CCA 2025, CERN Progress in 2G-HTS Tape Development at High Temperature Superconductors, Inc. (HTSI)



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IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 59, May 2025. Presentation given at CCA 2025, March 11-13, 2025, Geneva, Switzerland.

The HTSI Team (~ 20 people in Santa Barbara, CA)



Rohit Jain, Silvia Rasi – REBCO experts; Richard Behiel - Metrology





Ray Karam, CEO & Founder

Berkely Johnson, CFO



Adam Shelton, VP of Marketing & Business Dev.



Ines Wyrsta, Director of Engineering



Acquired PVD Products, Inc. in June 2022 (Jim Greer!)



On our path to build a 500 m/hr manufacturing line



- Manufacturing reel-to-reel equipment for the HTS industry for 20 years.
- Vertically integrated

HTSI is the only 2G-HTS tape manufacturer using PLD in the U.S.



A Glimpse Into Our Santa Barbara Production Facility

Buffer Layer Systems











REBCO PLD



Backend (Ag, Cu, Slitter, Edge)





Metrology





WIP Chart Snapshot – 600 m Length, 16 mm Width (!)

				~ WIP Tracking Chart ~ Chart does not show shipped or scrapped tapes. Last updated: 2/21 10:00 AM						HIGH TEMPERATURE SUPERCONDUCTORS			
x Coordinate (m) US Clean 1 AA41A 0000 AA607 AA607 A	Electropolish HA-AAHA. 0000 Ready H GZ 2/19 DM GY AAGY 0000 Ready G GY AAGY 0000 Ready G GY AAGY 0000 Ready G GY 1/19 DM GY 1/29 DM GU 1/15 DM GT 2/12 DM	US Clean 2 44 52 52 52 52 52 52 52 52 52 52	Alumina ALACS 0000 Ready X AAGX 0000 Ready X AAG	Yttria	MgO	LSMO	YBCO HA GZ- GY- GY- GV- GY- GT-	Silver	02 Anneal	Process	Edge Cu Plating	Status	
AAGS 0000 GS 12/12 0M AAGR 0000 GC GG 12/12 0M AAGG 0000 GC GG 11/19 0M AAGG 0000 GC GG 10/16 0M AAGG 0000 GC GG 10/16 0M AAGG 0000 GC GG 10/16 0M AAGG 0000 GC GG 10/10 0M AAGG 0000 GC GG 10/10 0M	40k	12/17.DM 10/14.DM 10/16.DM 10/16.DM	5 1/24 SR - AAGM 0000 Ready 0 1/29 SR - 10/29 SR	30k	17k	10k	AAS CODO HOLD	65 GR GO GO GO GM GL GL	65 65 68 68 69 69 60 60 60 60 61 60 61 60	Electropolish	100	Production	
AAGH 0000 AAGG 0000 AAGG 0000 Cd 9/2D JM AAGE 0000 Cd 9/2D JM AAGE 0000 Cd 9/1D JM AAGE 0000 Cd 9/1D JM AAGE 0000 Cd 9/5D JM AAGE 0000 Cd 9/5D JM	GH 10/7 DM G GG 10/4 DM G GE 12/11 DM G GC 9/11 DM G GAAGD 0000 Ready G GAAGD 0000 Ready G GAAGA 0000 Ready G	50 10/7 DM 56 10/7 DM 56 10/7 DM 56 12/12/DM 50 50 50	AAGG 0000 Ready of 12/17 SR	SH 11/11552 с 56- 56- 50- 50- 50- 50- 50- 50- 50- 50- 50- 50	SH AAGH ODDD Ready (GG TAAGE ODDO Ready) GC GC GC GC GC GC GC GC GC GC GC	50- 50- 50- 50- 50- 53- 53-		6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	5 - 5 - 5 - 5 - 5 - 5 - 5 - 5 - 5 - 5 -	Alumina/Yttria	360	Production	
AAF2 0000 AAF2 0000 AAFX 0000 AAFX 0000 AAFX 0000 AAFX 0000 AAFX 0000 AAFX 0000 AAFX 0000 AAFY AAFY AAFY AAFY AAFY AAFY AAFY AAFY	72 9/5 DM FY AAFY 0000 Exp FX AAFX 0000 Exp FW 1/16 DM FV 1/22 DM FU 1/23 DM FU 1/23 DM FT 8/8 DM	Z 9/10 DM FX W 1/17 DM V 1/22 DM U 1/24 DM U 1/24 DM	2 10/7 SR Y X 4 1/22 SR Y AAFV 0000 Ready T 11/14 SR	Z 10///SR FY 	72 - AARZ 00000 BEBESY FY FX W	72- FY- FX- TV- TV- TT-		- 花- ドゲ- 秋- ドゲ- ドゲ- ドゲ- ドゲ- ドゲ- ドゲ- ドゲ- ドゲ		IBAD/EPI MgO	100	Production	
