

Bruker Energy & Supercon Technologies (BEST)



BRUKER HTS GmbH

CERN phone conference – Status ARIES Project

BHTS – August 1, 2019





OUTLINE

- INTRODUCTION
- WORK PLAN
- ACHIEVEMENTS
- CHALLENGES
- POSSIBLE APPROACH
- SUMMARY



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INTRODUCTION

BHTS Tasks in WP 14.5. of the ARIES Project:

- Demonstrate pilot production (5 to 15 m long) and verification of higher performance ($J_c \text{ eng} > 600 \text{ A/mm}^2$ - vs. 400 for Eucard2 - at 4.2 K and 20 T) ...
 - ... goal: increase of $J_c \text{ eng}$ by a factor two, aiming at a minimum of 600 A/mm^2 and targeting 800 A/mm^2 , at 4.2 K, 20 T;
- Fabricate at least two long length cables (80-100 m) and verify their electrical, mechanical and magnetic properties
 - ... goal: decrease by a factor of two the total cost of production. Critical in this step of doubling the process output of production.

INTRODUCTION

Key features during processing HTS coated conductors for ARIES project:

- Mechanical polishing of 12mm wide and 50mic thick stainless steel substrates
- YSZ coating of substrates on drum coater ABAD2 (w.o. diffusion barrier)
- Ceria and YBCO coating of YSZ substrates on drum coater PLD300 and PLD600
- Ag coating of HTS tapes on drum coater MET1 first, later on R2R coater Tacoma M, annealing of Ag-coated tapes on R2R oven Tacoma F
- Cu-plating of ARIES HTS coated conductors on R2R coaters PLA1

PROCESSING CHAIN OF HTS PILOT-LINE PRODUCTION

SUBSTRATE PREPARATION (SUB)

BUFFER LAYER COATING (ABAD)

HTS LAYER COATING (PLD)

METAL COATING (MET)

COPPER PLATING (PLA)

FINAL TAPE INSPECTION (INS)





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WORK PLAN

- Overview about 12mm HTS tapes (50mic substrate) processed:

Tape ID#			SUB		ABAD		PLD		MET		CAP		INS		Bemerkungen *tape length in [m]
			IN*	OUT*	IN*	OUT*	IN*	OUT*	IN*	OUT*	IN*	OUT*	IN*	OUT*	
15087-0-0-0			100	0											Tape surface damaged during mechanical polishing
15088-0-0-0	15088-1-0-0		100	86	86	86									
		15088-1-1-1					28	27	27	27			27	27	First trial from Nov. 2016
		15088-1-1-2					58	57	57				58	58	Second trial from Oct. 2018, not yet Ag-coated
17700-0-0-0			100	0											Mechanical polishing not sufficient, surface damaged
17701-0-0-0			100	0											Tape surface damaged during mechanical polishing
17702-0-0-0	17702-1-0-0		100	90	85	85									
		17702-1-1-0					85	81	81	81			81	79	First 50mic HTS tape with 80m length
17703-0-0-0	17703-1-0-0		100	84	84	84									
		17703-1-1-0					35	30	30	30			30	30	First 50mic HTS tape with excellent Ic in field performance
		17703-1-1-1									15	15			Cu20 shipped to CERN
		17703-1-1-2									8	8			Cu07 shipped to CERN
		17703-1-2-0					5	5					5	5	
		17703-1-3-0					20	20					20	20	
17704-0-0-0	17704-1-0-0		100	90	5	0									back side coating B trial
	17704-2-0-0	17704-2-1-0			85	85	82	81	81	0					back side coating B, coating delamination
17705-0-0-0	17705-1-0-0	17705-1-1-0	100	90	85	85	75	75	75	75			75	75	First 50mic HTS tape 2 x 75m batch processing
17706-0-0-0	17706-1-0-0	17706-1-1-0	100	85	85	80	75	75	75	75			75	75	First 50mic HTS tape 2 x 75m batch processing
17707-0-0-0	17707-1-0-0		100	86											
		17707-1-1-0			56	56									
		17707-1-1-1					26	24	24	24			24	24	
		17707-1-1-2					30	26	26	26			26	26	
		17707-2-1-0			30	30	30	25	25	25			25	25	back side coating A, first 50mic HTS tape with improved flatnes
		Total	1000	611	601	591	549	526	501	363	23	23	446	444	

