

High performance coated conductor wires for magnet applications

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HTS – PRODUCTION LINE

Setting worldwide standards

Pilot line features

- Built 2012-2014, commissioned end of 2015
- Maximum production capacity: 150 km/yr (@ 12 mm-width)
- Production tape length: 300 m,
up to 600 m demonstrated!

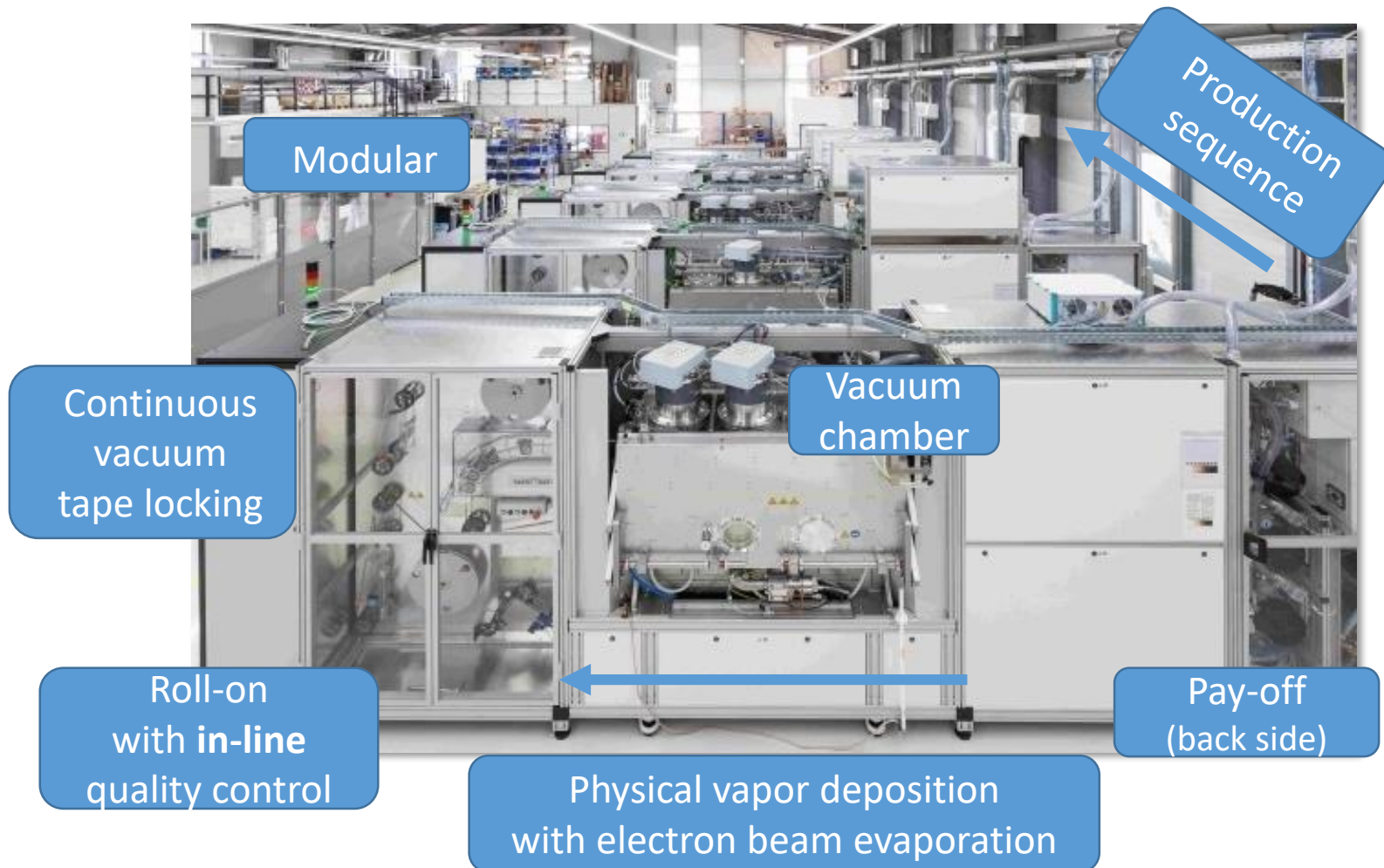
Goals

- Cost efficient production
- Robust process allowing high yield
- Implementation of industrial standards
- Proof of production: high quality tape

First step towards industrial HTS wire production

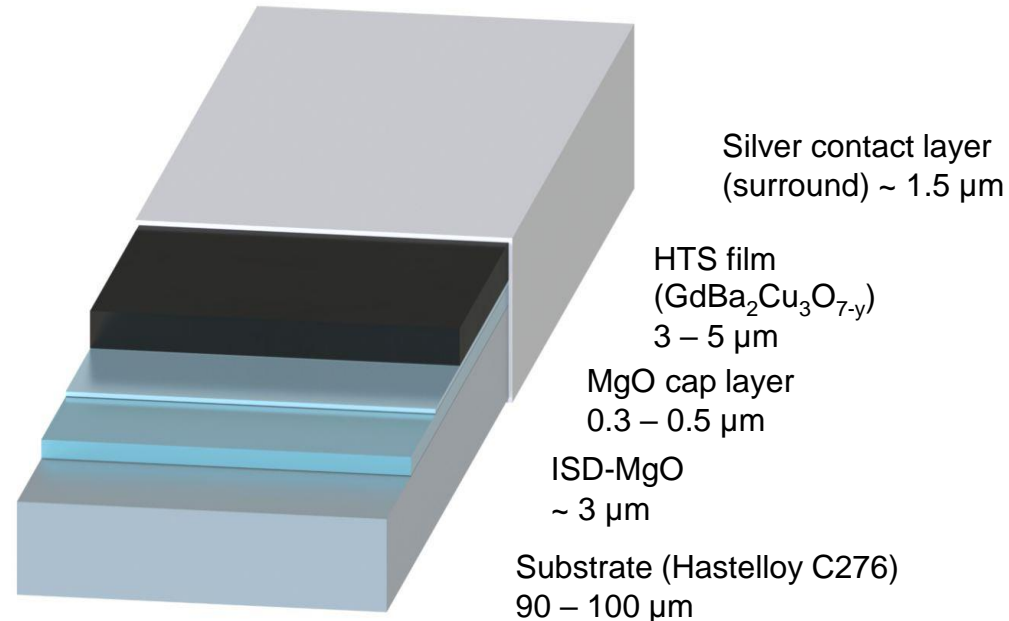
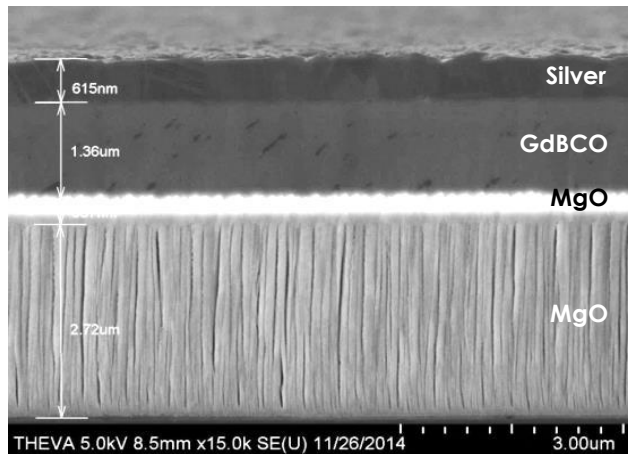


