Wire-bonding studies on LTU foils and dummy parts for module prototyping

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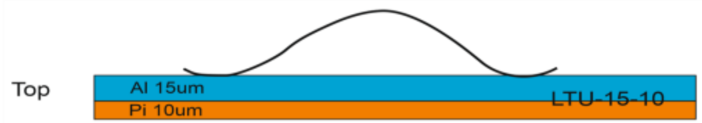
UK EIC WP1 Face-to-face meeting

Brunel University of London

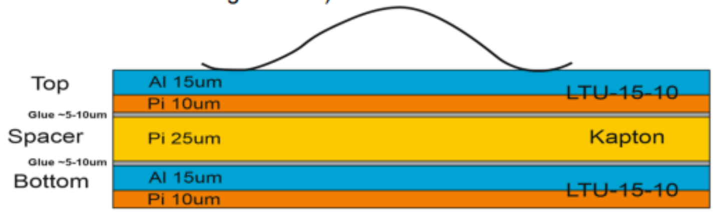
Foils and bonding equipment

- Two types of foils received in March (details see the presentation by LTU)
- Equipment Used
  - Hesse BJ820 Wire Bonder
  - Dage 4000 Pull Tester

➢ Single-layered (LTU-15-10 material)



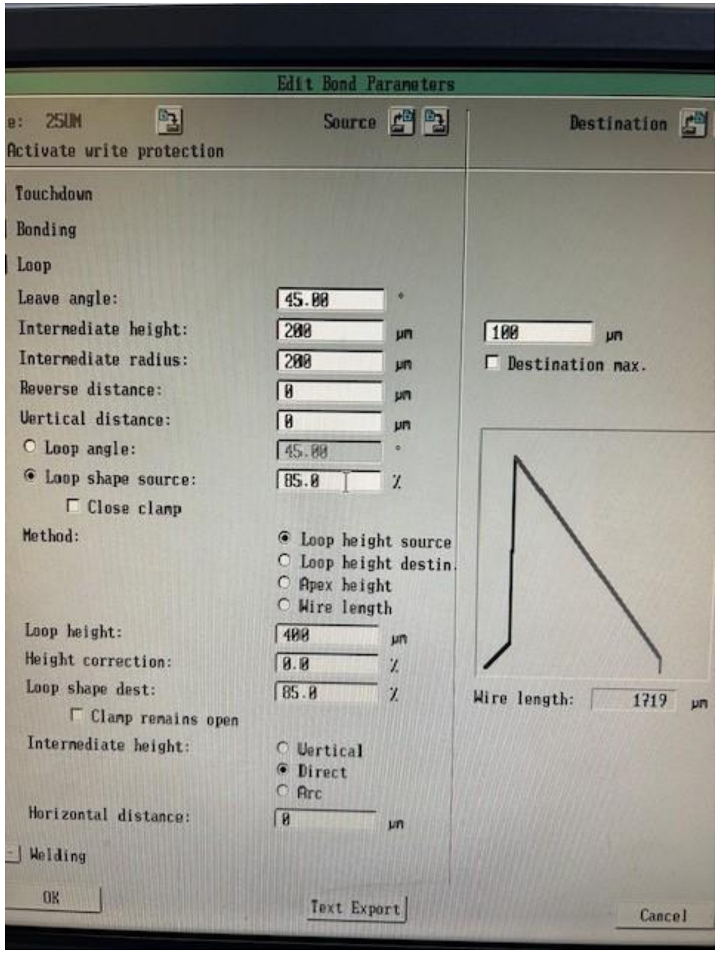
➢ Multilayered structure (LTU-15-10+Kapton 25um + LTU-15-10 similar to ePIC FPC and similar ultralight flexes)

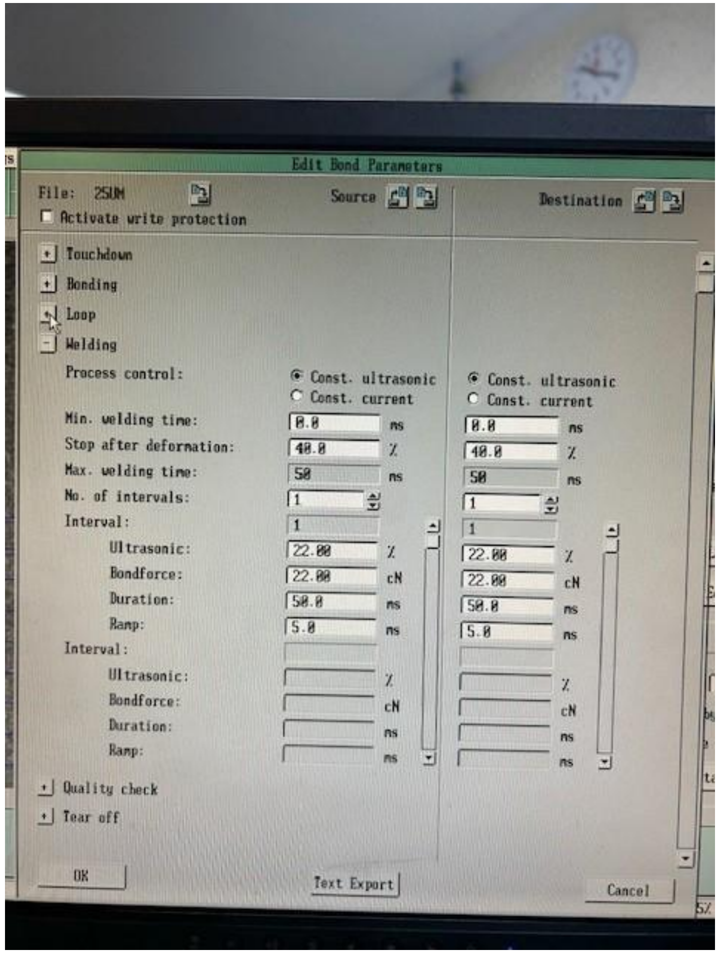


Initial trials

Bonding parameters

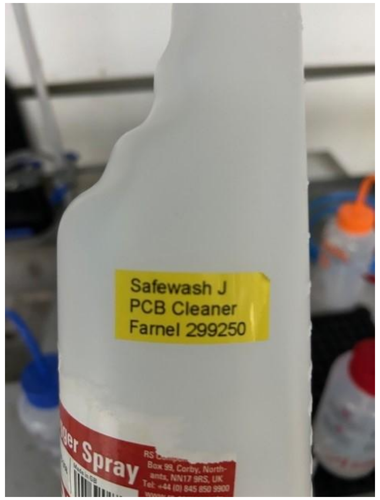
- First attempts in March
  1. A gold board used for pull tests after wire spool or wedge changes
  2. Single-layer foil
  3. Multi-layer Foil
- 50 Al wires, 100 µm pitch, 25 µm diameter, 1.5 mm length
- Default setting (used for the gold board test)
  - Ultrasonic: 22%
  - Bondforce: 22 cN

