HTS tape insulation

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HTS tape insulation
- outline

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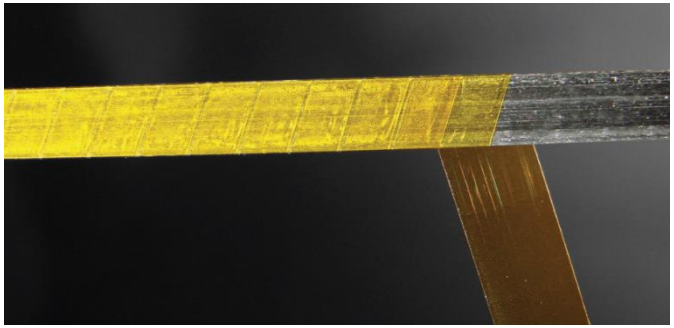
- Evaluation of new HTS insulation techniques:
  - Epoxy-based
  - Liquid polyimide
  - Sol-Gel
- Study of defects in HTS coil from Danfysik

HTS insulation



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Insulation	Pros	Cons
Kapton/polyimide tape wrapping	Commercially well-established	Not compatible with impregnation
Fiber glass and kapton wrapping	Well-known from LTS accelerators	Thick (poor Je)
Fiber glass sock with epoxy impregnation	Simple handling	Thick; problems with epoxy impregnation penetration
Black varnish (Innost)	Thin; compatible with impregnation	Health and safety issues
Epoxy (Danfysik, Florida State U)	Compatible with impregnation	Not established commercially?
Sol-Gel (DTI, FSU)	Thin (good Je)	Not developed
Liquid polyimide (SuperOx)	Good insulation	Not established commercially?

Liquid based – good candidates for ”up-scaling”. Not well-suited for Roebel.

SuperOx

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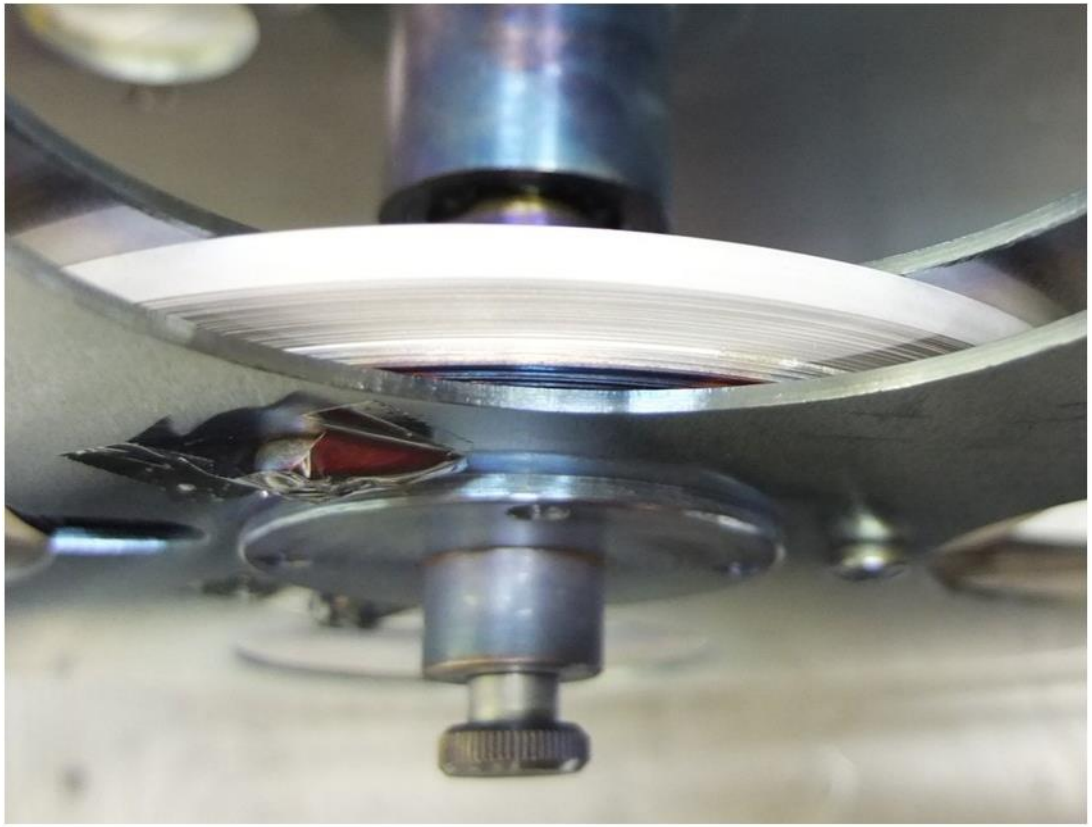
SuperOx