HTS tape production à la THEVA



THEVA Pro-Line™

- High performance 2G HTS tape
- Simple layer architecture
- Contains 20 years of R&D
- Unique approach – all IP owned by THEVA

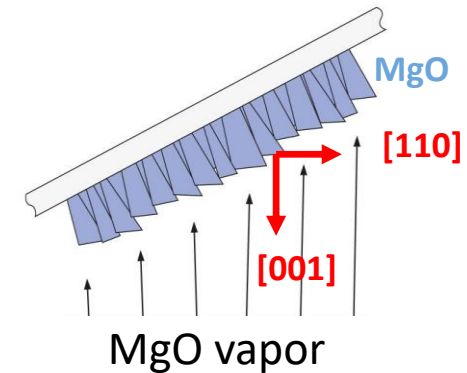


ORIENTED BUFFER LAYER

Inclined substrate deposition (ISD)

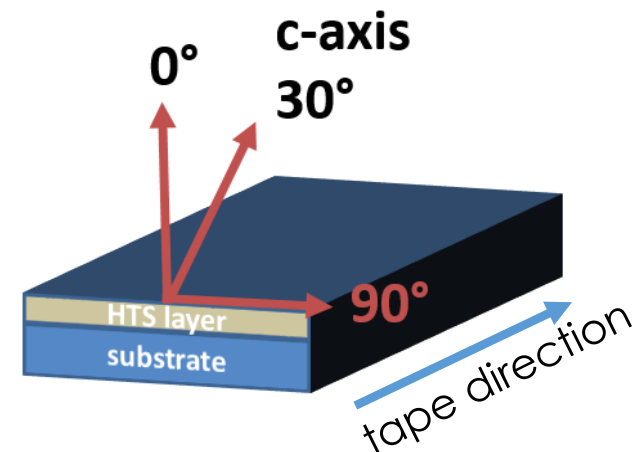
ISD MgO process

- E-gun evaporation on a tilted substrate (30°)
- Simple process and fast ($> 6 \text{ nm/s}$)
- Tilt angle of $\text{MgO}\langle 100 \rangle$: $\beta_{\text{MgO}} \approx 30^\circ$
- In-plane texture: $\Delta\phi_{\text{MgO}} \approx 10^\circ$



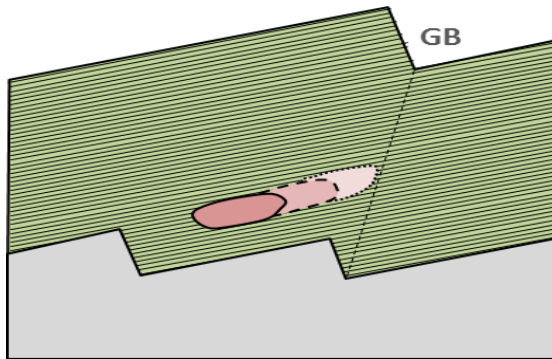
HTS process

- Tilt angle is transferred
- Texture improves
- Tilt angle of HTS c-Axis $\beta_{\text{GdBaCuO}} \approx 30^\circ$
- In-plane HTS $\Delta\phi_{\text{MgO}} \approx 6^\circ$