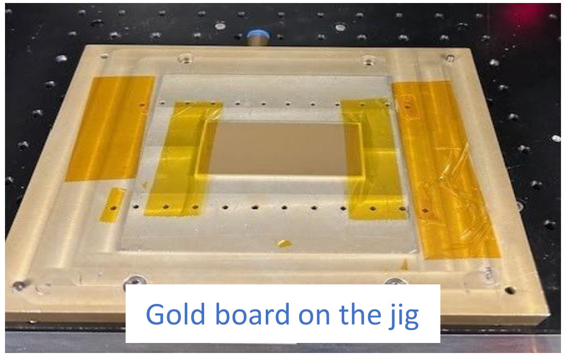




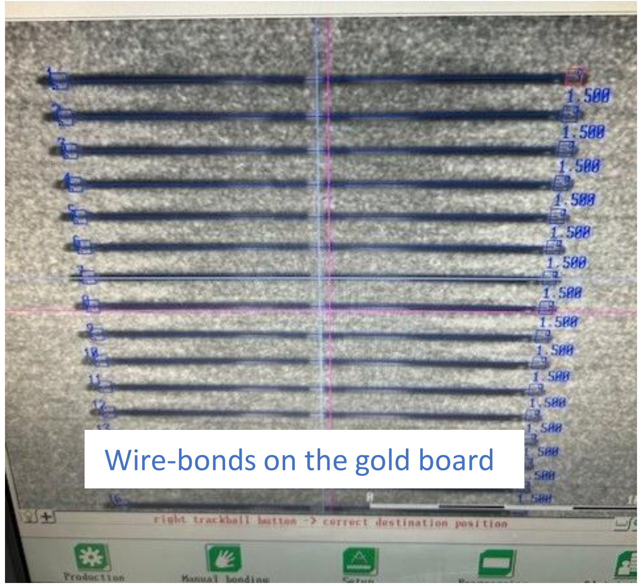
Wire-bonding on gold board

- Clean the gold board using the safewash and rinse with DI Water
- Tape the board to a jig used for wire bonding
- No failed wires