SUPERCONDUCTOR TO THE FUTURE

- Polyimide layer insulation



SuperOx

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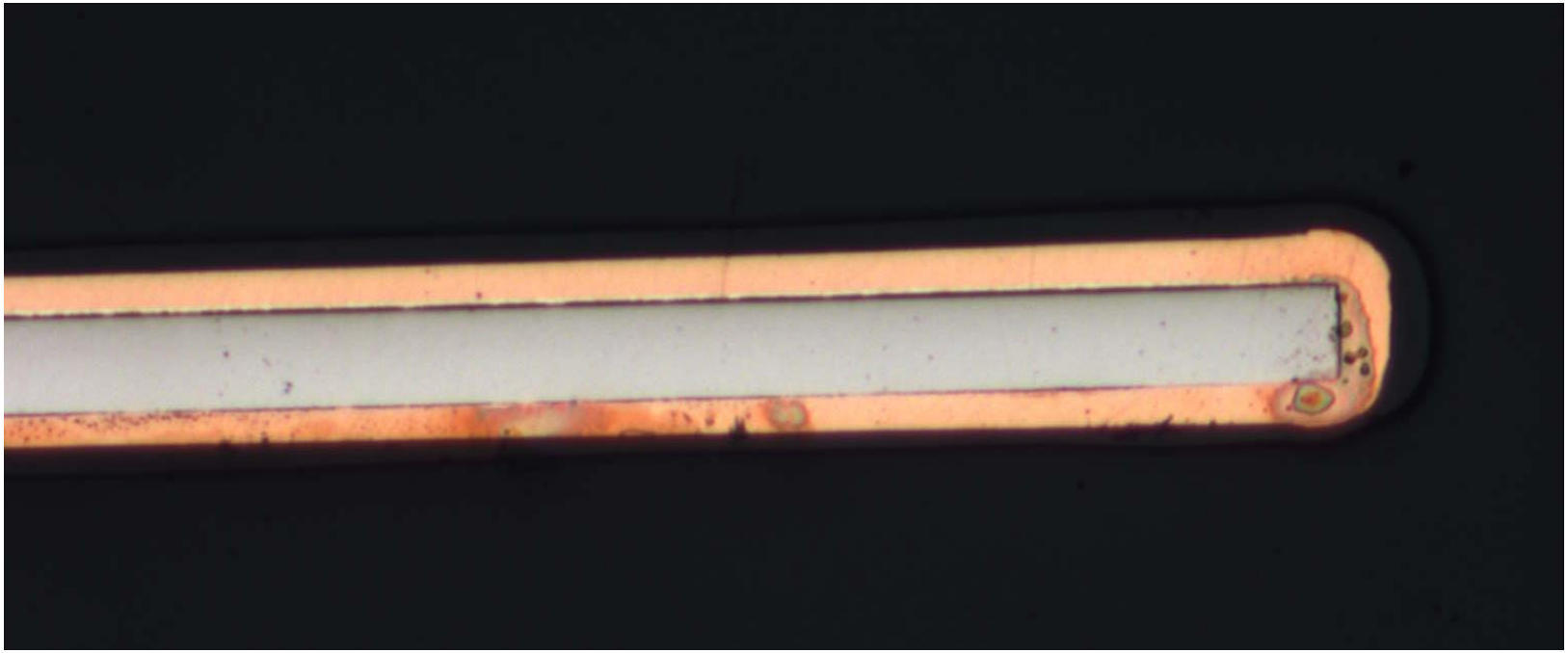
- Insulation and tape from SuperOx (2015)
- Thickness ca. 20 µm
- Very good uniformity of insulation



Danfysik

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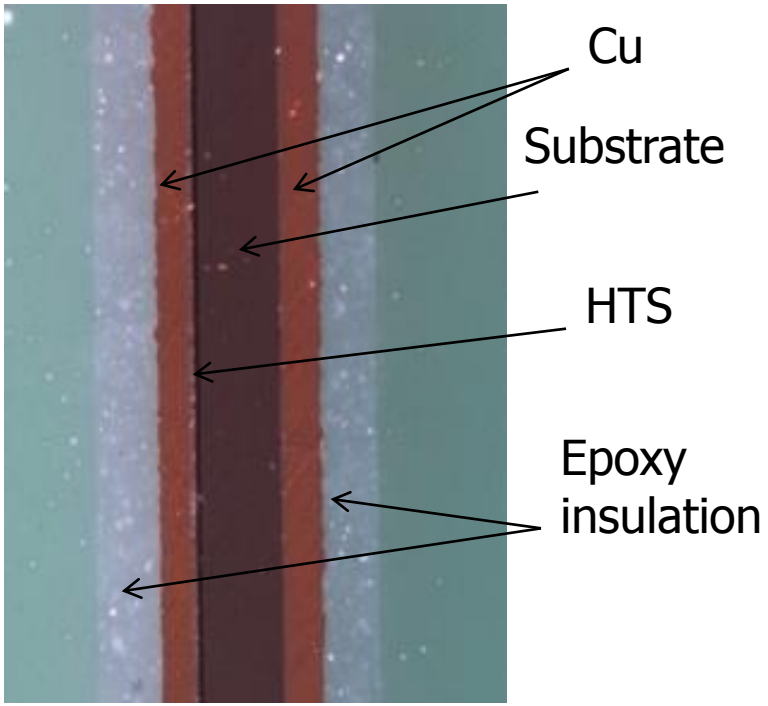
- Epoxy + heat conductive filler

HTS tape pulled through liquid epoxy bath and cured.

(also performed at Florida State University).