Tunable performance

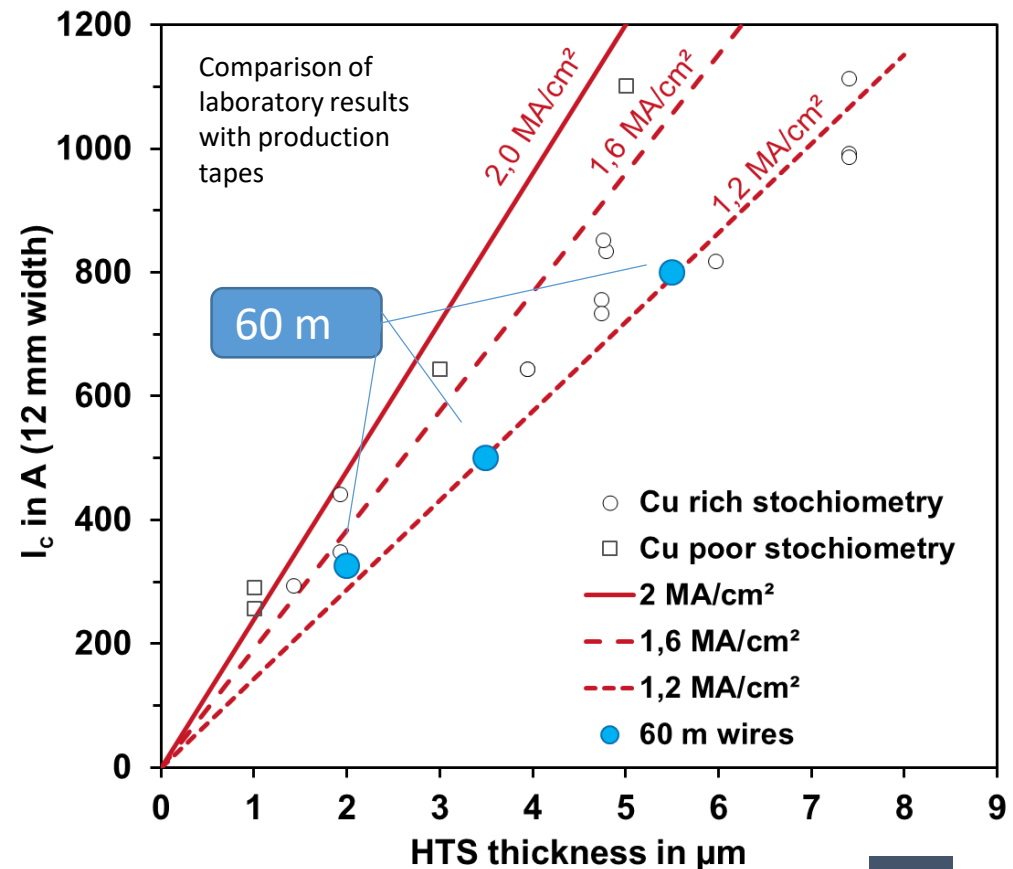
Positive effect of the tilt angle



Tilt leads to **textured** overgrowth of precipitates and misoriented regions

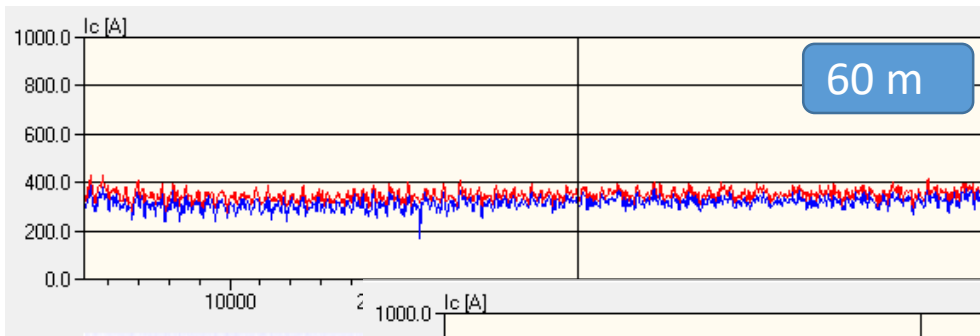
- J_c is thickness independent
- **Very high I_c possible**

Previous results from 2016



Tunable performance

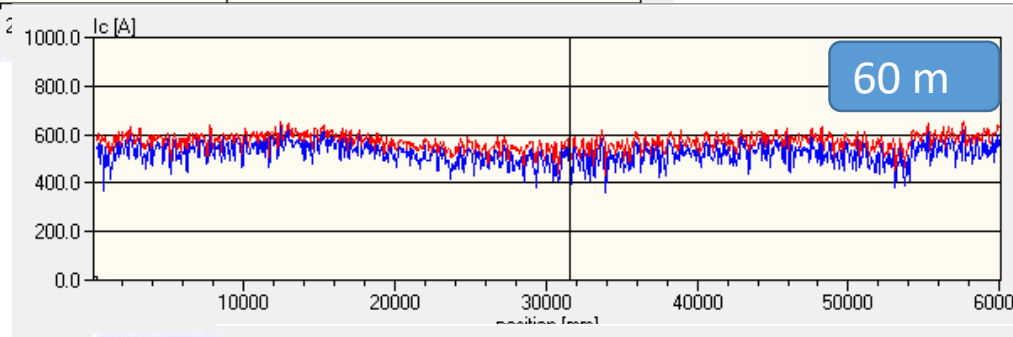
First effect of the tilt angle



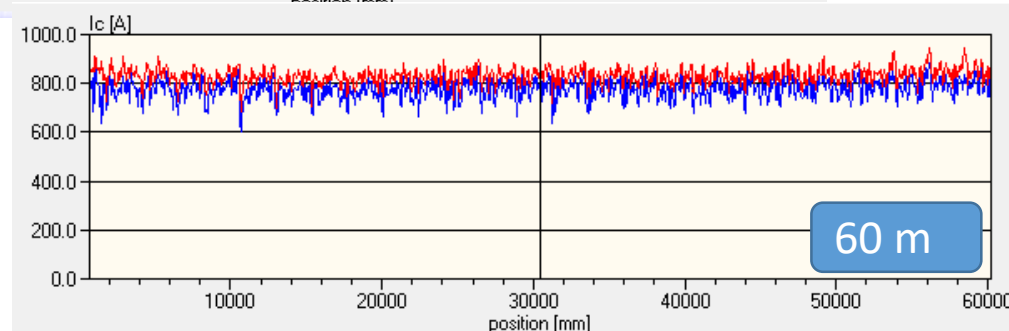
2,0 μm
 $I_c \approx 325 \text{ A}$
 12 mm