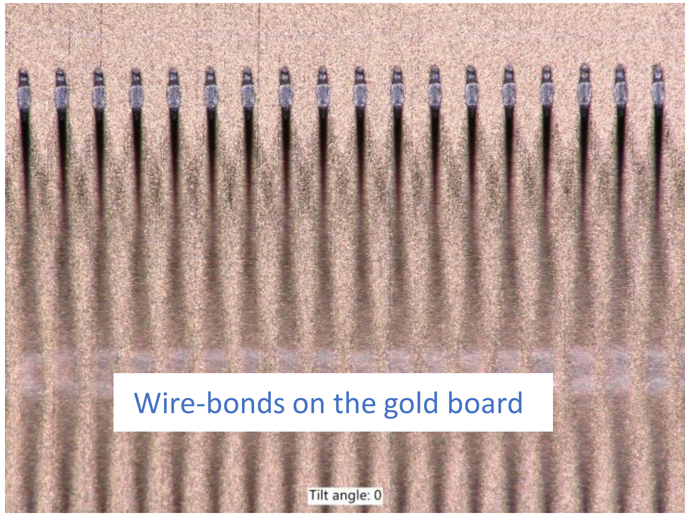




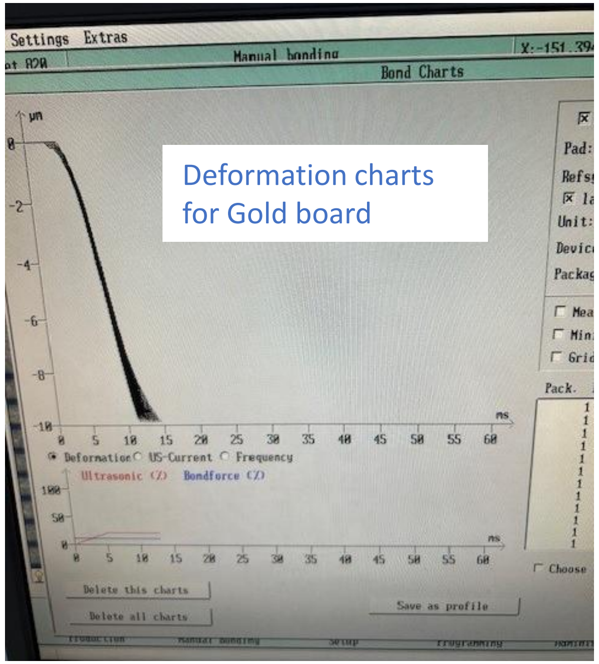
Gold board on the jig



Wire-bonds on the gold board



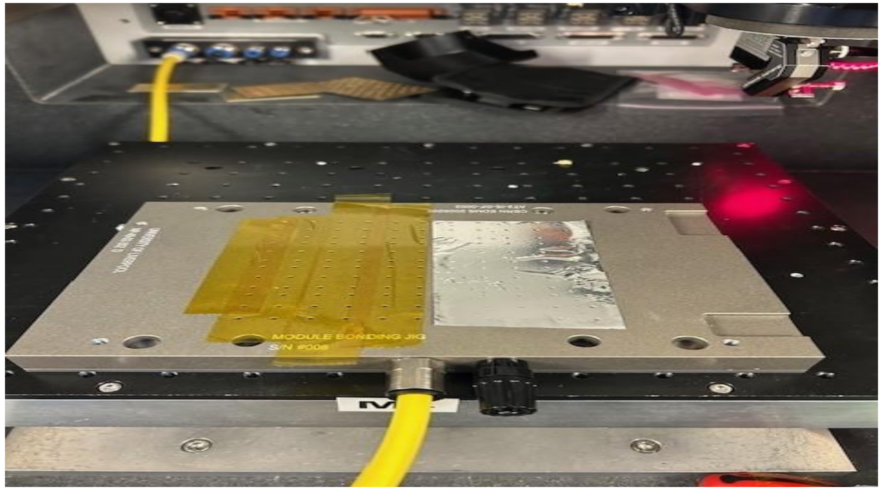
Wire-bonds on the gold board

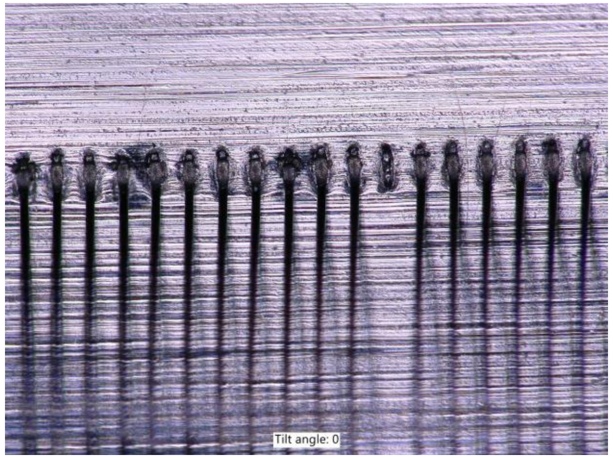


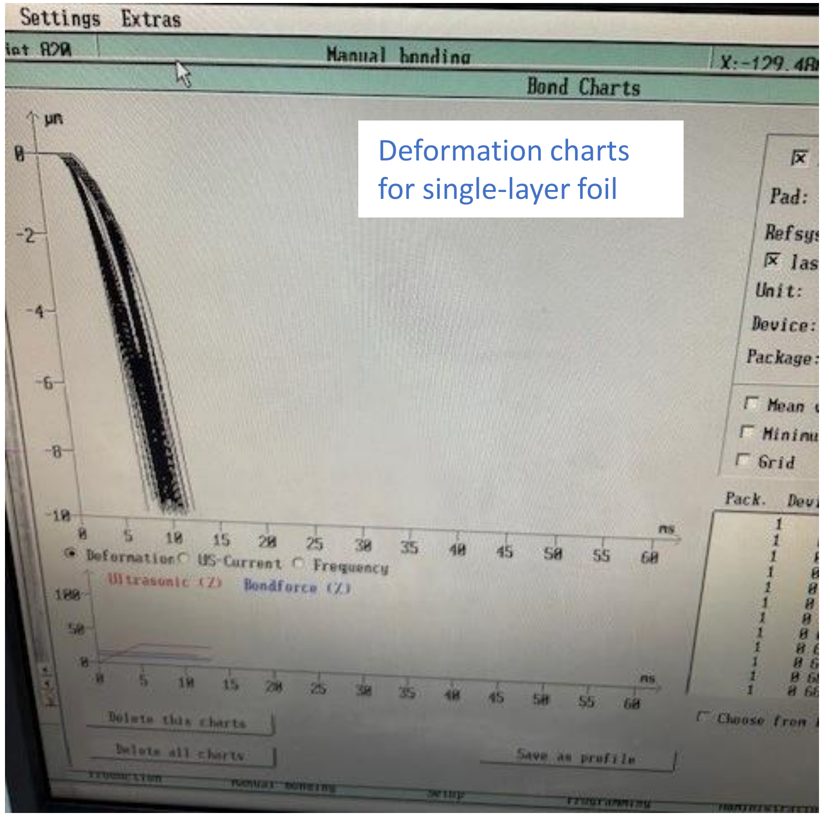
Deformation charts for Gold board

Wire-bonding – single-layer foil

- Foil was initially taped down as with the gold board → multiple wire failures occurred
- Vacuum fixing improved bonding yield, though failures persisted
- Increasing bonding parameters to 30% Ultrasonic and 30 cN Bondforce further improved results
- Final test: 1 failure out of 50

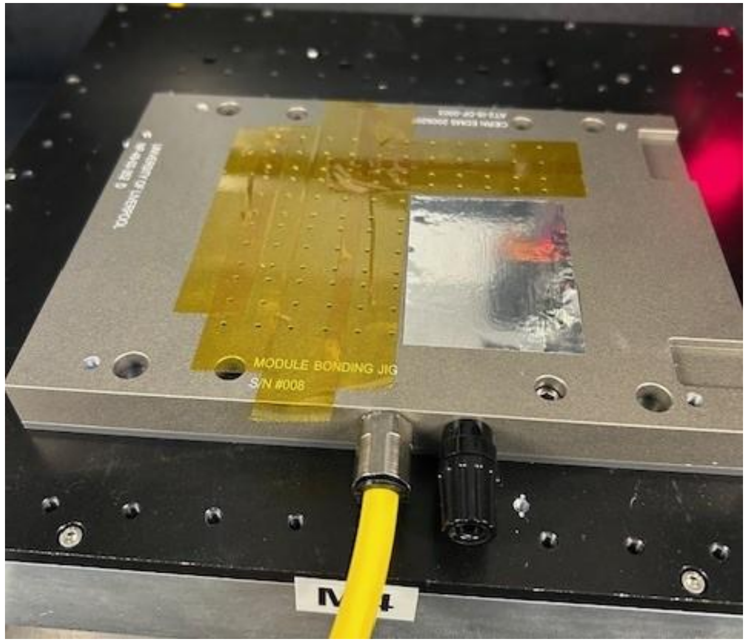


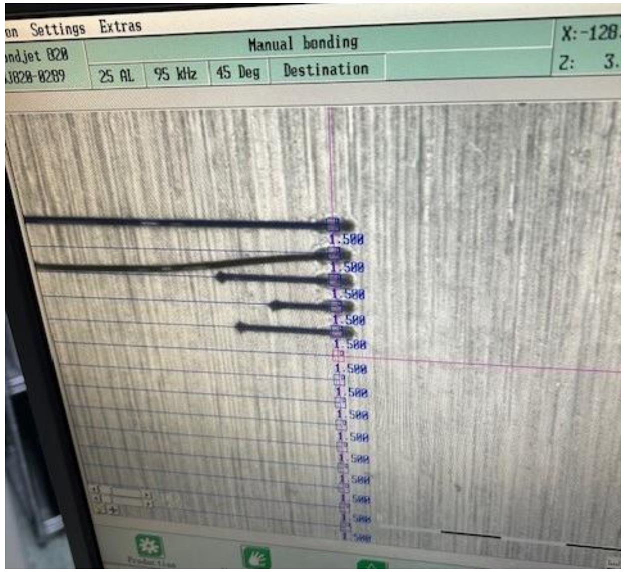


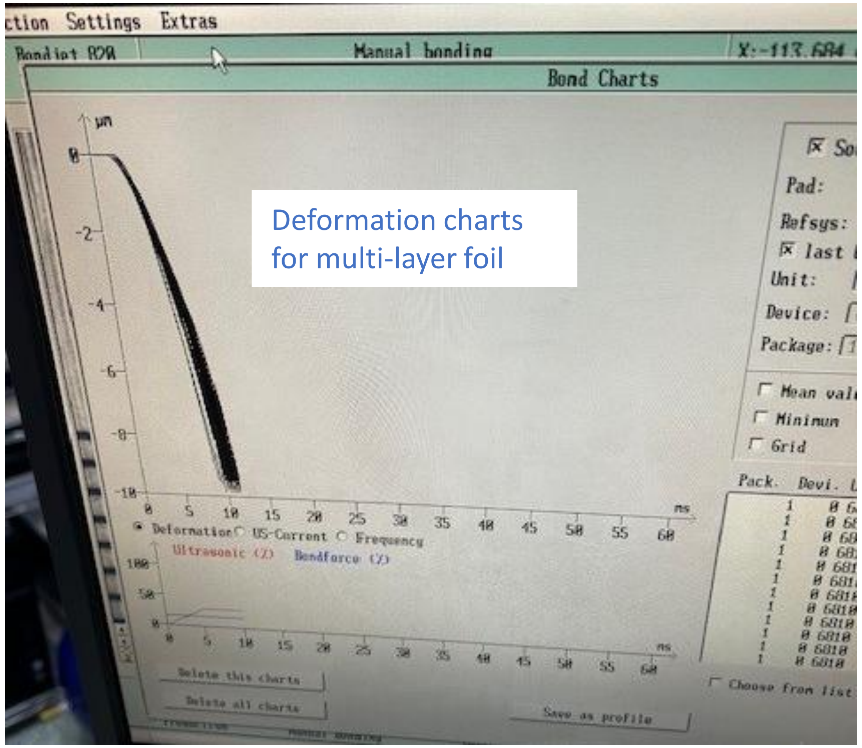


Wire-bonding – multi-layer foil

- Foil vacuumed to jig, but multiple wire failures still observed
- Switching to higher welding parameters improved bonding
- Final test: 3 failures out of 50