Danfysik

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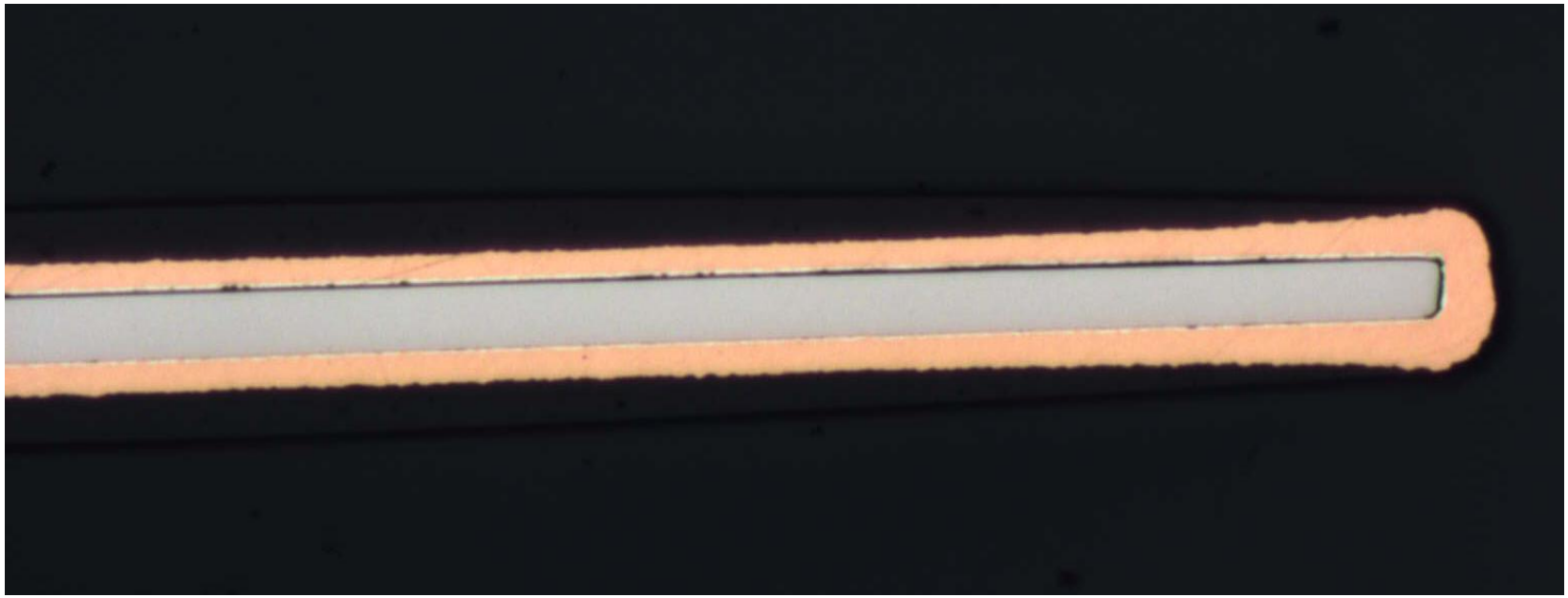
- Insulation and tape from SuperPower (2012)
- Cu dog-bone at edges (old tape)
- Insulation thickness ca. 25 µm



Sol-Gel coatings at DTI

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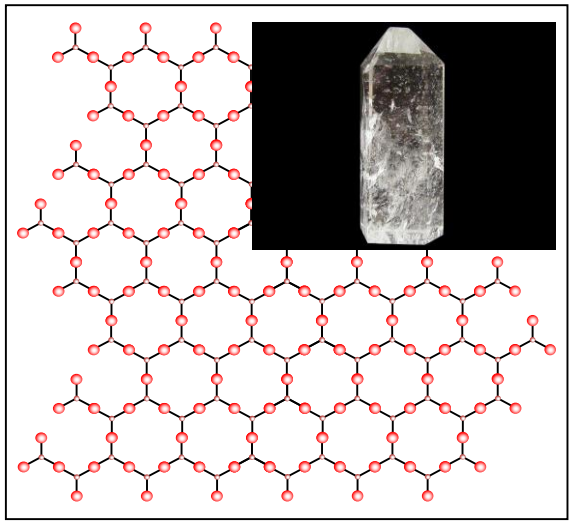
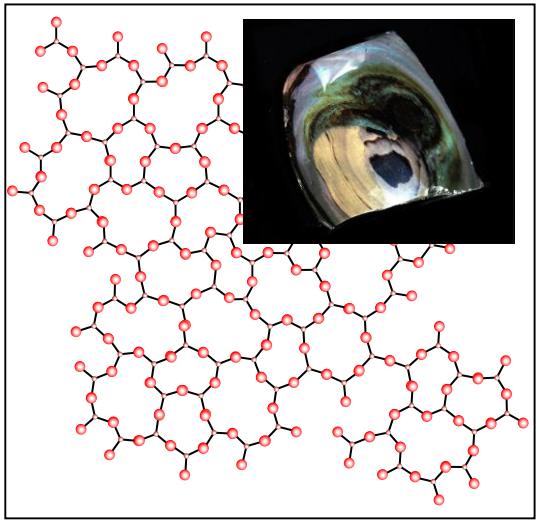
- Inorganic organic hybrid coatings (organosilane based coatings, sol-gel systems)
- Applied by spraying / dip-coating / paint brush
- Curing between room temperature and 200 °C
- Also performed at Florida State University
- Applied to SuperPower 12 mm wide tape (2014)

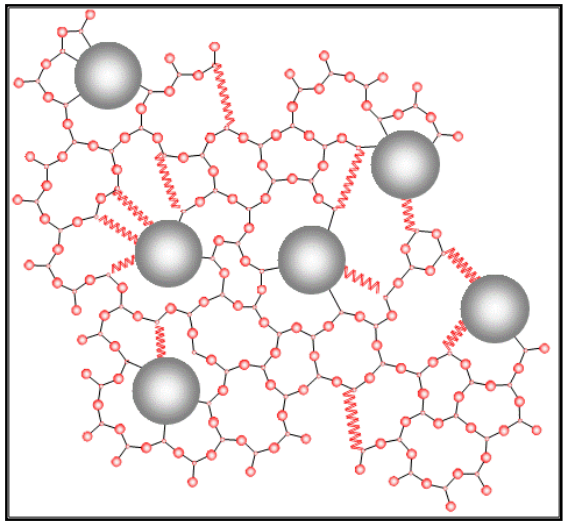
crystalline SiO_2 (quartz)



amorph SiO_2 (glass)



Inorganic siloxane network + organic groups and/or NPs



Sol-Gel application process

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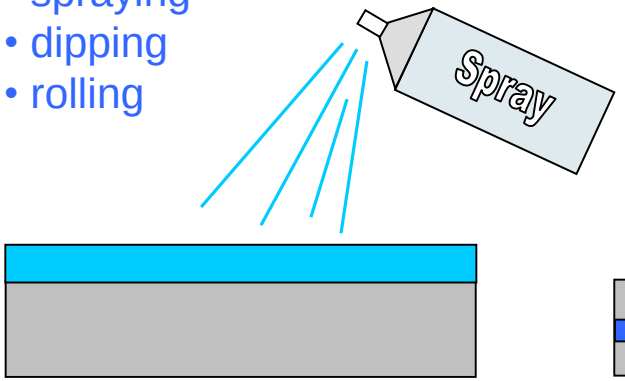
Step 1