77 K, self field
 Tapestar measurements



3,5 μm
 $I_c \approx 500 \text{ A}$
 12 mm



5,5 μm
 $I_c \approx 800 \text{ A}$
 12 mm

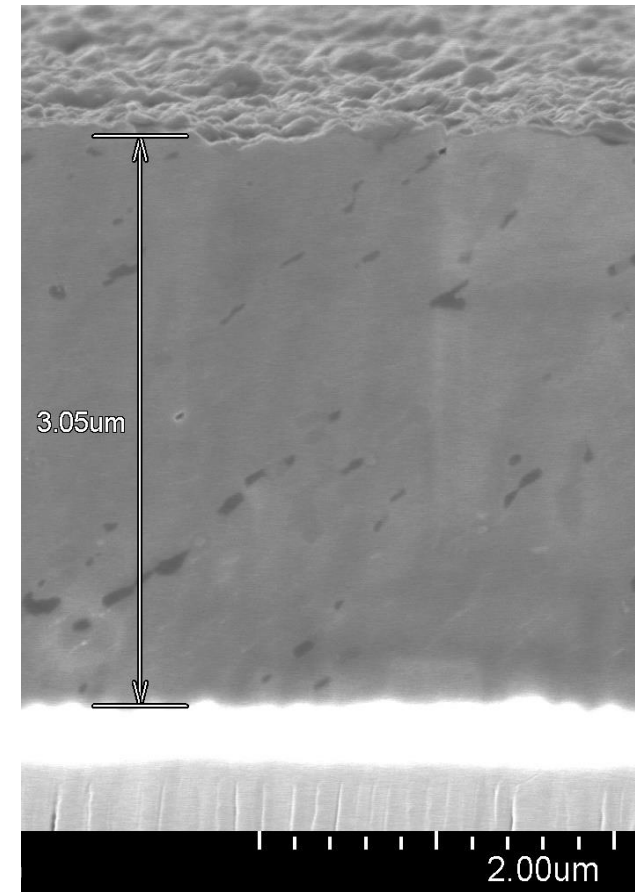
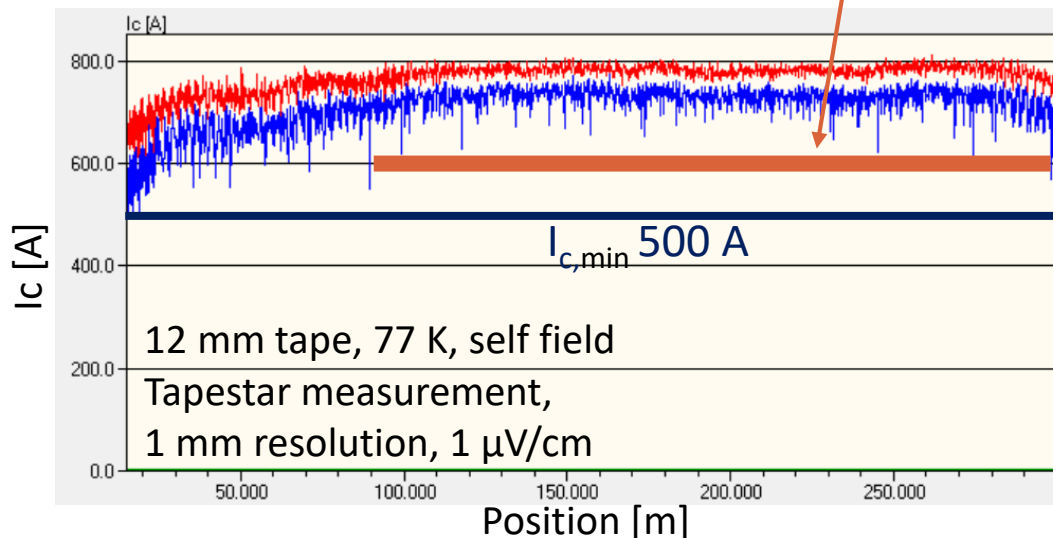
Increase of thickness
 Increase of I_c

Performance on production tapes

Improved performance was successfully transferred to production

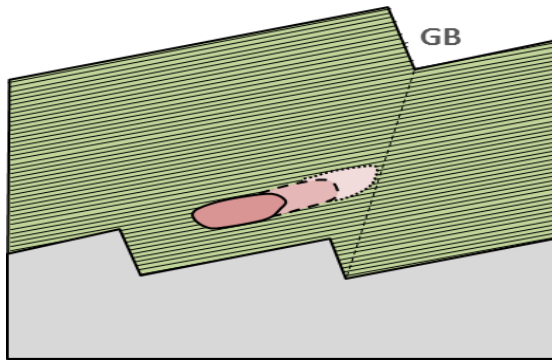
- Homogeneous cross section
- High performance over long length