Deformation charts for multi-layer foil

Pull tests

- Peel failures dominated for both foil types; none observed on gold board
- No consistent pattern in peel location (source vs. destination bonds)
- Bonds were placed between vacuum holes (not directly over)
    - Foil lifting observed during pull tests, likely due to slight vacuum leakage
- Some foil bonds achieved > 12 g
- Foil bond strength showed higher variation compared to gold board

CARTRIDGE	50 g	20326722	Pull (theta)
TESTSPEED	557	um/s	
TESTLOAD	25	g	
FALLBACK	30	%	
TEST	1		10.62
TEST	2		10.713
TEST	3		10.604
TEST	4		10.549
TEST	5		10.647
TEST	6		10.915
TEST	7		11.161
TEST	8		11.078
TEST	9		11.033
TEST	10		10.742
TEST	11		11.447
TEST	12		11.397
TEST	13		11.296
TEST	14		11.298
TEST	15		10.931
TEST	16		11.171
TEST	17		10.668
TEST	18		11.326
TEST	19		11.312
TEST	20		11.111

Samples	Mean [g]	STDEV [g]	STDEV [%]	Max [g]	Min [g]
50	11.03	0.26	2%	11.45	10.55

Gold board

CARTRIDG	50 g	20326722	Pull (theta)
TESTSPEEI	557	um/s	
TESTLOAD	25	g	
FALLBACK	30	%	
TEST	1		11.19
TEST	2		10.411
TEST	3	3	12.203
TEST	4		10.002
TEST	5		10.648
TEST	6		9.1082
TEST	7		11.633
TEST	8		11.227
TEST	9		10.943
TEST	10		4.9457
TEST	11		11.051
TEST	12		4.8058
TEST	13		12.228
TEST	14		6.0968
TEST	15		10.435
TEST	16		9.7686
TEST	17		8.0488
TEST	18		10.168
TEST	19		10.26
TEST	20		9.7136

Samples	Mean [g]	STDEV [g]	STDEV [%]	Max [g]	Min [g]
49	9.02	2.69	30%	12.3	3.86

Single-layer foil

CARTRIDGE	50 g	20326722	Pull (theta
TESTSPEED	557	um/s	
TESTLOAD	25	g	
FALLBACK	30	%	
TEST	1		4.3809
TEST	2		2.9231
TEST	3		5.8723
TEST	4		4.8029
TEST	5		8.6724
TEST	6		5.8365
TEST	7		6.4746
TEST	8		6.6812
TEST	9		9.0281
TEST	10		9.3168
TEST	11		7.194
TEST	12		6.4875
TEST	13		6.3363
TEST	14		5.1966
TEST	15		5.7042
TEST	16		10.054
TEST	17		10.216
TEST	18		9.8386
TEST	19		9.4333
TEST	20		12.161

Samples	Mean [g]	STDEV [g]	STDEV [%]	Max [g]	Min [g]
47	7.46	2.66	36%	12.24	2.52

Multi-layer foil

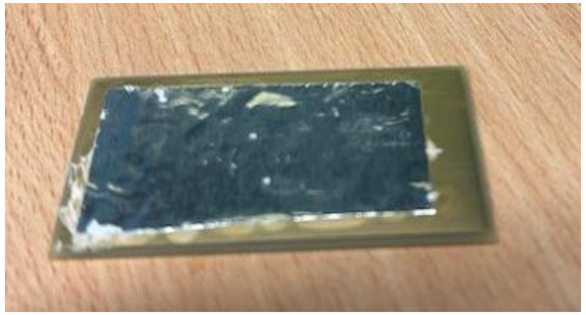
Summary – initial trials

- Foil type comparison
    - Multi-layer foil felt stiffer, as expected
    - No major difference in bonding behaviour; both required parameter adjustment beyond standard settings
- Some foil bonds achieved > 12 g → demonstrates potential for strong, reliable bonding
- Foil bond strength showed higher variation compared to gold board

Second tests

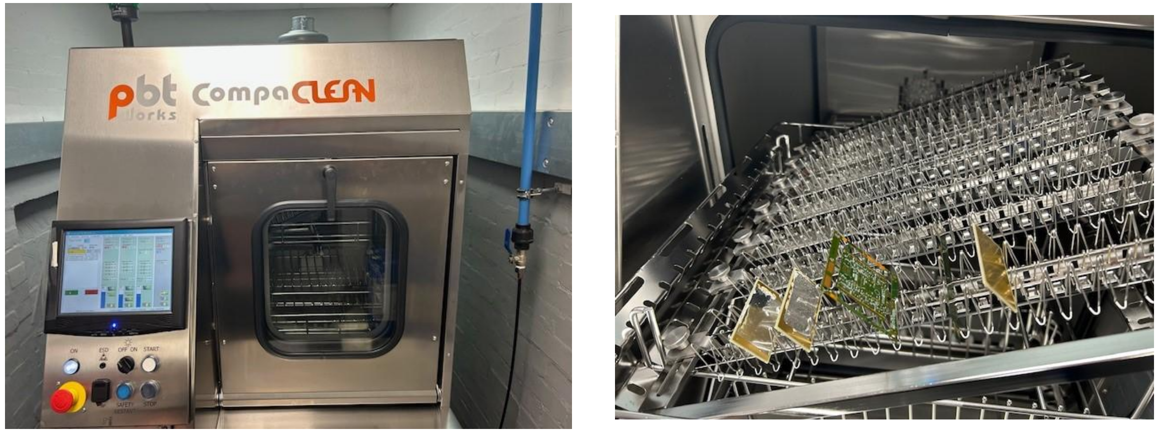
New tests – foil onto PCB

- Foils glued onto FR4 PCB to improve vacuum contact during bonding
- Some glue spilled onto the top surface of the foil
- Cleaned with PCB cleaner (cleaning + 2 rinse cycles + drying)
- Glue residue on top side successfully removed



Single layer foil

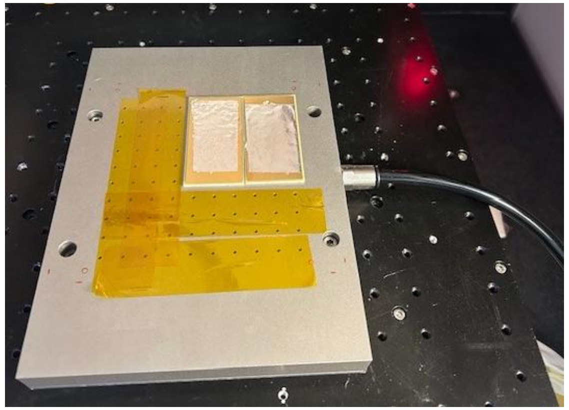
Multi layer foil



PCB cleaner

- Ran out of the wires used for the previous tests
  - CCC: Al-1%Si, 25 um diameter, El % 1-4, TS 15-18g
- New Heraeus wire will now be used
  - Al Si-M, 25 um diameter, EL > 1%, BL 15-17 cN
  - Personal experience: this wire is not as good as the previous wire
- Foil on jig
  - Vacuum contact significantly improved
  - Foils were held firmly on the jig throughout testing