AAFS 0000 FS-81/2 DM AAFR 0000 FR-81/2 DM AAFQ 0000 FR-81/2 DM AAFQ 0000 FR-71/2 DM AAFQ 0000 FR-71/2 DM AAFQ 0000 FR-71/2 DM AAFW 0000 FR-71/2 DM AAFW 0000 FR-71/2 DM AAFW 0000 FR-71/2 DM FR-71/2 DM FR-71/2 DM	IS- 8/13 DM FR 8/12 DM FO- 8/12 DM FO- 8/15 DM FO- 8/15 DM FN- 8/12 DM FN- 8/11 DM FM- Part of AAFM FM- Part of AAFM	5-8/13 DM R-8/12 DM 0-8/5 DM 50-8/2 DM N-8/1 DM N-7/17 DM M-7/16 DM F	S- AAFS 0000 Exp 9/11 SR 9/11 SR 9/11 SR 1/16 SR AAFM 0002 Ready F AAFM 0001 Ready F	S- 9/11 SR - 11/12 SR 0- 9/11 SR N- 1/16 SR M- M- F	FS AAFR 0000 EXP 12/15 VS AAFO 0000 Ready AAFO 0000 Ready Mark 0000 Ready	FS FR FO FO FO FN FN FM FM FM	FS FR FO FN FN FM	FS- FR- FQ- FQ- FN- FM- FM-	FS FS FS FR FR FR FO FO FO FO FO FO FN FN FM FM	LSMO	75	Production	
AAFL 2000 Ft 7/11 DM AAFL 0000 Ft 7/30 DM AAFL 0000 Ft 6/26 DM AAFF 0000 Ft 6/25 DM AAFF 0000 Ft 6/25 DM AAFF 0000 Ft 5/25 DM	FF 7/16 DM FJ 7/25 DM FJ 7/23 DM FH 7/10 DM FH 7/10 DM FF 7/11 DM FF 7/22 DM	F) 7/16 DM F) 7/25 DM AAFI 0000 Ready* H 7/10 DM G 7/8 DM F) 7/11 DM F) 7/23 DM	12/9 SR AAFF 0000 Ready* 17/19 SR AAFF 0000 Ready* 12/2 SR AAFF 0000 Ready* 1/31 SR	FL- 12/258 FL- FL- FL- FL- FL- FL- FL- FL- FL- FL-	FL MARE 0000 Ready: FL AAFH 0000 Ready: FG 12/5 V5 FL AAFE 0000 Ready:	FL- FI- FI- FI- FI- FI- FI- FI- FI- FI-	1. 	和 	11、11、11、11、11、11、11、11、11、11、11、11、11、	PLD		Development	
AAFC 0000 70 6/32 0 Mil AAFC 0000 72 6/32 D Mil AAFE 0000 74 6/32 D Mil AAFE 0000 74 6/32 D Mil AAFZ 0000 74 6/32 D Mil AAFZ 0000 74 6/32 D Mil AAFZ 0000 74 6/32 D Mil AAFY 0000 74 6/32 D Mil	PC 6/26 DM FC 6/25 DM FB 6/25 DM FA 6/20 DM F2 6/19 DM EY Part of AAEY EX 6/17 DM EX 6/13 DM	C 6/26 DM B 6/25 DM 6/25 DM 6/25 DM 6/20 DM C 6/20 DM C 7/20	AFB 0000 Ready 9/10 SR 9 Part of AAEY 8 8/12 SR 9 8/12 SR 8/12 SR	2 1/2/ 3A 1/21 SR 1/21 SR 9/10 SR 2 9/9 SR Part of AAEY 8/12 SR 8/2 SR	TATE 0000 Ready TB 10/28 VS 11/19 VS EY Part of AAEY SY 9/11 VS 8/13 VS	00 FB- 11/13 TM E2 11/20 SR EY 8/20 SR EY 9/26 TM EX 9/26 TM	FC FC FA AMARA COOC Ready EX AMARA COOC Ready EX AMARA COOC Exp AMARA COOC Exp AMARA COOC Exp AMARA COOC Exp	но- пс- пв- бх- бх- бх- бх- бх- бх-	10 10 10 10 10 10 10 10 10 10 10	Ag sputter	200	Production	
AAEU 70000 EU-5/6 0M AAET 70000 ET-4/29 DM AAER 70000 ER-4/23 0M AAER 70000 ER-4/23 0M AAER 70000 ER-4/23 0M AAER 70000 ER-4/23 0M AAER 70000 ER-4/10 DM AAER 70000 ER-4/10 DM AAER 70000 ER-4/10 DM AAER 70000 ER-4/10 DM	EU 6/5 DM E ET 5/31 DM E ER 5/9 DM E EP 5/3 DM E EO 5/2 DM E EM 4/18 DM E Ex 4/8 DM E	U 6/5 DM T 5/31 DM R 5/9 DM P 5/3 DM O 5/2 DM M 4/19 RP8 C 4/8 DM	U 10/9 5R 6 7/30 5R 7/23 5R 9 9/13 5R 9/13 5R 10/11 5R 10/11 5R 10/11 5R 10/11 5R 10/11 5R 10/12 5R 10	U-10/9 SR T-7/30 SR R-7/23 SR P-9/13 SR O-1/15 SR M-10/11 SR E-9/12 SR	EU-AAEU 0000 Ready ET-8/6 VS ER-AAER 0000 Ready AAEP 0000 Ready AAEO 0000 Ready M-12/18 VS EK-9/16 VS	EU ET AAET 0000 Exp. EP- E0- M AAEM 0000 Exp. 9/17 TM	EU ET ER EP EO EM EM	EU- ET- ER- EP- EO- EM- EK-	EU- EU- ET- ER- EP- EO- EO- EM- EK- EK-	Slitting		Development	