The substrate undergoes a cleaning and activation procedure

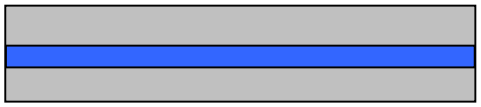
Step 2

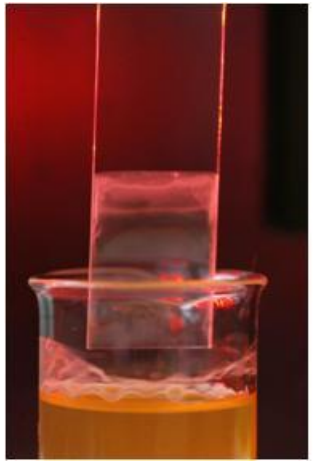
The coating is applied by means of
- spraying
- dipping
- rolling



Step 3

The coating is cured by
- Heating (RT to 200 C)
- UV or IR light
- air drying





Breakthrough voltage

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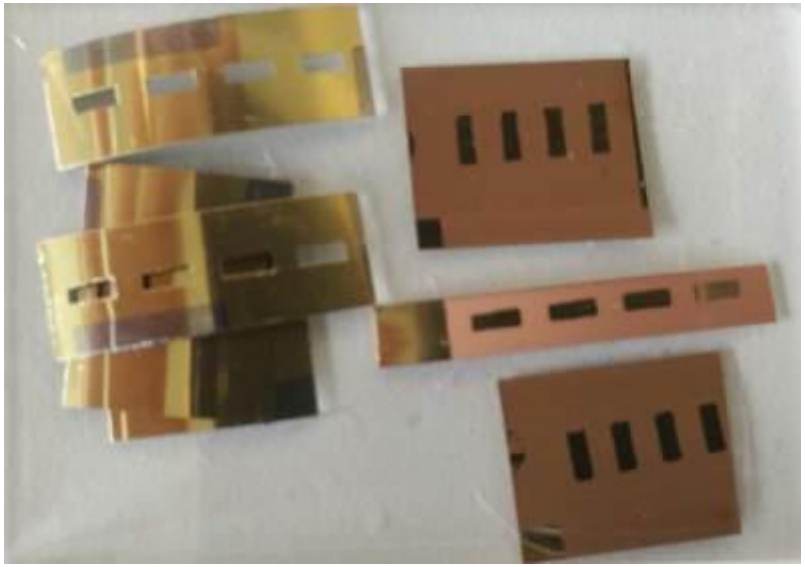
Gold masking used to prevent edge effect.

On 4 mm tape (SuperOx, Danfysik) or 12 mm tape (Sol-Gel)



Insulation	Insulation thickness	600 V	1000 V
Polyimide (SuperOx)	25 µm	OK	OK
Epoxy (Danfysik)	20 µm	OK	OK
Sol-Gel (DTI)	6 µm	OK	Fail

Study of defective coil from Danfysik HTS magnet

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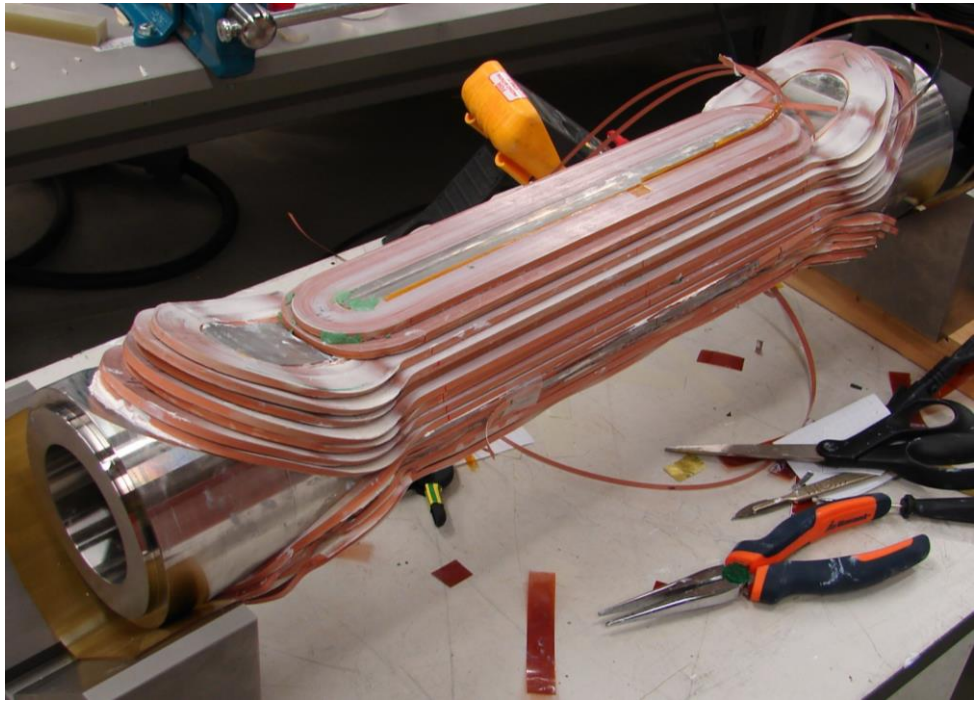
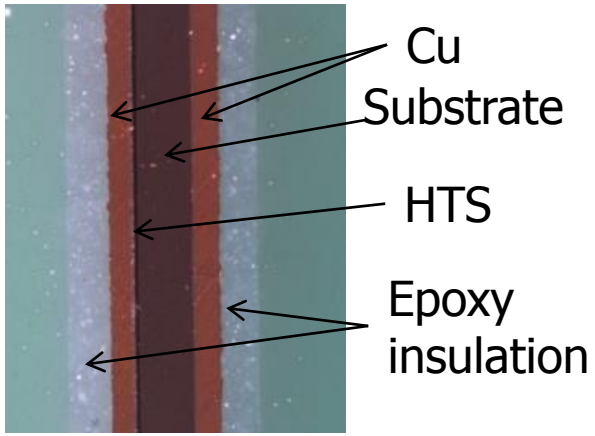
Danfysik demonstration stand-alone HTS dipole magnet