New wire



Foils on jig

Standard parameter

- Standard settings (full details in backup slide):
  - Ultrasonic: 22%
  - Bond force: 22 cN
  - Deformation: 40%
  - Overtravel: 25 µm

- 100 µm wire spacing, 1500 µm bond length → ~30° pull angle
- Increased ultrasonic relative to bond force helped bonding
- See next slide for failure observations

Single Layer					
		US%			
Mean		22	25	22	25
	22	9.2			
	22		10.6		
	25			5.7	
CN	25				9.7

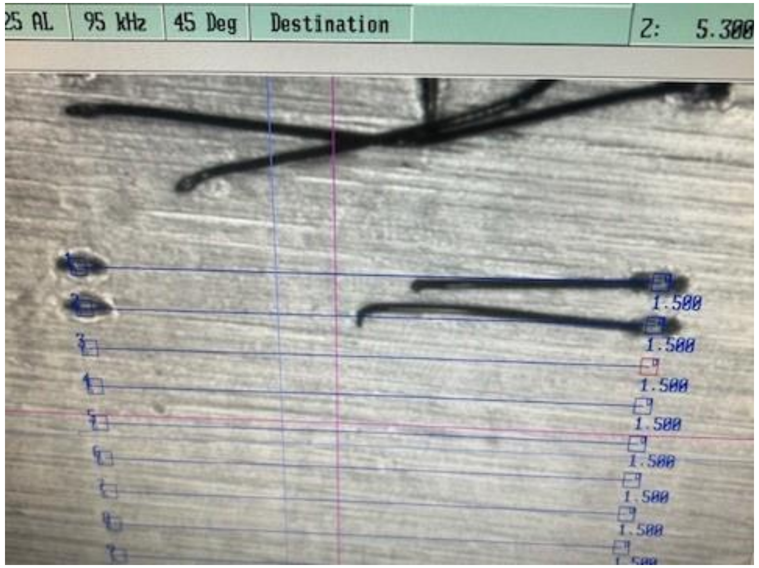
Multi Layer					
		US%			
Mean		22	25	22	25
	22	9.1			
	22		9.3		
	25			6	
CN	25				

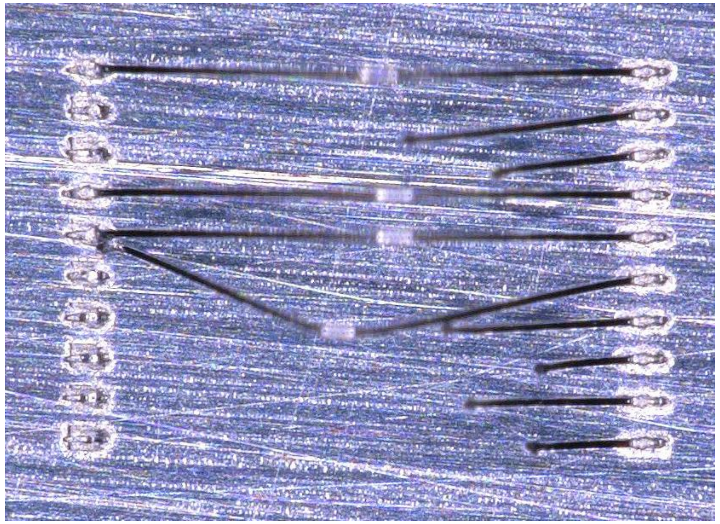
Single Layer					
		US%			
Std Dev		22	25	22	25
	22	1.73			
	22		0.68		
	25			2.92	
CN	25				1.26

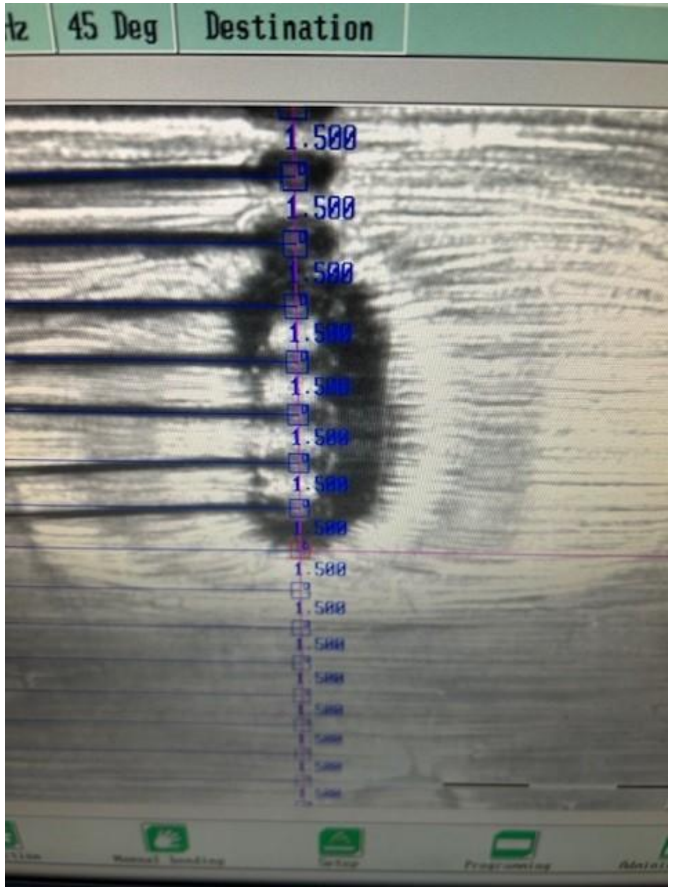
Multi Layer					
		US%			
Std Dev		22	25	22	25
	22	1.51			
	22		2.04		
	25			2.26	
CN	25				

Failures

- Bond force or US <22 led to high failure rate → use parameters >22
- Failures also observed near black spots at source/destination
    - Likely due to insufficient glue support
    - Poor pull strengths in these regions
- Bonding was avoided in areas with uncleaned glue residue







Repeat standard test

Repeated test

Single Layer — Mean

		US%			
Mean		22	25	22	25
	22	7.33			
	22		10.11		
	25				
CN	25				9.32

Multi Layer — Mean

		US%			
Mean		22	25	22	25
	22	9.7			
	22		7.17		
	25				
CN	25				10.32

Single Layer — Std Dev

		US%			
Std Dev		22	25	22	25
	22	2.12			
	22		1.31		
	25				
CN	25				1.42

Multi Layer — Std Dev

		US%			
Std Dev		22	25	22	25
	22	2.12			
	22		2.07		
	25				
CN	25				2

- Standard bonding test repeated on a different foil area
- Aimed to verify reproducibility of bond quality