AAE T 0000 Er 4/12 DM AAE T 0000 D 3/20 DM AAE C 0000 Ec 3/14 DM AAE C 0000 Ec 3/16 DM AAD C 0000 D 2/16 DM AAD C 0002 D D AAD C 0003 D Part of AAD C ADD C 0000 D D	9- 4/4 DM 17- 3/28 DM EC 3/15 DM EA 3/19 DM DZ Part of AADZ DY- Part of AADY DS- 1/30 DM	EI 4/5 DM EI 3/29 DM EC 3/14 DM EA 3/19 DM D2 Part of AADZ D9 Part of AADZ D5 1/31 DM	9/17 SR AAEF 0000 Exp AAEF 0000 Exp AAEF 0000 Exp A 5/21 DM Part of AADZ 9 6/6 IW 4 AADS 0000 Exp	EI- 9/17 SR EF- EC- 5/21 DM FA- 5/21 DM FA	EJ- AAEJ 0000 Peady EF- EC- EA- 5/23 AY Part of AAD2 Dr- 6/13 AY	E)- EC- EC- 5/29 TM D2- 8/29 SR D4- 8/30 SR D5-	E) EC EA AADZ 0000 Exp DY AADZ 0002 Ready DY AADY 0003 Ready DS	E) EF- EC- EA- D7- D7- D5-	탄 탄 탄 EF EF EF EF EF EC	Cu sputter	100	Production	
AADD 0000 00 - 1/37,084 AADD 0000 02 - 172,044 AADD 0000 02 - 172,046 AADD 0000 02 - 172,048 AADD 0000 02 - 172,048 AADX 0000 02 - 172,048 AADX 0000 02 - 172,048 AADX 0000 02 - 172,048 AACY 0000 02 - 172,018 AACY 0000 02 - 172,017 AACY 0000 02 - 172,018 AACY 0000 02 - 172,019	2/7 DM 0 - 2/9 DM 0 - 9/18 DM 0 - 9/17 DM 0 - 9	2/8 DM 2/9 DM cs 1/0	- 2/27 EP - 4/23 W - 3/22 TM - 1/81 W - 3/22 TM - 1/81 W - 3/27 TM - 3/27 TM	2/27 EP 14/23 W 3/22 TM 3/22 TM 3/22 TM 3/22 TM 3/27 TM 3/2	2/28 VS 0 6/11 AV C 1710 VS 10/77 VS 10/77 VS 10/77 VS 11/70 VS 11/70 VS 11/70 VS 11/70 VS 12/20 AV 12/20 AV 12/20 AV 12/20 VS 12/20 VS 12/20 VS 12/20 VS C 4ACC 0000 Ready ACC 0000 Ready ACC 0000 Ready	3/5 TM 0 AADL 0000 Exp 4/4 TM 4/4 TM 4/4 TM 4/5 TM W 4/5 TM W A/5	AARDS (0000 Ressty) DALLS (0000 Ressty) TAARD (9 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	5-2-5-5-5-5-5-5-5-5-5-5-5-5-5-5-5-5-5-5	Cu plating		Short length Long length out-sourced Being built	
AACE '000 AACE '000 AASE '	CD- 7/25 DM 0 97/21 DM 0 97/19 DM 9 97/19 DM 9 97/26 RPB 9 98 Part of AAB5 98 Part of AAB5 97/25 DM 4 47/25 DM 4 AV 4/6 DM 4 AV 4/6 DM 7 97 T DHK AAAQ 4 Y 3.69 Km ready 4 t for Electropolish	D 7/26 DM 0 7/24 DM 0 7/20 DM 87/24 DM 0 0 97/26 DM 0 0 987 6/26 DM 0 0 987 6/26 DM 0 0 987 6/26 DM 0 0 987 6/27 DM 0 0 987 6/27 DM 0 0 997 6/27 DM 0 0 997 6/7 AB 0 0 997 6/7 AB 0 0 907 0/7 AB 0 0	AACE 0000 Exp. 2 AACE 0000 Exp. 2 AACE 0000 Exp. 2 AACE 0000 Exp. 4 ABE 0000 HOLD 5 Part of AAB 7 /5 TM 6 /9 TM 5 /3 TM	0 8/16 SR 22 2/19 IW 24 9/17 of AABS 25 9/17 of AABS 26 7/6 GVR 37/6 GVR 6/19 IM 30 0 m ready 50 7 Yttria	ACD 0000 Ready 2722 V5 2772	2728 TM 2728 TM 274 FD 271 FD	AMP 2000 Exp 30 40 40 40 40 40 40 40 40 40 4	CD B2 B2 B2 B2 A2 A2 A2 CD D m ready for Silver	CD- CD- CD- CD- CD- CD- CD- CD- CD- CD-	2/4 Ik) 0 m ready r Cu Sputter 0 m ready for TapeStar 1 108 m ready for TapeStar 1 0.08 m ready for TapeStar 1	ready er Edge	Backend or ready for TapeStar 2	