About 550m ARIES tape has been processed through PLD

549	526
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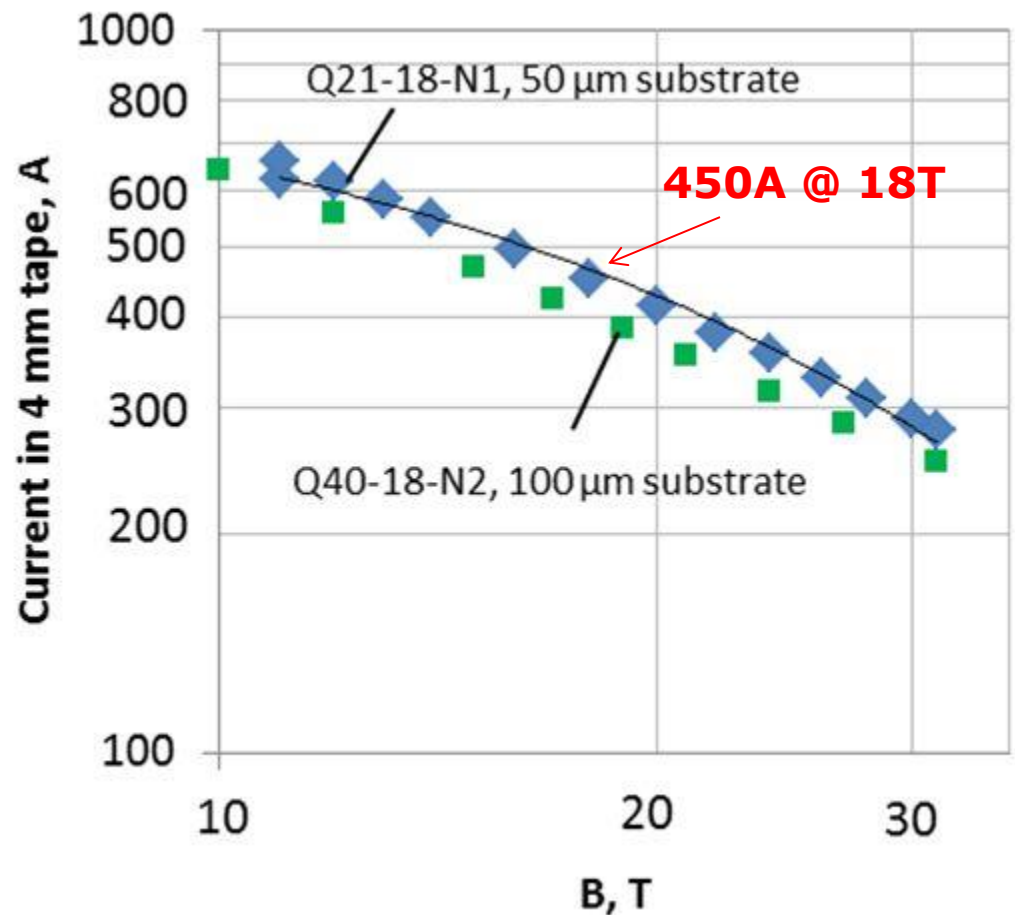


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ACHIEVEMENTS

- A 4 mm wide sample piece was cut from the 12 mm wide HTS tape with 50 μm thick substrate.
- I_c in-field measurements were performed at 4.2K up to 31 T (B//c).
- With a total thickness of about 95 μm for the 4mm HTS tape sample an excellent engineering current density of **Je well above 1000 A/mm²** at 4.2 K 18 T (B//c) is obtained.

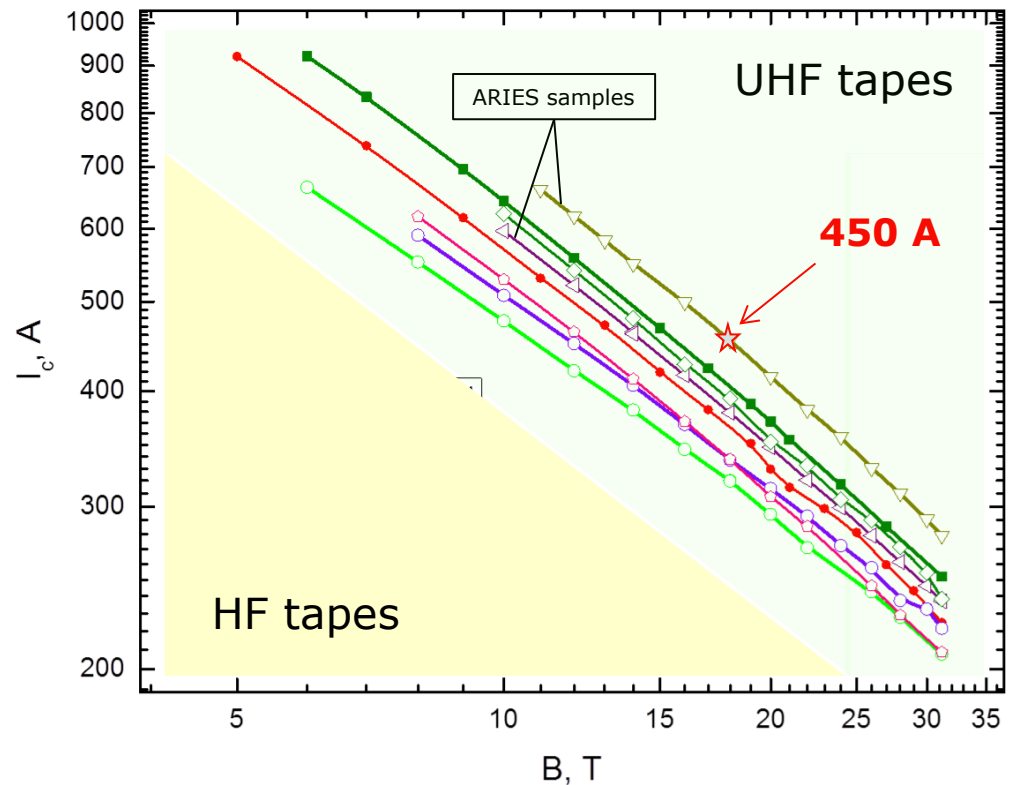


Feasibility has been demonstrated

ACHIEVEMENTS

- I_c in-field performance comparison of ...
 - ... ARIES HTS tape samples with 50mic substrate, 4mm wide piece cut out of 12mm tape,
 - ... and 4mm wide HTS samples out of BHTS long length tape production with 100mic substrates.