Coil layout: 18 coils in block/ellipse design

A few of the coils were not able to carry the designated current

Defective top coil made available for DTI in EuCARD2 project





Mapping of defects in coil

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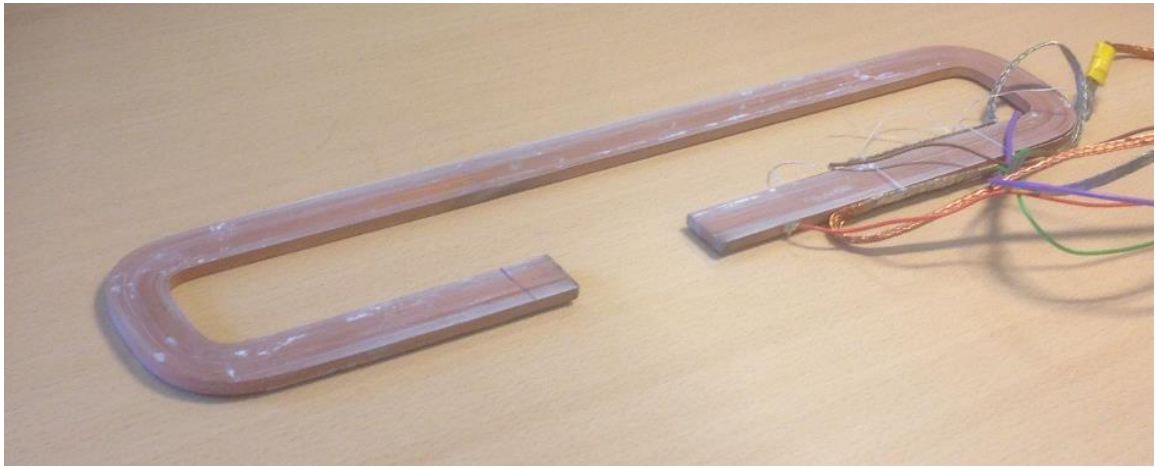
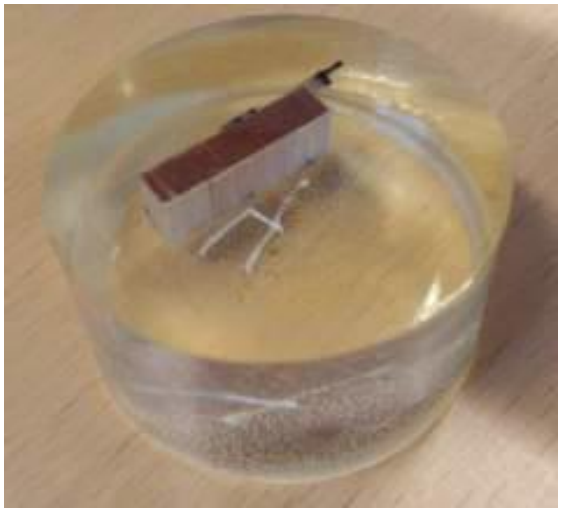
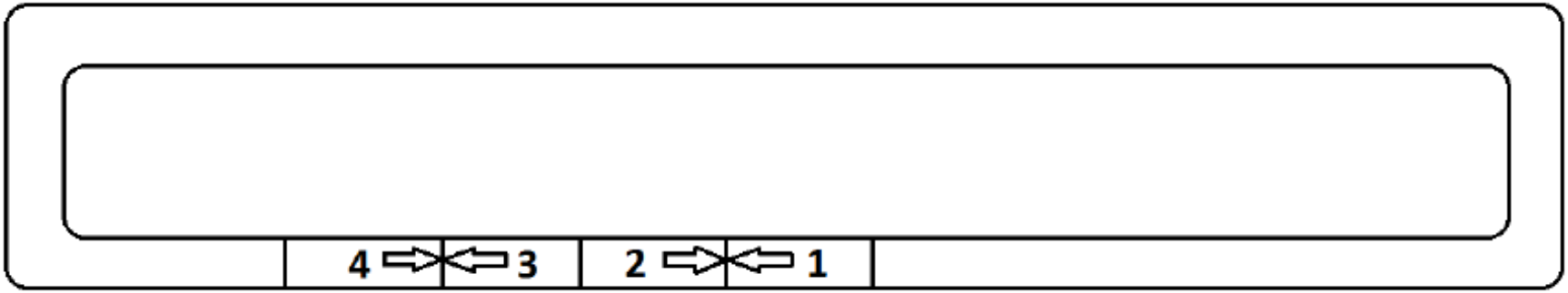




Metallographic sections (cut, grind, fine polish)