Initial test

Single Layer — Mean

		US%			
Mean		22	25	22	25
	22	9.2			
	22		10.6		
	25			5.7	
CN	25				9.7

Multi Layer — Mean

		US%			
Mean		22	25	22	25
	22	9.1			
	22		9.3		
	25			6	
CN	25				

Single Layer — Std Dev

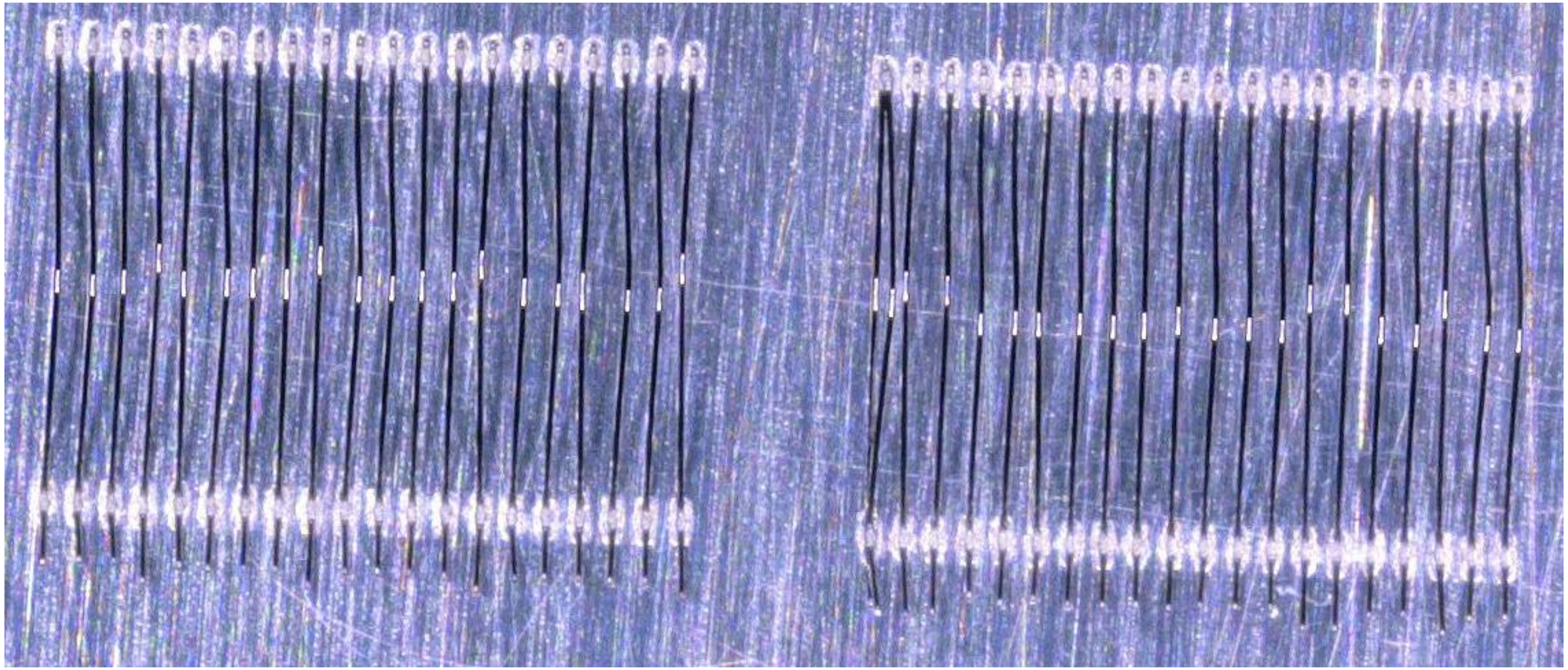
		US%			
Std Dev		22	25	22	25
	22	1.73			
	22		0.68		
	25			2.92	
CN	25				1.26

Multi Layer — Std Dev

		US%			
Std Dev		22	25	22	25
	22	1.51			
	22		2.04		
	25			2.26	
CN	25				

Longer tails

- Tail length was increased in later tests
- Result: fewer failed wires, stronger and more consistent pull results
- All tests after this point used longer tails



Pull test matrix

Single Layer										
		US % Ultrasonic								
Mean		22	25	25	28	28	30	30	32	32
(CN) Bondforce	22	11.18								
	22		11.46							
	25			11.26						
	25				11.21					
	28					11.33				
	28						11.04			
	30							10.49		
	30								10.99	
	32									10.66

Multi Layer										
		US % Ultrasonic								
Mean		22	25	25	28	28	30	30	32	32
(CN) Bondforce	22	10.73								
	22		10.45							
	25			11.04						
	25				11.03					
	28					11.04				
	28						11.06			
	30							11.03		
	30								10.8	
	32									9.45

Single Layer										
		US % Ultrasonic								
Std Dev		22	25	25	28	28	30	30	32	32
(CN) Bondforce	22	0.69								
	22		0.18							
	25			0.59						
	25				0.62					
	28					0.36				
	28						0.8			
	30							0.82		
	30								0.65	
	32									0.77

Multi Layer										
		US % Ultrasonic								
Std Dev		22	25	25	28	28	30	30	32	32
(CN) Bondforce	22	1.77								
	22		1.32							
	25			0.67						
	25				0.25					
	28					0.88				
	28						0.69			
	30							0.49		
	30								0.82	
	32									1.2

- Best results (mean and standard deviation) achieved with settings between 25–30
- Foil bondability improved significantly under these conditions

30% and 50% deformations

30% deformation

Single Layer					
		US%			
Mean		25	28	28	30
	25	10.98			
	25		11.39		
	28			10.71	
CN	28				11.21

Multi Layer					
		US%			
Mean		25	28	28	30
	25	10.44			
	25		11.12		
	28			10.33	
CN	28				11.03

Single Layer					
		US%			
Std Dev		25	28	28	30
	25	0.94			
	25		0.26		
	28			0.79	
CN	28				0.87

Multi Layer					
		US%			
Std Dev		25	28	28	30
	25	1.34			
	25		0.79		
	28			0.91	
CN	28				0.57

50% deformation

Single Layer					
		US%			
Mean		25	28	28	30
	25	11.14			
	25		11.24		
	28			10.77	
CN	28				10.58

Multi Layer					
		US%			
Mean		25	28	28	30
	25	11.39			
	25		11.42		
	28			11.07	
CN	28				11.05