Transport $I_c(B, 4.2K)$ measured in resistive magnet up to 31T in $B \perp$ tape orientation

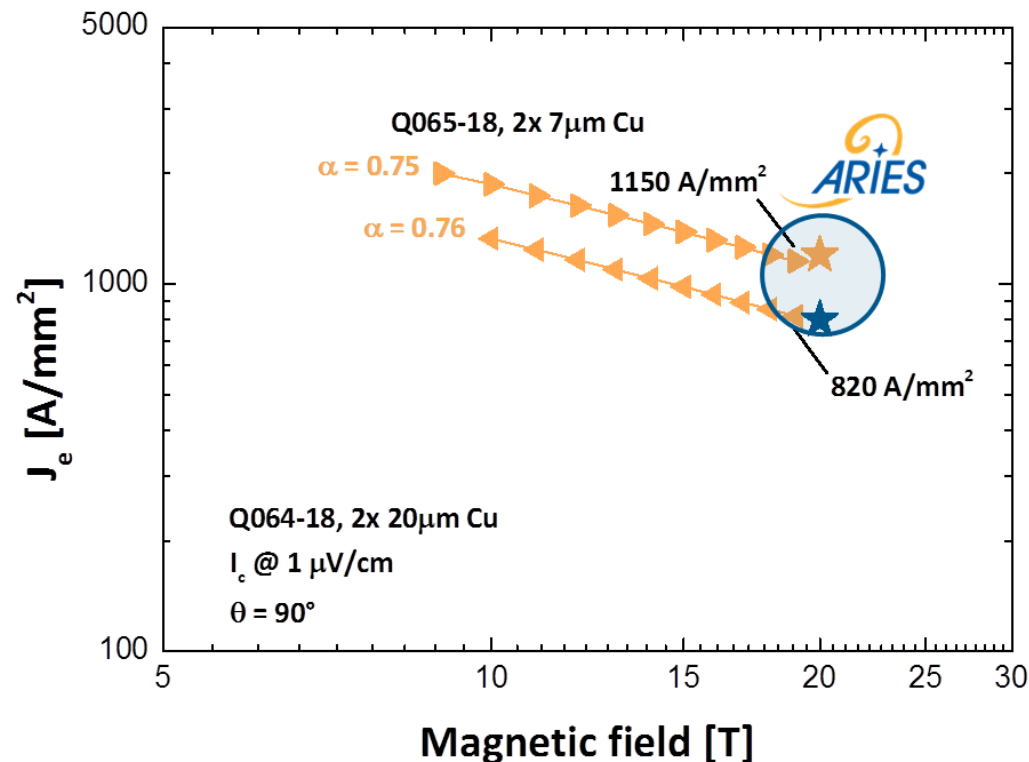


T=4.2K

ACHIEVEMENTS

WAMHTS-5:

Carmine SENATORE, Christian BARTH, Damien ZURMUEHLE

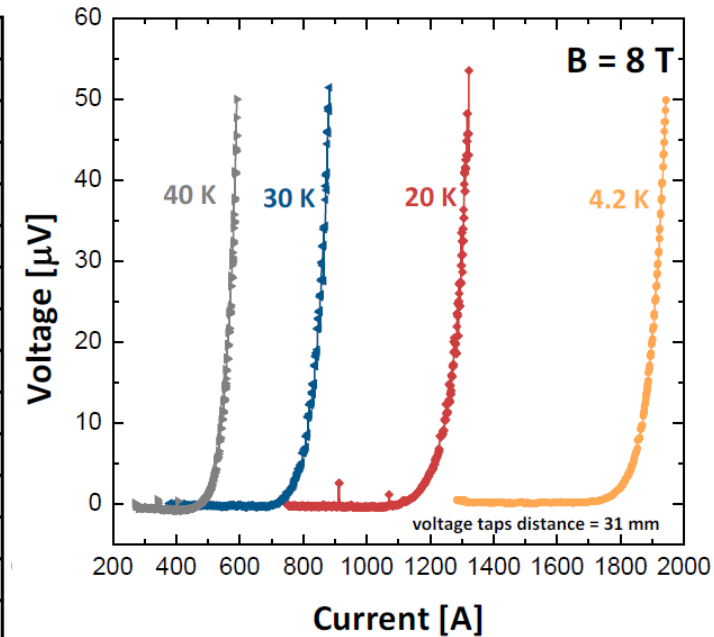
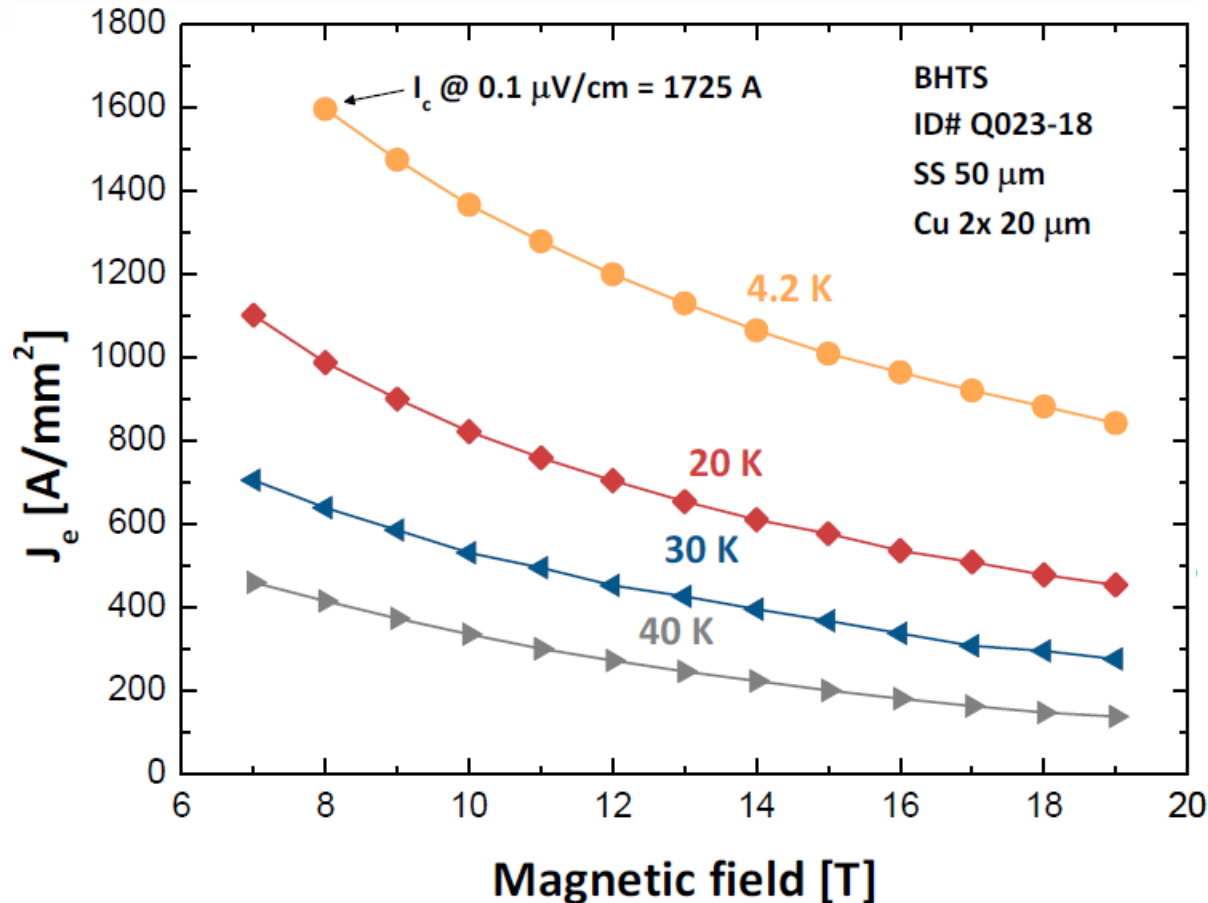


Tape Q065-18 (with 2x 7μm Cu) reached the record (?) performance of 1150 A/mm² at 4.2 K, 19 T, 90°