Light Optical Microscopy and SEM/EDX



Tape/coil delamination

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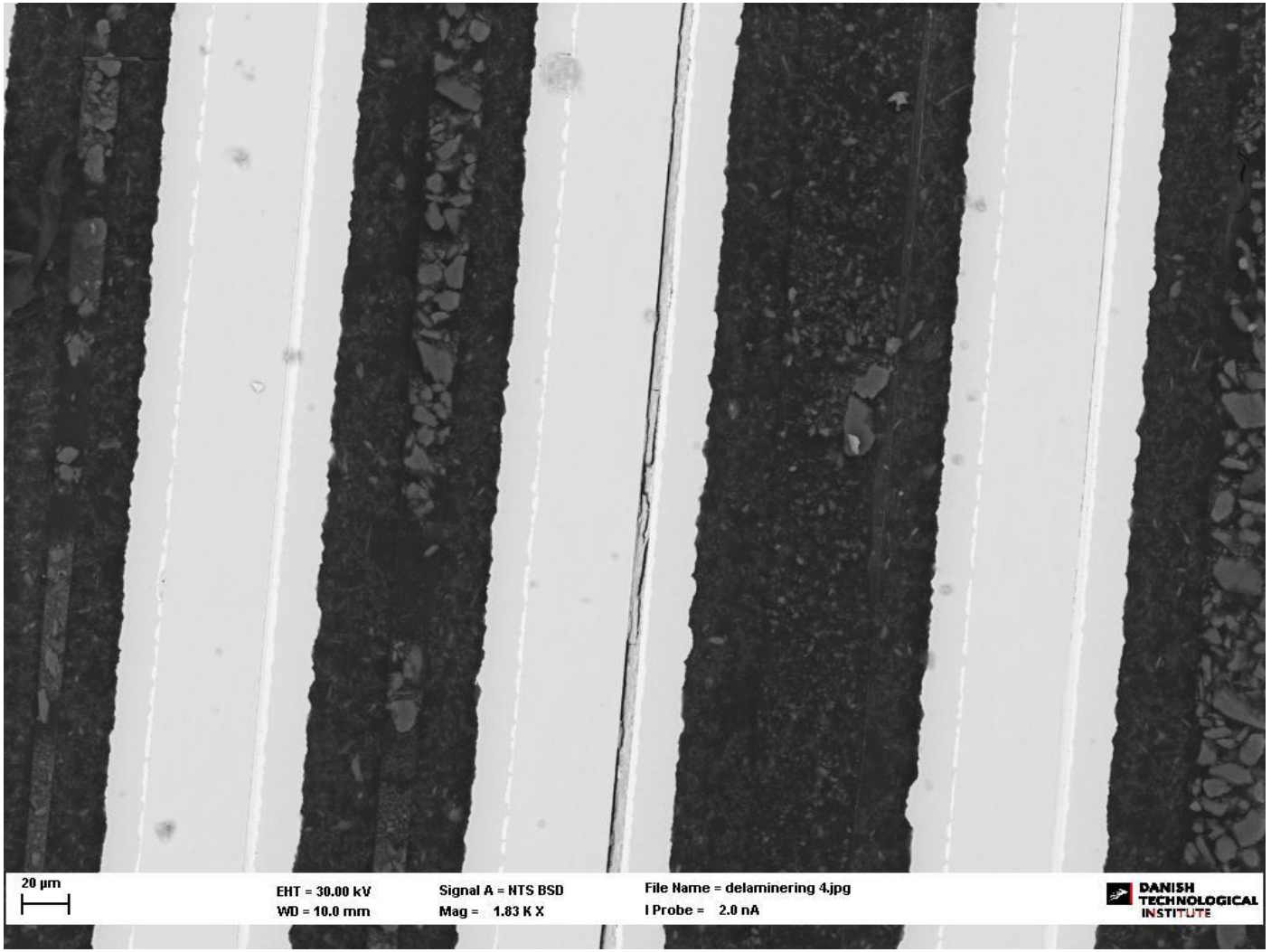
Example of delamination (electron microscopy)



Tape/coil delamination

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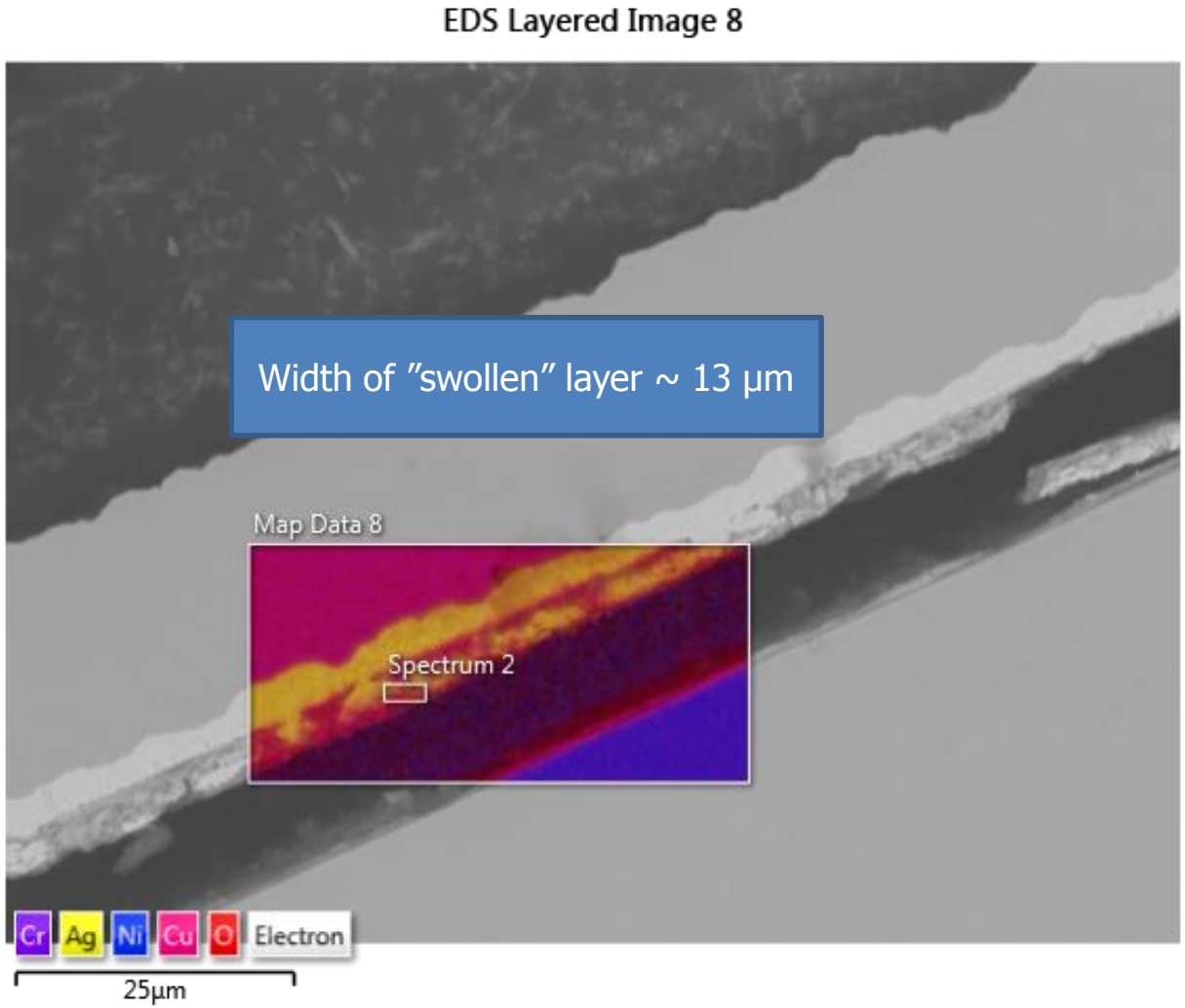