Over 200 m: $I_c \approx 700$ A, $I_{c,min} = 600$ A



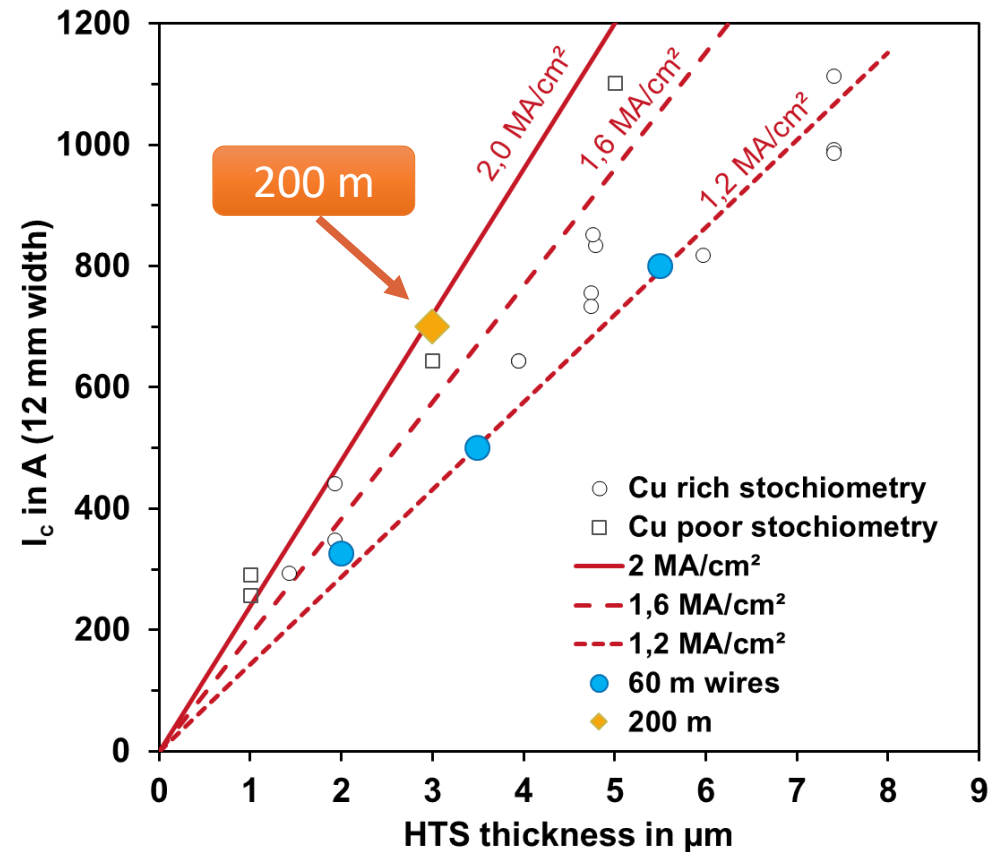
Tunable performance

positive effect of the tilt angle



Tilt leads to **textured** overgrowth of precipitates and misoriented regions

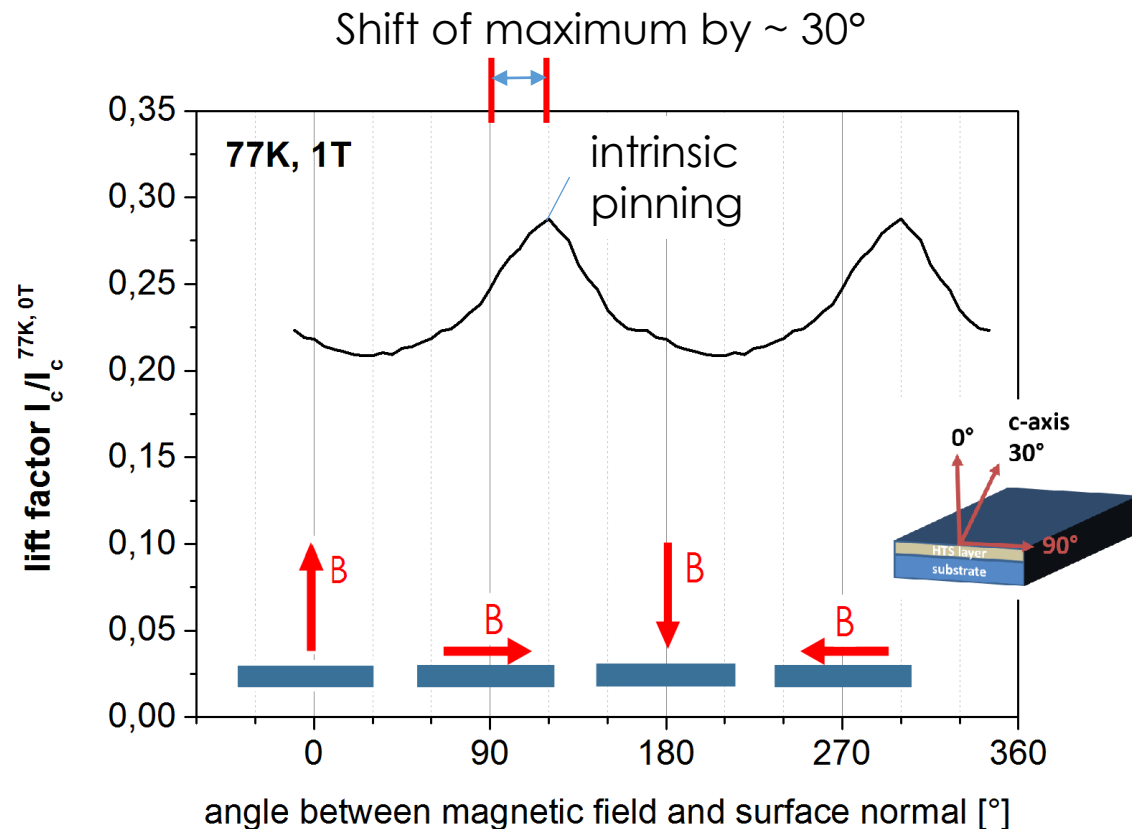
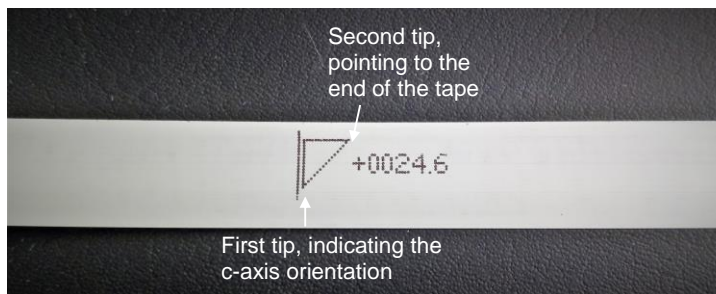
- J_c is thickness independent
- **Very high I_c possible**



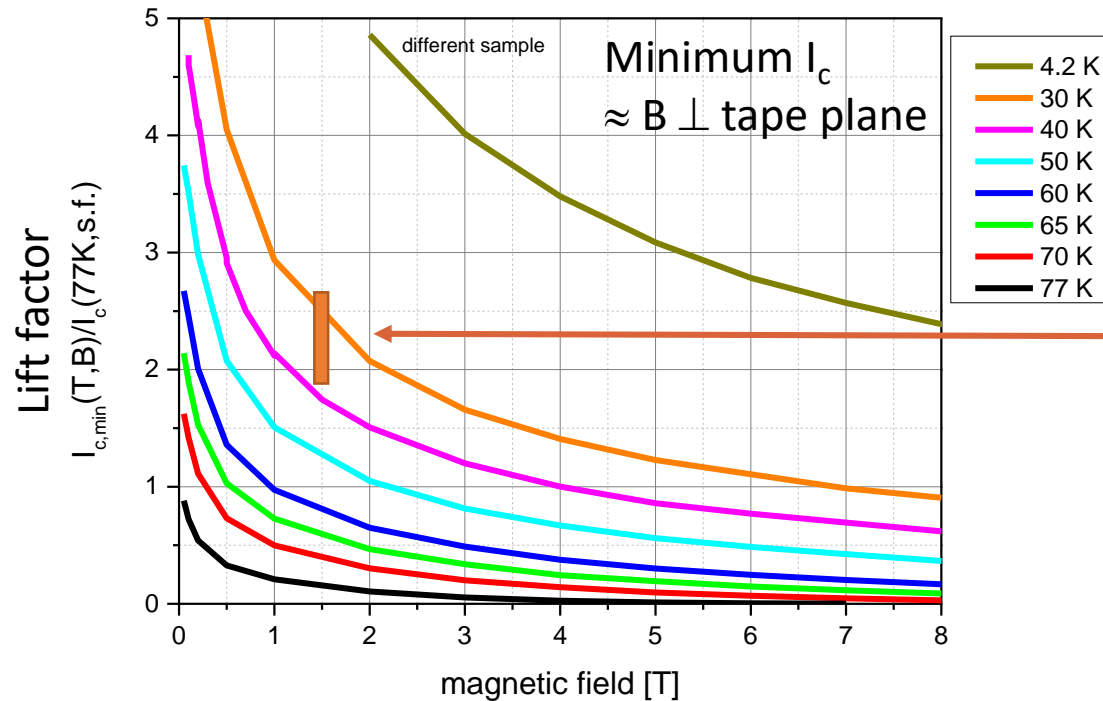
Shifted magnetic field performance

An effect of the tilt angle

- $B \parallel c$ is not $B \parallel n$
- Value of tilt is about 30°
- Tilt is always to the side of the tape
- Tilt direction is marked on the tape