ACHIEVEMENTS

12-mm ARIES tape: 50 μm SS + 2x 20 μm Cu

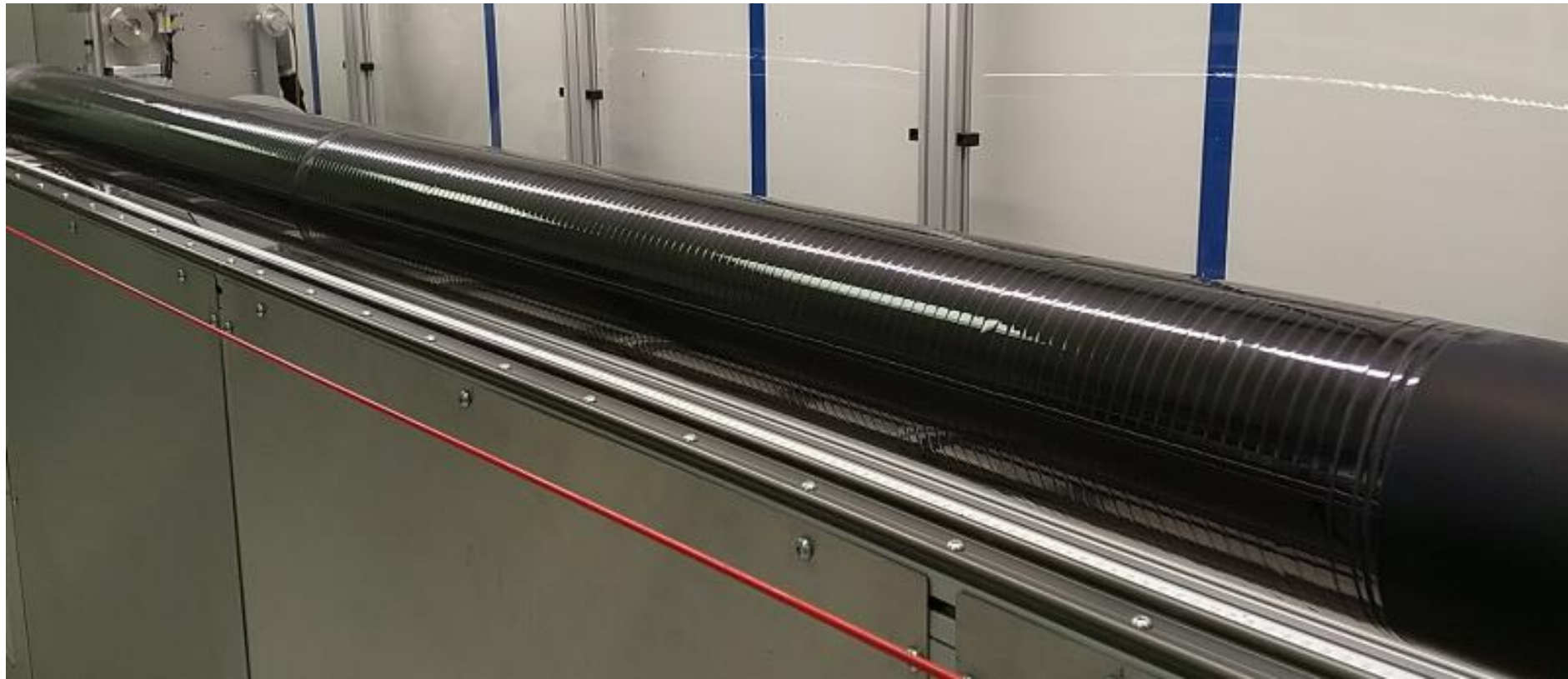
full-width test!!



Carmine SENATORE, Christian BARTH, Damien ZURMUEHLE

ACHIEVEMENTS

- Successful YBCO coating of 150m batch 12mm HTS tapes in PLD600





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CHALLENGES

The 50mic thin stainless steel substrate for ARIES ...

- ... is very hard to polish mechanically (tape edges get easily damaged),
- ... is very sensitive during tape handling and winding (tolerances of tools and set-up must be kept very narrow),
- ... suffers from our spring on drum technology to keep tape under tension when processing,
- ... is very difficult to connect by spot welding (e.g. tape joints for R2R-transport),
- ... does show a strong tape curvature and twist due to film stresses,
- ... is more sensitive to process temperature fluctuations.

CHALLENGES

Examples ...





CHALLENGES

Possible solution to overcome the technical issues:

- Using substrate with a higher strength (e.g. Hastelloy),
- Replacing mechanical polishing by electro-polishing,
- Avoiding spring on drum technology,
- Improving tape handling set-up of the equipment used.

(significant efforts, not possible in the frame of the ARIES project)



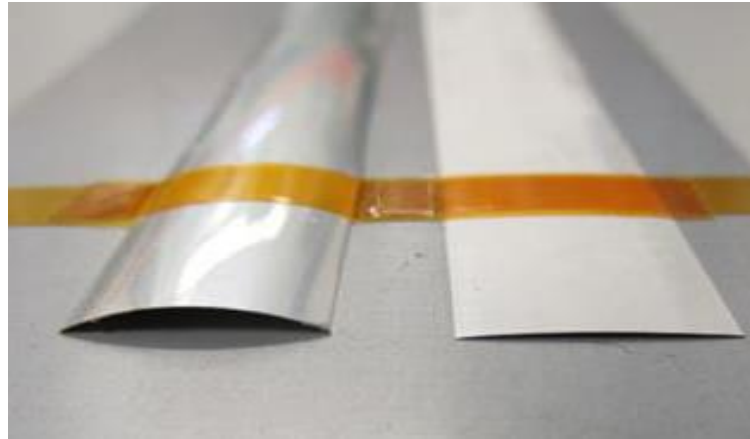
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POSSIBLE APPROACH

One approach to overcome curvature and twist of the thin HTS tapes within the ARIES project has been applied ...