Please note: The investigated tapes/coil are from 2011-2012.
Present day performance is not evaluated.

Coil defect registration

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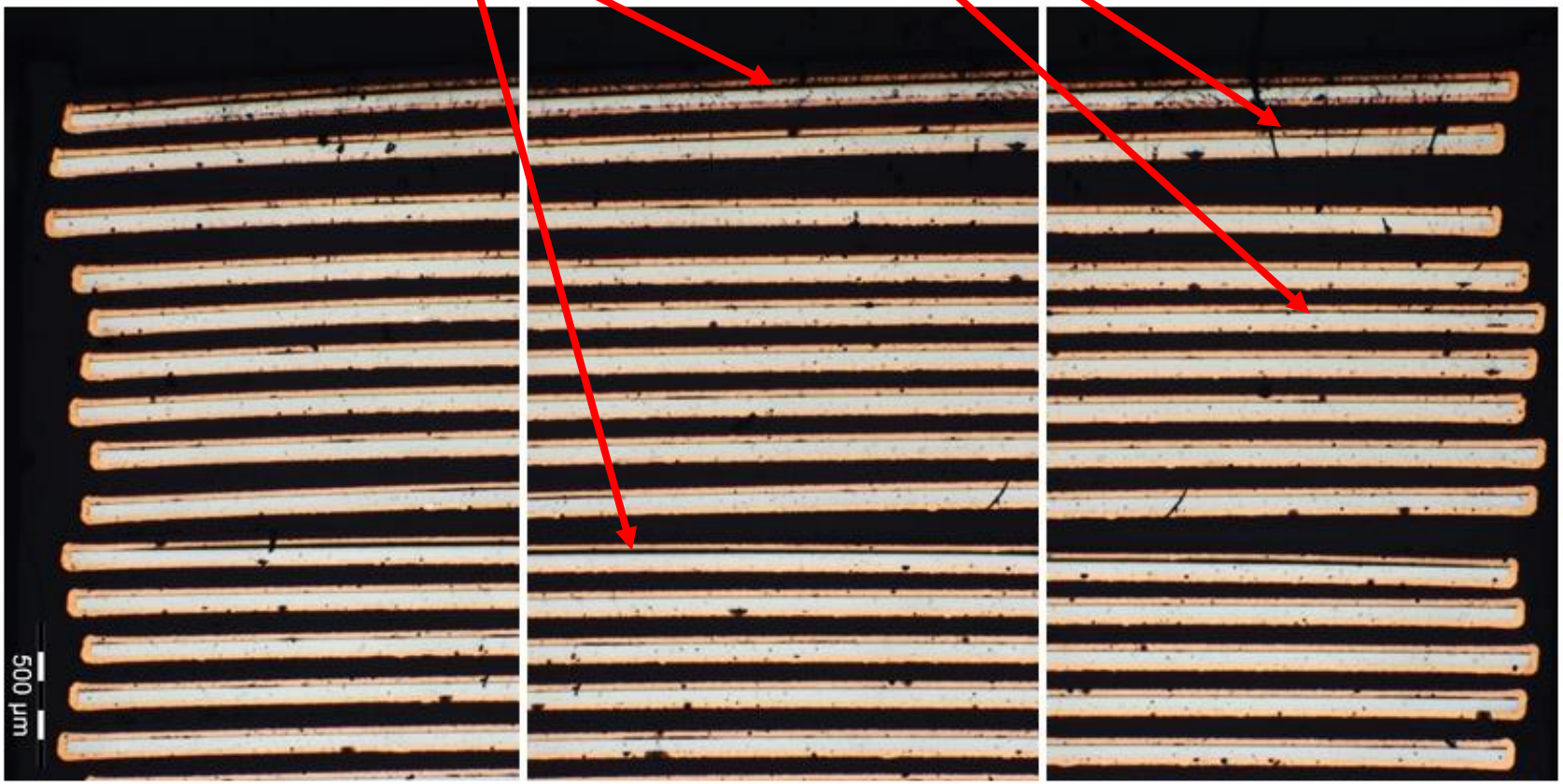
- A) defect (partial delaminiation)
- B) complete delamination