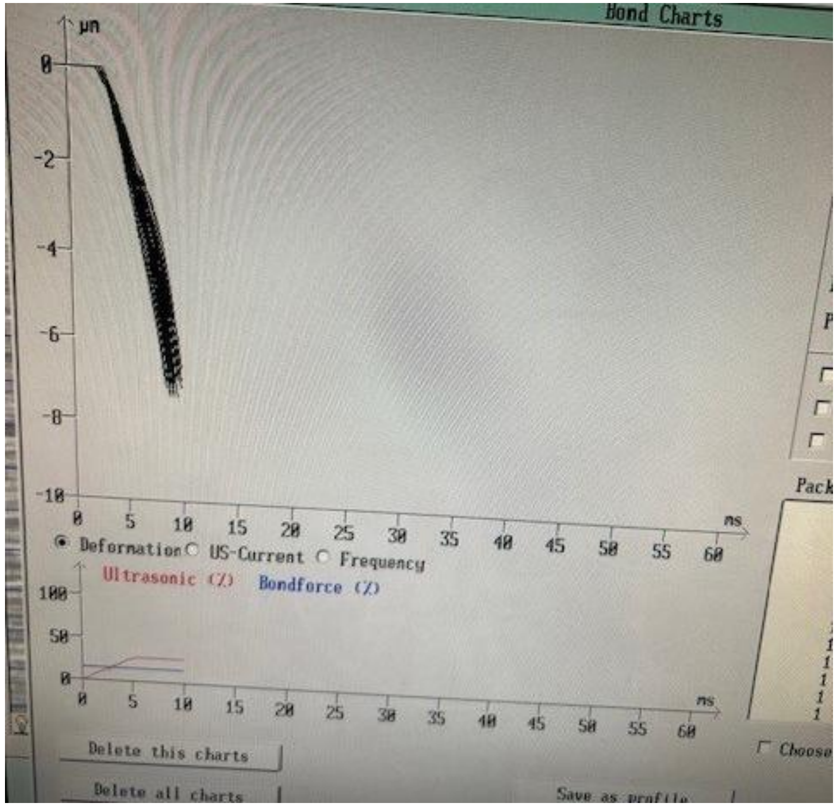
Single Layer					
		US%			
Std Dev		25	28	28	30
	25	0.76			
	25		0.86		
	28			1.01	
CN	28				1.04

Multi Layer					
		US%			
Std Dev		25	28	28	30
	25	0.4			
	25		0.28		
	28			0.66	
CN	28				0.63

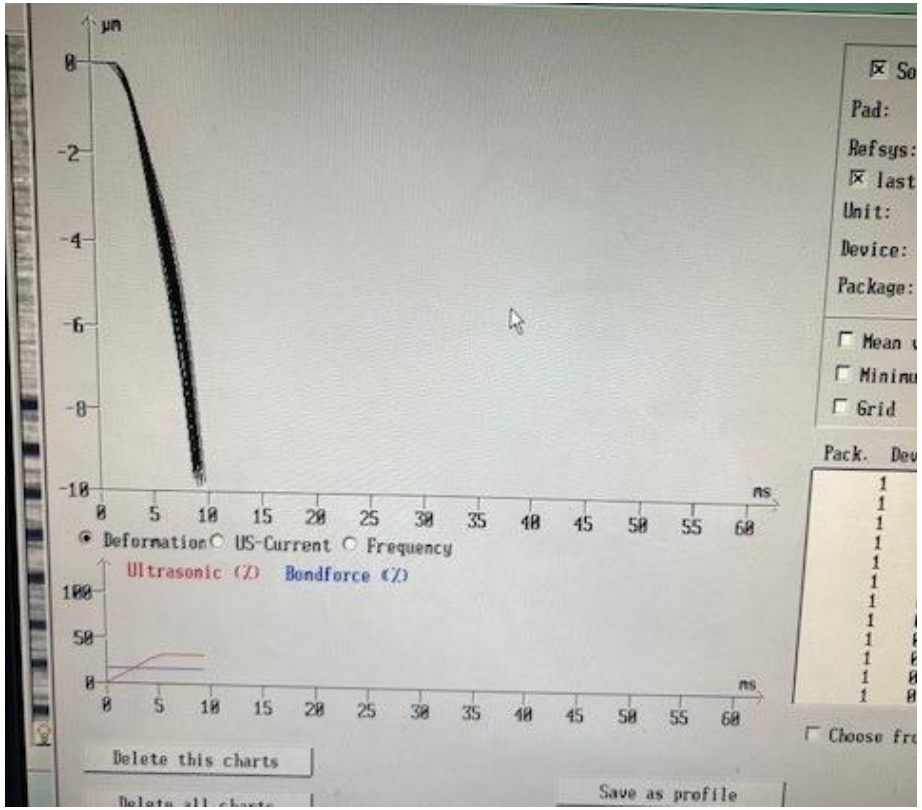
- Bond foot width estimation
  - 30% → ~32.5 μm
  - 40% → ~35 μm
  - 50% → ~37.5 μm

- 30% deformation
  - Appears comparable to best-case pull matrix results
- 50% deformation
  - Mean pull force similar to 30%, but improved standard deviation for multilayer foil

Deformations



30% deformation



50% deformation

- Deformation charts for 30% and 50% cases (US 30%, BF 30 cN)
- All wires reached maximum deformation within 10 ms → good bondability

15 µm overtravel

		US%						
Mean		25	25	28	28	30	30	32
	22	11.21						
	25		10.89					
	25			11.34				
	28				10.79			
	28					11.06		
	30						11.3	
CN	30							11.25

Single Layer

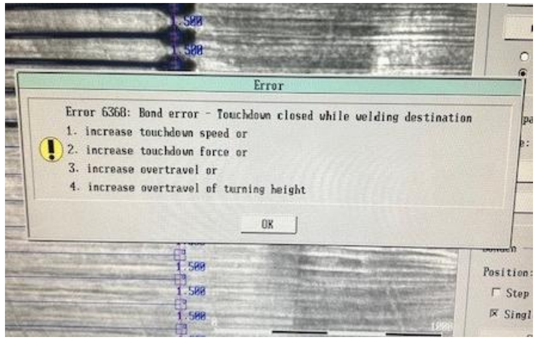
		US%						
Std Dev		25	25	28	28	30	30	32
	22	0.47						
	25		0.88					
	25			0.39				
	28				0.94			
	28					0.82		
	30						0.65	
CN	30							0.38

		US%						
Mean		25	25	28	28	30	30	32
	22	11.48						
	25		10.96					
	25			11.34				
	28				11.09			
	28					11.09		
	30						10.82	
CN	30							11.06

Multi Layer

		US%						
Std Dev		25	25	28	28	30	30	32
	22	0.44						
	25		1.09					
	25			0.65				
	28				0.43			
	28					0.64		
	30						0.76	
CN	30							0.66

- Inspired by positive results from James @ Birmingham: reduced overtravel to 15 µm
- Good bonding results achieved: strong mean force, low std deviation
- But: touchdown errors appeared at US or BF >30%



Wire comparison

- Used in the initial tests
  - CCC: Al-1%Si, 25 µm, El % 1-4, TS 15-18g
- Currently using
  - Heraeus: AlSi-M, 25 µm, EL > 1%, BL 15-17 cN
- Planned (not provided by Accelonix)
  - Tanaka TABN Type aluminium wire (Al–1%Si with nickel doping, 25 µm)
- Alternative (Accelonix in stock)
  - Heraeus H74-41 (around £400): Aluminum Wire 25µm, 100m, AlSi-S, EL 1,0-4,0%, BL 14-16g, 2x1" spool
    - Plan to use this soft wire for performance comparison