- ... back side coating



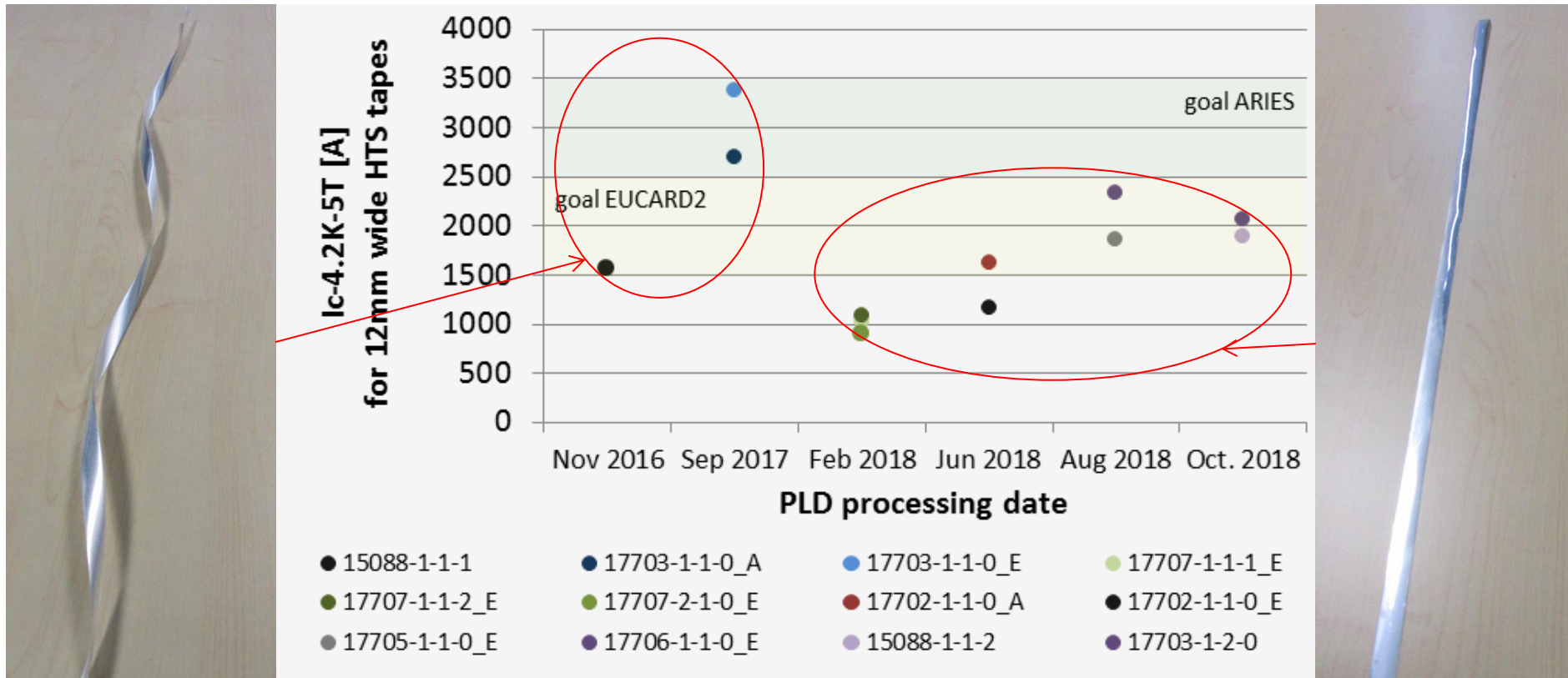
Approach: Compensating the film stresses on the functional side with a back side coating process.



POSSIBLE APPROACH

The impact of back side coating on the I_c performance of thin HTS tapes

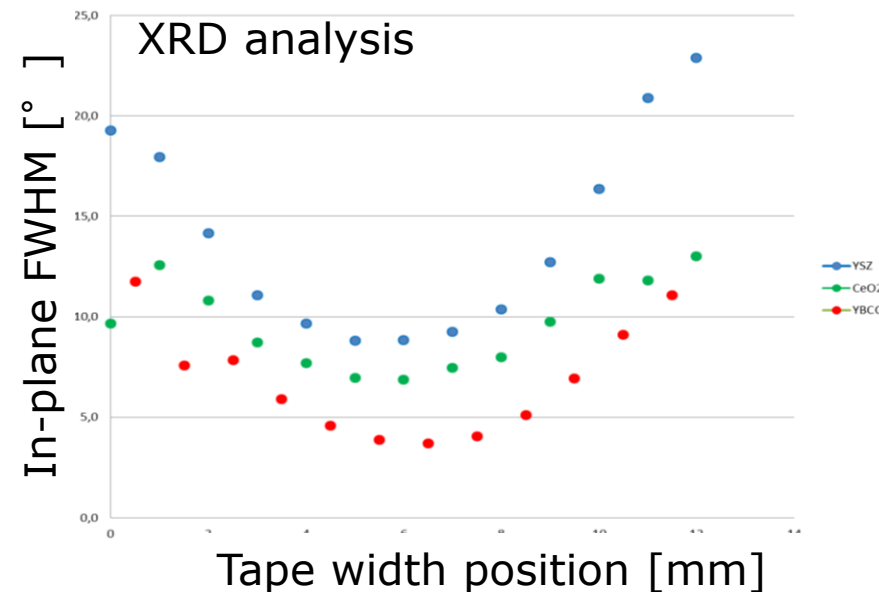
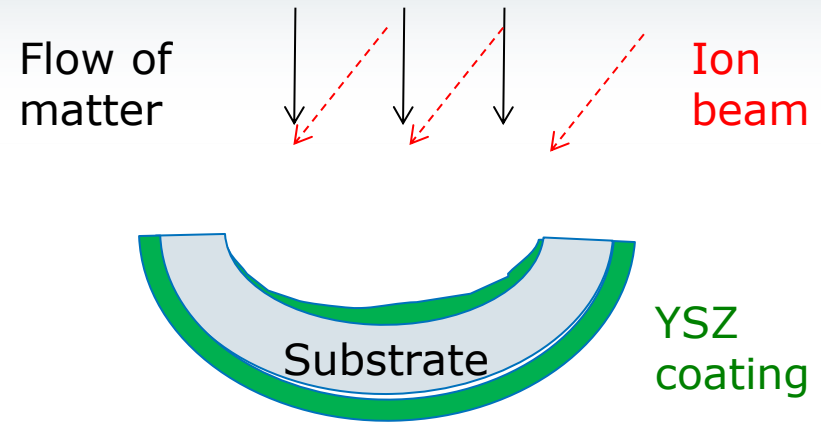
- I_c in-field performance is reduced by about 30%