Magnetic Field Performance



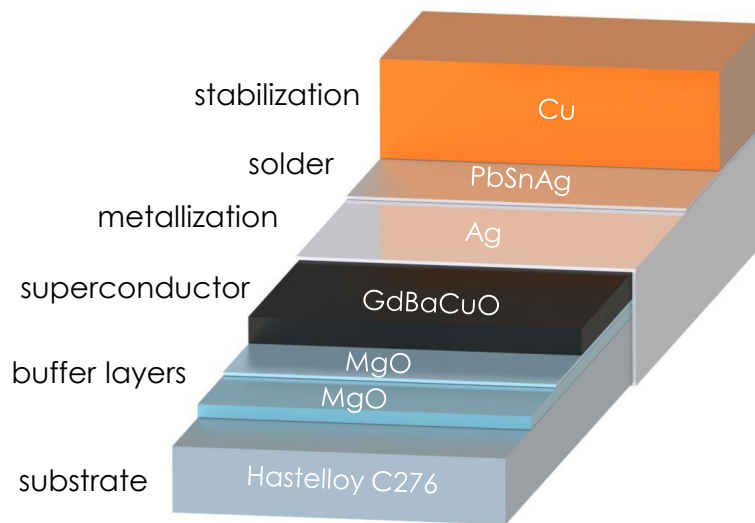
- No artificial pinning centers
- Lift factor of 15 samples taken out of production over about 1a:
 $LF(1.5\text{ T}, 30\text{ K}) = 2.2 \pm 0.4 (\pm 18\%)$

Reliable magnetic field performance!

more data available!

Pro-Line HTS wire

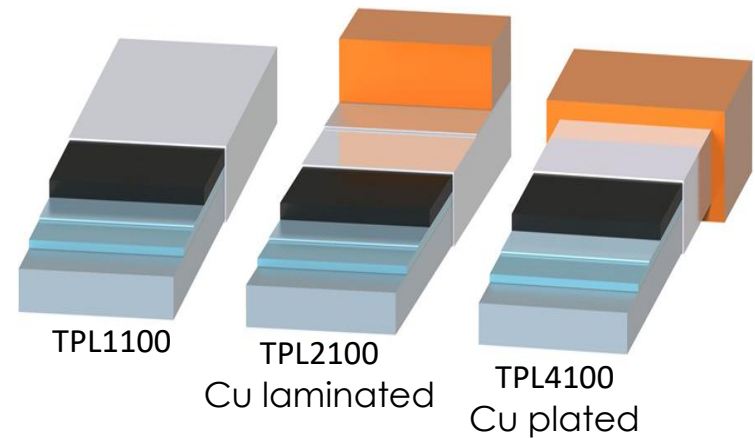
Different wire types available



TPL2100

Used for  ecoswing

More information
TUE-Mo-Or14 and Thu-Af-PI7-01

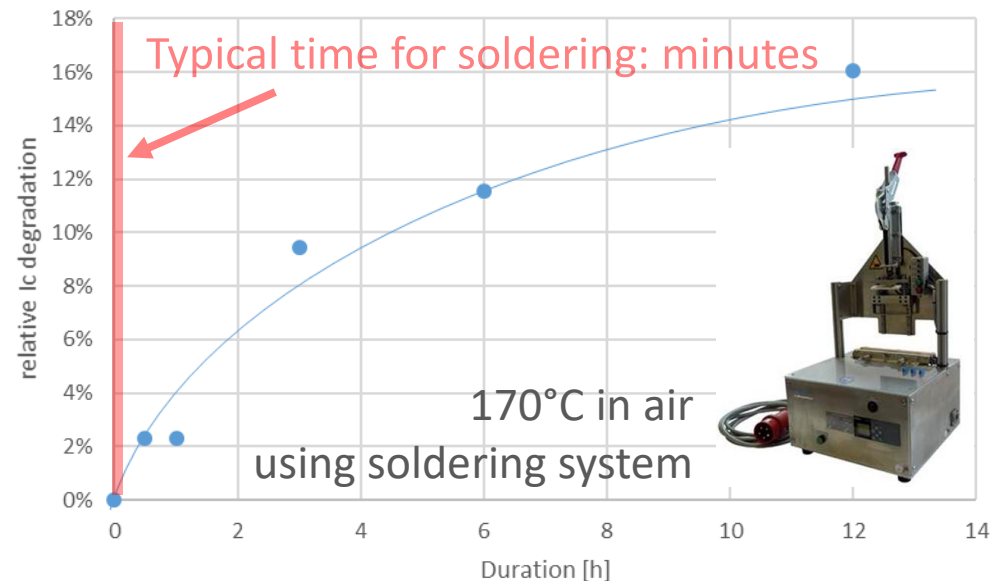
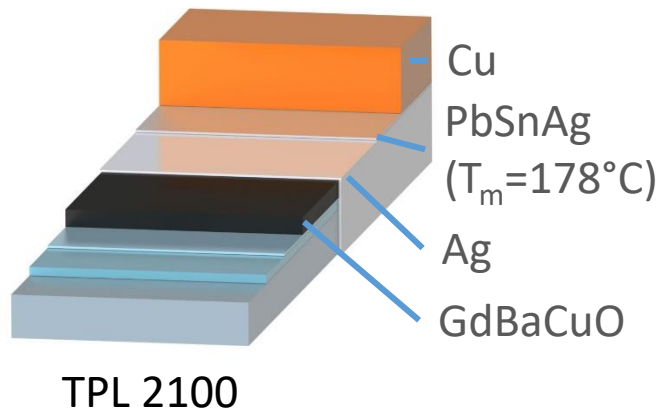


