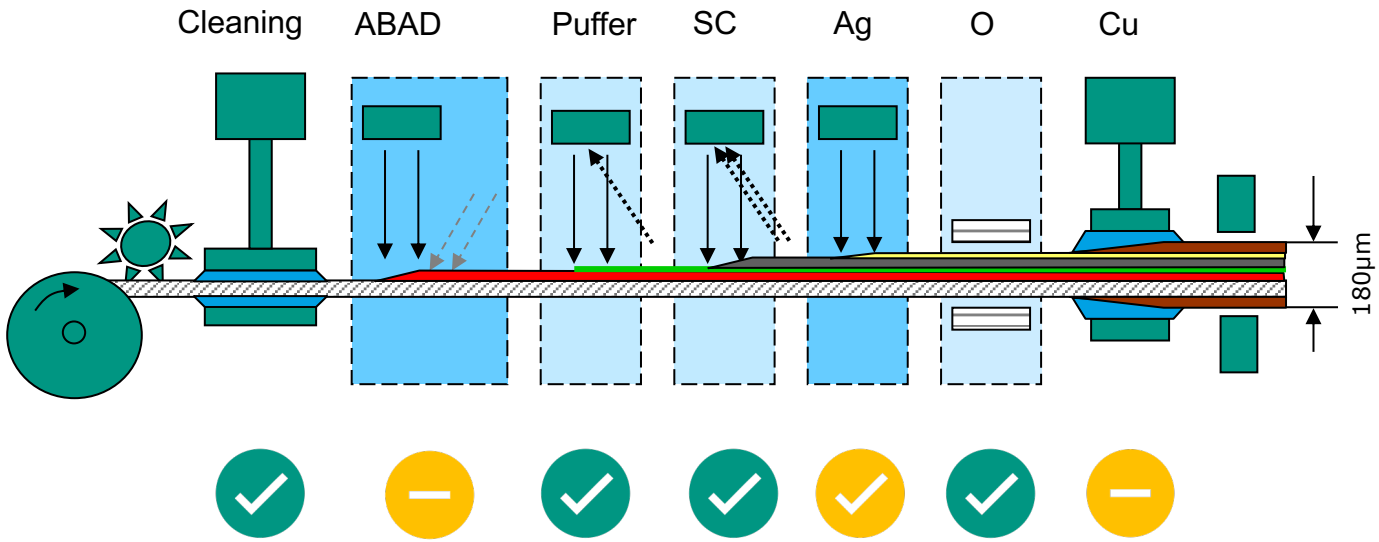
Current Project Status
(intermediate 20m length scale)



1st full deposition run
on march 1st, 2023