POSSIBLE APPROACH

The impact of back side coating on the I_c performance of thin HTS tapes

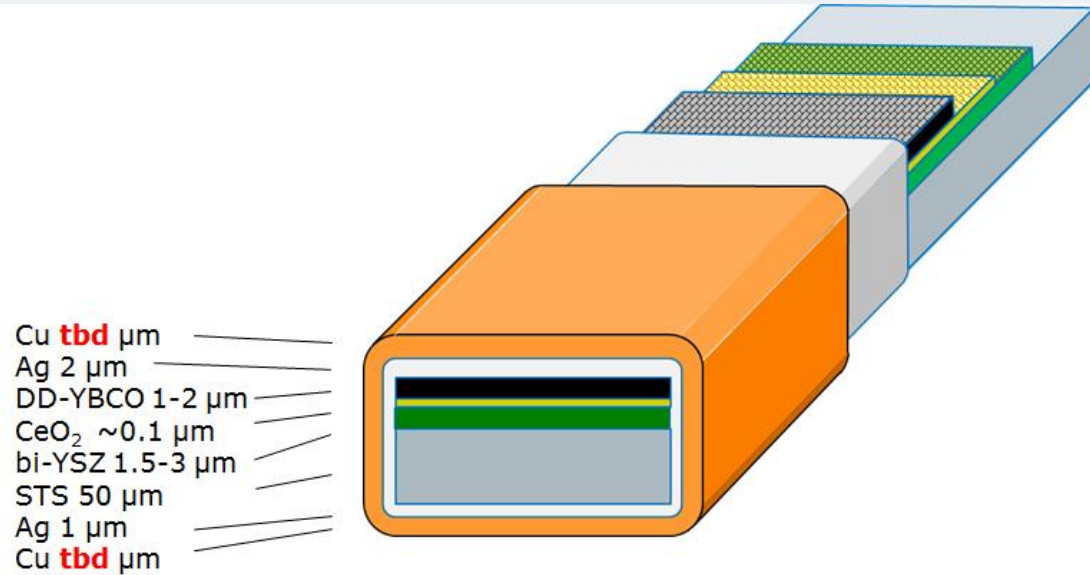
- Reason for the 30% reduced I_c in-field performance is the non-homogeneous crystallographic buffer layer texturing.
- Due to the tape bow (caused by the back-side coating) a variation of the incident angle of the structuring ion-beam in respect to the substrate surface is present during the ABAD process.
- Therefore, the in-plane texture of YSZ, CeO₂ and YBCO layers is significantly reduced at the edge of the tape.



POSSIBLE APPROACH

Je at 18 T versus total thickness of the tape:

$I_c(5T, 4.2K, B//c) = 2000A$
assumed



t_{total} , μm	60	70	80	100	140
Je at 18 T, A/mm ²	1110	952	833	666	476

Thickness example: 50mic substrate + 10mic functional coatings + 2 x 20mic Cu encapsulation



CHALLENGES

Possible solution to reduce the I_c -performance loss during back side coating:

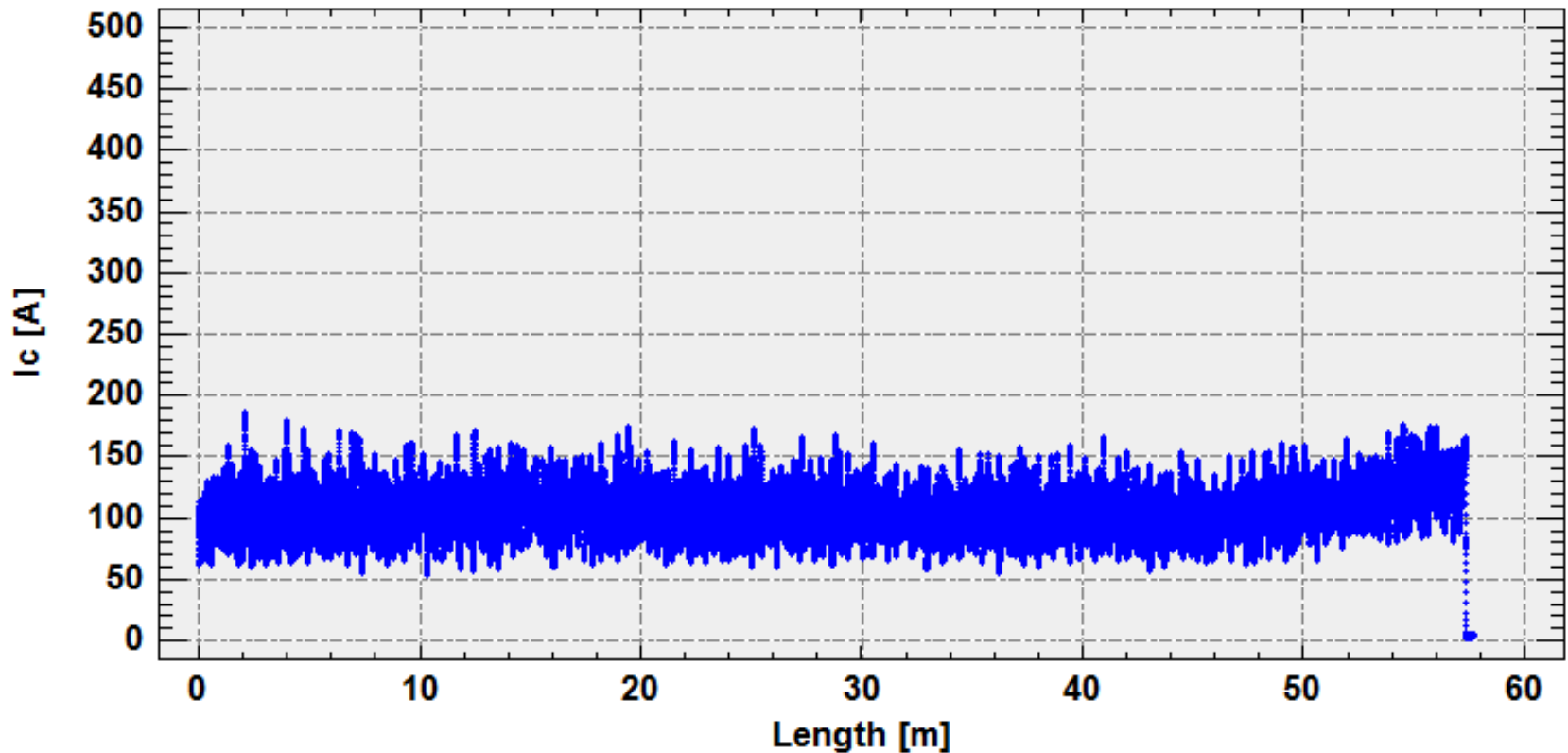
- Alternating or parallel coating of functional side and back side

(significant efforts, not possible in the frame of the ARIES project)



POSSIBLE APPROACH

- Tapestar results of the latest long tape ID# 15088-1-1-2 PLD processed during Oct. 2018 (tape has not yet been Ag-coated)





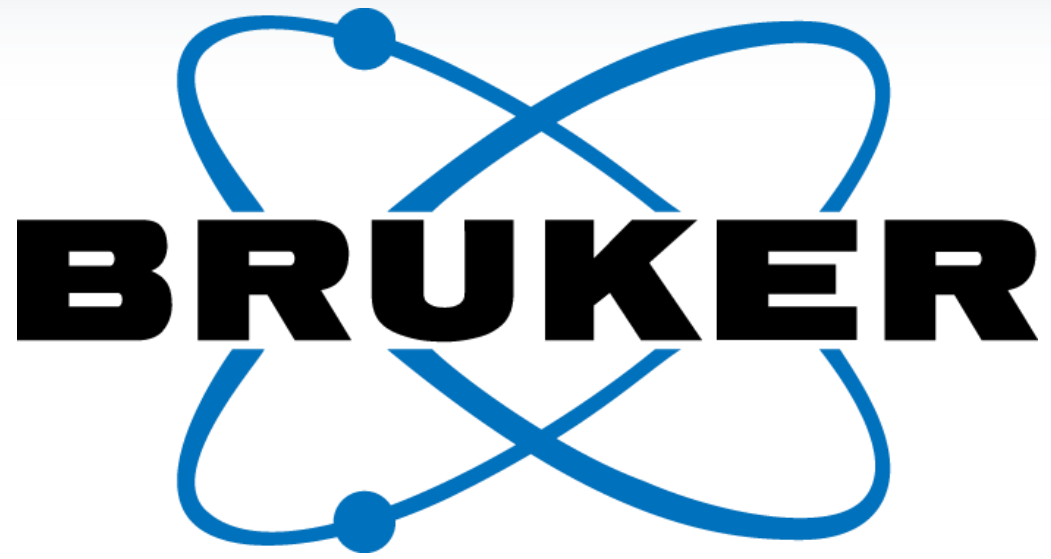
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SUMMARY

- The feasibility of achieving critical engineering currents of 1000A/mm² at 4.2K, 18T B//c by processing HTS tapes using 12mm wide and 50mic thick stainless steel substrates has been demonstrated.
- The processing capability for 12mm wide HTS tapes has been enhanced by doubling the batch size during PLD coating and utilizing the Ag-coating equipment for reel-to-reel processing.
- Summing up, about 550m of ARIES tape has been processed through PLD and the maximum batch size was 150m.
- However, a significant HTS tape bow and twist due to film stresses is present when using the thin substrate material which impacts the tape processing.
- Within the ARIES project the approach to compensate the tape bow by back side coating has been studied and applied. The effectiveness of the approach to reduce the tape bow has been shown. However, so far the back side coating also resulted in a 30% reduction of the I_c in-field performance.



Innovation with Integrity