High Quality Buffer Delivered to Select Customers



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- In production. All HTSI tapes made on in-house produced buffer.
- Qualified for use with PLD and MOCVD (Selva's group!)
- Excellent adhesion.
- Delivering up to 550.

Specs for LSMO:

- Delta phi < 7.0
- Delta omega <3.0
- Tilt typically 1.5 < x < 4.0 (not guaranteed)



Transmission Wire: Transport at 77 K, s. f.



- Achieved industry spec I_c > 150 A for 4 mm tape
- Doubled J_c to 3 MA/cm²
 - Moving to multiple lanes to increase speed and length.
- 100 m run



Transport J_c Comparable to Competitors at 30 Tesla





- Un-plated (thin Cu) samples survived 31 T (!)
- *J_c* and pinning for B // c-axis is comparable to competitors
- High Field I_c needs to improve by 2x
- * Data from Aixia Xu, Jan Jaroszynski, Silvia Rasi at the High Magnetic Field Laboratory



Torque Magnetometry at 30 Tesla





 Torque Magnetometry data at 30 T confirm excellent J_c comparable to competitors and robustness with B // ab (magnet applications)



Nanostructure & Pinning



* Data from Yan Xin, FSU

Y₂O₃ platelets for pinning

- Stacking faults
- **Threading dislocations**
- Large 2nd phase regions especially towards upper layer inhibiting current percolation \rightarrow Room for improvement!



Threading dislocations

PLD240530



0.2

0

0.6

0.4 Sample Strain [%] 0.8

We would like to acknowledge funding by the U.S. government under ARPA-E Award No. DE-AR0001815 for part of this work



Buffer line in production → Ask for a quote! Competitive current / current densities for transmission and fusion.

THANK YOU



IEEE-CSC, ESAS and CSSJ SUPERCONDUCTIVITY NEWS FORUM (global edition), Issue No. 59, May 2025. Presentation given at CCA 2025, March 11-13, 2025, Geneva, Switzerland.