- Cu stabilization according to application
- Standard width 12 mm
- Smaller width samples available

Thermal stability of Cu laminated type

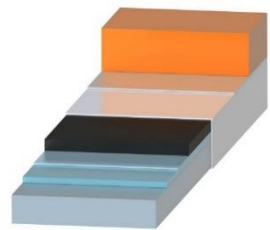
HTS Tape has to withstand thermal stress during further processing:

- VPI or potting: curing for hours at elevated temperature (100°C typical)
- Soldering: high temperatures for shorter time ($< T_m$ of solder of lamination)

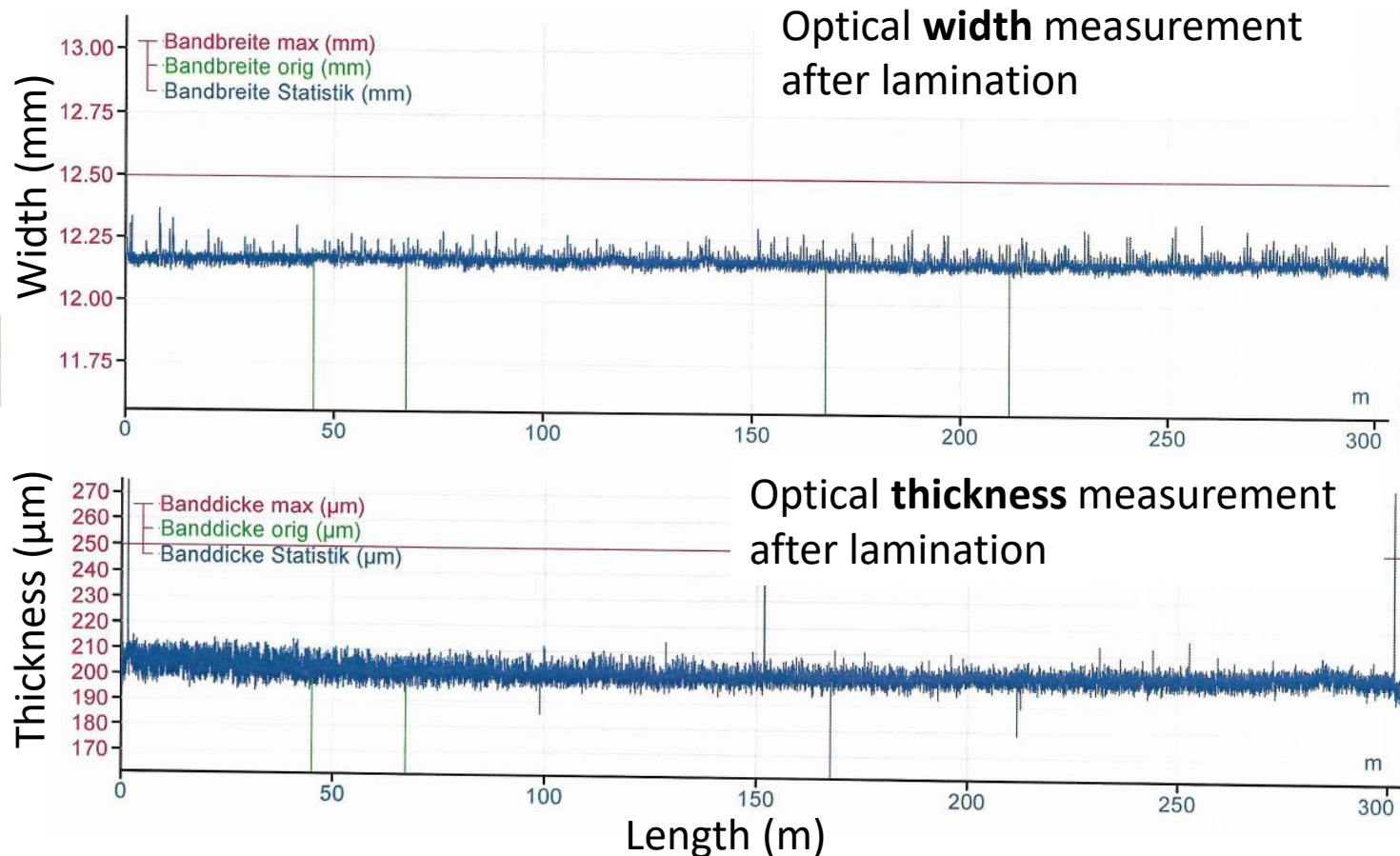


No degradation within usual processing times!