Complete delaminations

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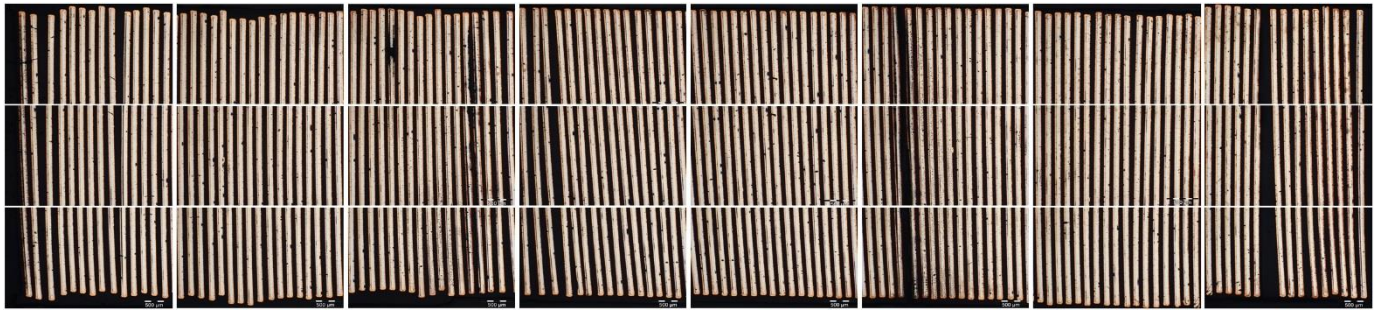
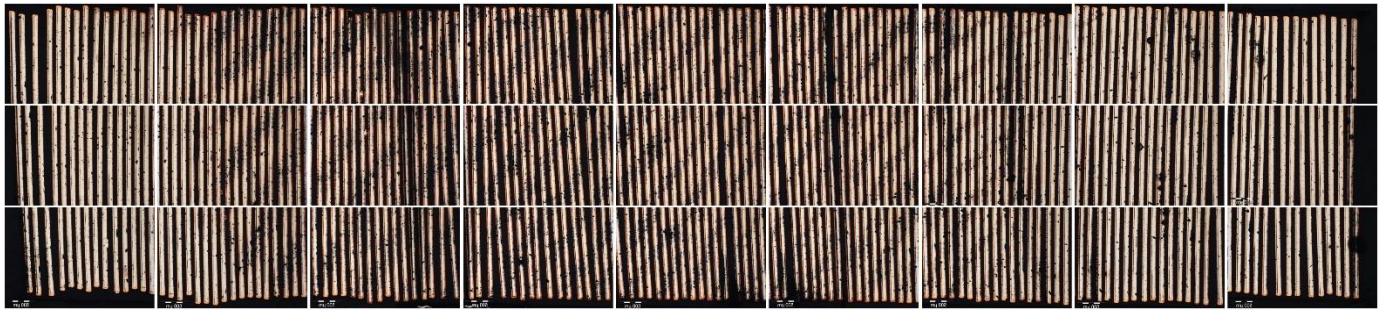
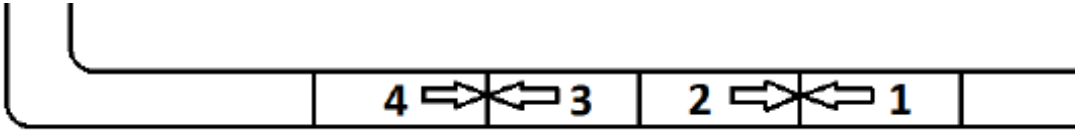
Coil section #1



Coil section #2 (inverted)





Sec. 1	Sec. 2
1	1
	2
10	
	13
	30
	35
36	36
37	37
67	67
68	68
	77
	84
	85
	86
	98
109	109

Defect studies - conclusions

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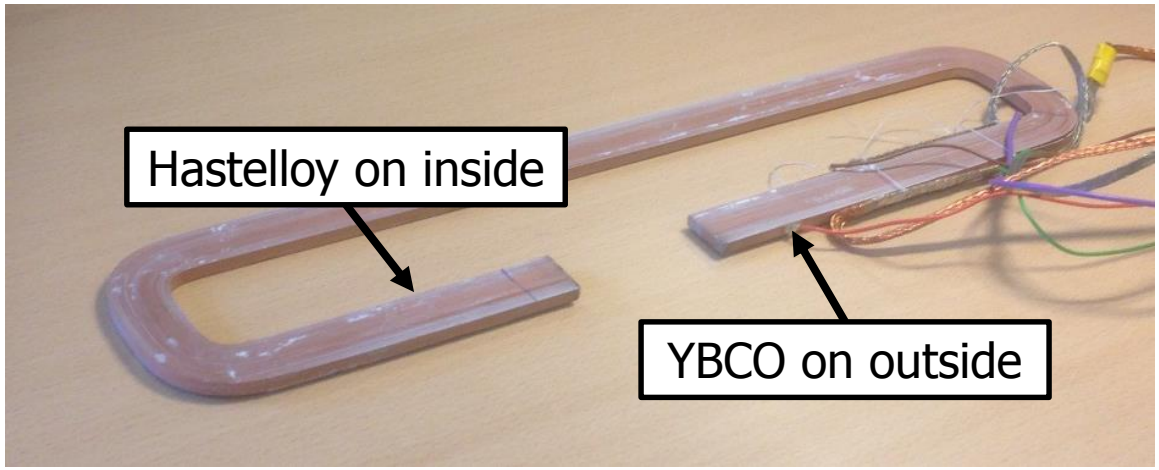
Complete delaminations occur with some correlation between 1-2 and 3-4 (to a smaller extent). Serious conductor damage.

Damage may have be caused by outwards pressure on YBCO layer without mechanical backing from Hastelloy.



No correlation between partial delaminations in coil sections 1-2 and 3-4. Defect origin from section preparation cannot be excluded.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Thank You!