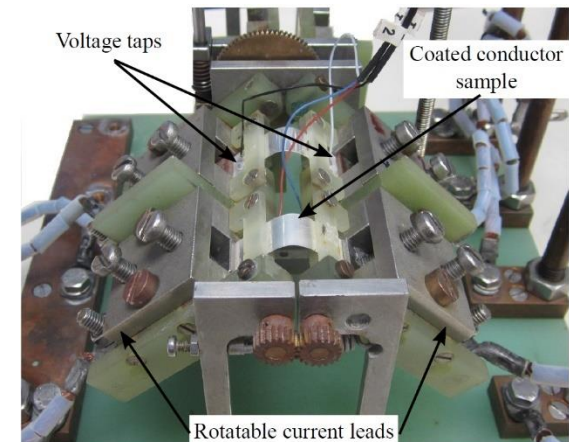
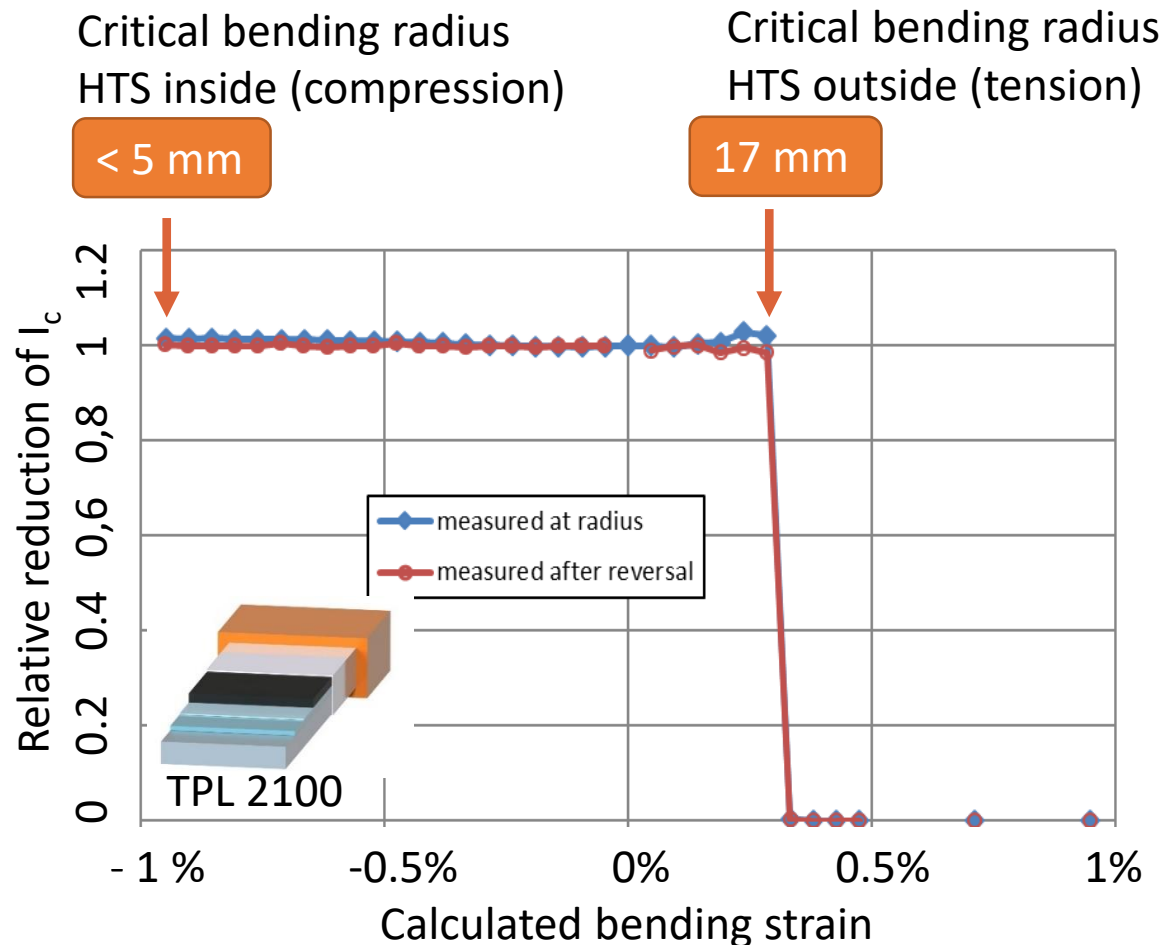
Mechanical properties of laminated tape



TPL 2100



Bending test of Cu plated tape

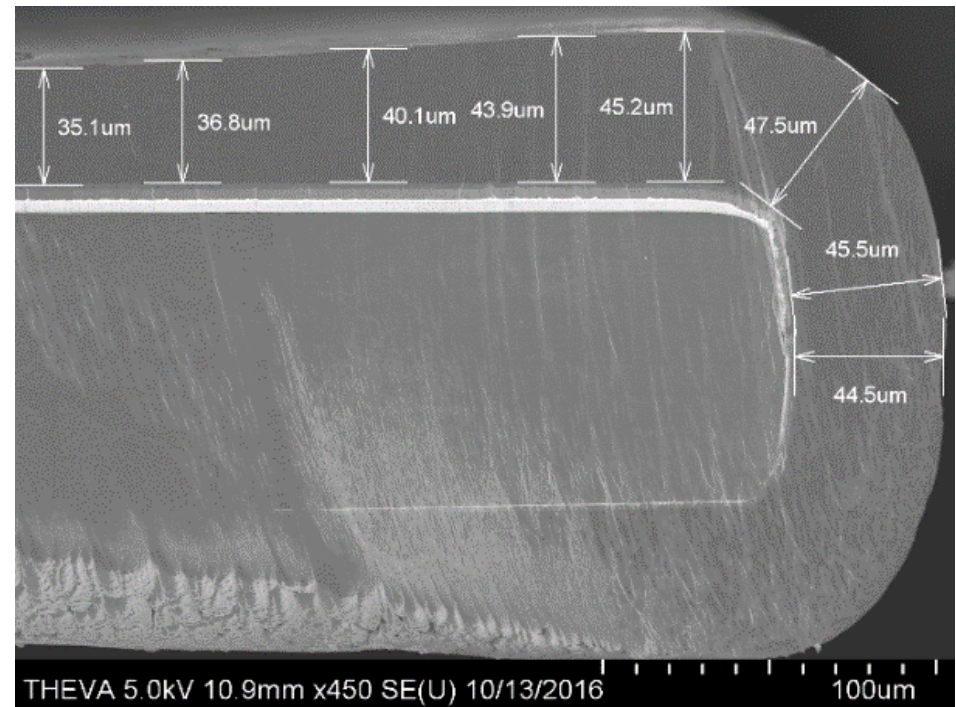
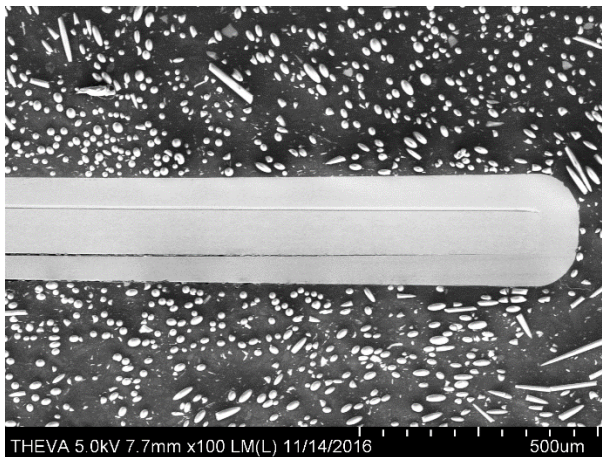


Similar results found
for laminated tape!

Copper plating

Dog boning

- Important for high density packing of turns and reproducible coil thickness
- Development of homogeneous thickness



Acknowledgements to our team



Veit Große, Raphaela Burzler, Roman Dzhafarov, Anh Tu Bohn, Stefan Furtner,
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