Summary

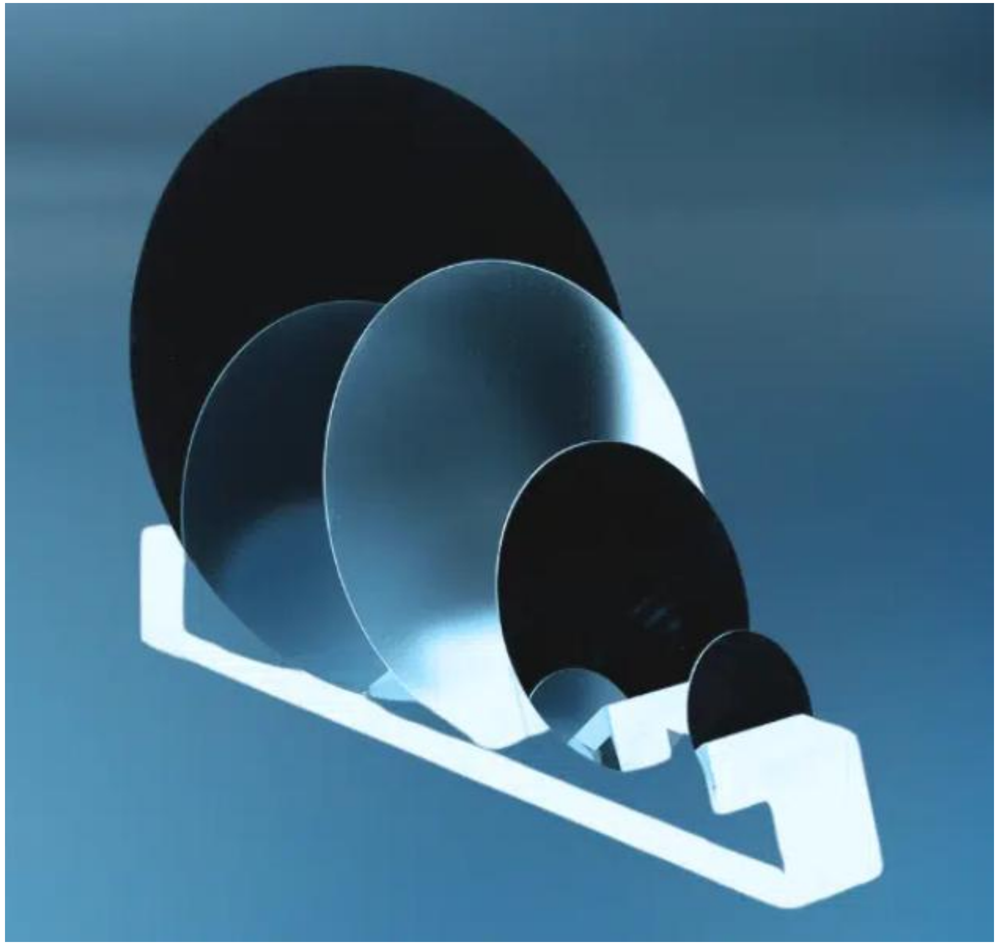
- Bonding on FR4 PCB with longer tails
  - Significantly improved foil stability
  - Parameter optimisation led to stronger bonds and fewer failures
  - Single-layer foils outperformed multilayer ones — likely due to their stiffer mechanical response, allowing more consistent bonding
  - While the FR4 substrate does not replicate the final detector environment, it demonstrates that reliable bonding is achievable under controlled conditions
- Detailed test results can be found here: https://cernbox.cern.ch/s/jCSqHk7Fm7xzpqr

- Next step
  - Repeat tests with vacuum + diffuser setup (Birmingham method)
  - Perform comparative tests with alternative wire type

Dummy parts for module prototyping

50 µm thick glass or silicon?

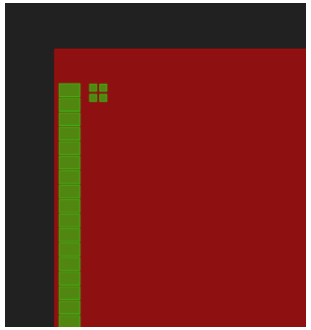
- Inquired suppliers
  - PI-KEM
  - PLANOPTIK AG
  - Valleydesign
  - Silicon Valley Microelectronics
  - Nanosystems JP
- General feedback
  - At 50 µm or 100 µm with bonding pad deposition, glass wafer not available or requires additional initial tests and special procedures → less cost effective than silicon
- Moving on with silicon
  - Nanosystems JP is the only supplier can provide the dummy parts we requested

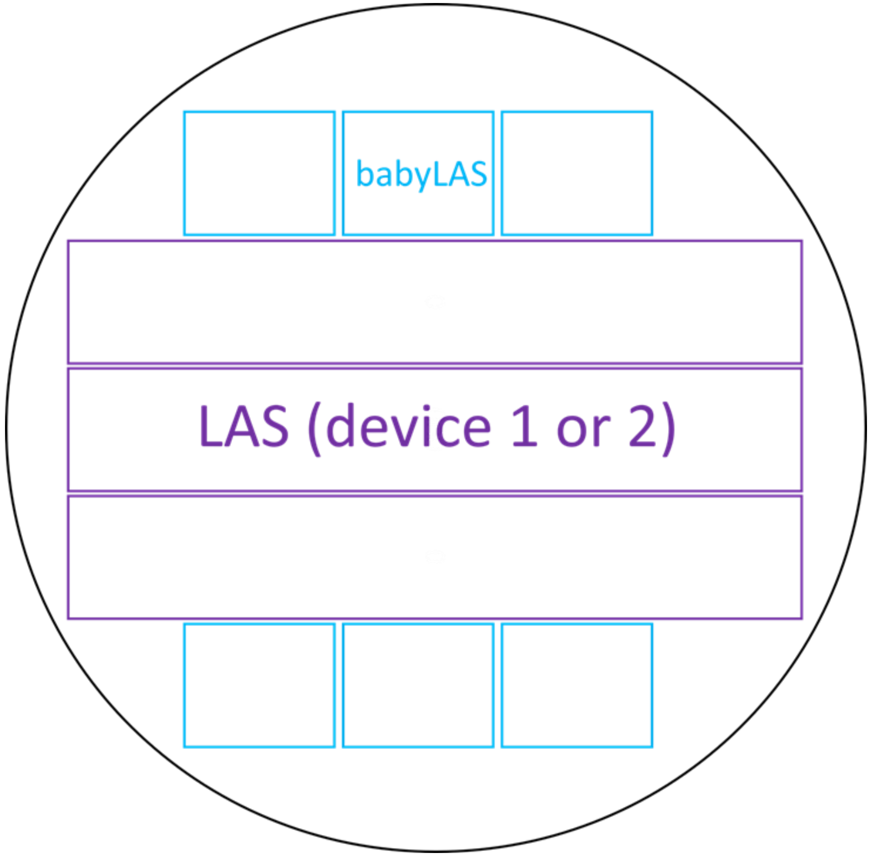


Dummy parts – 5RSU/6RSU LAS

Device Dimensions

- Thickness: 50 µm
- Dicing Requirements
  - Device 1 (optional)
    - Length: ~136 mm
    - Width: ~19.6 mm
  - Device 2 (baseline):
    - Length: ~115 mm
    - Width: ~19.6 mm
  - babyLAS
    - Length: ~27.7 mm
    - Width: ~19.6 mm





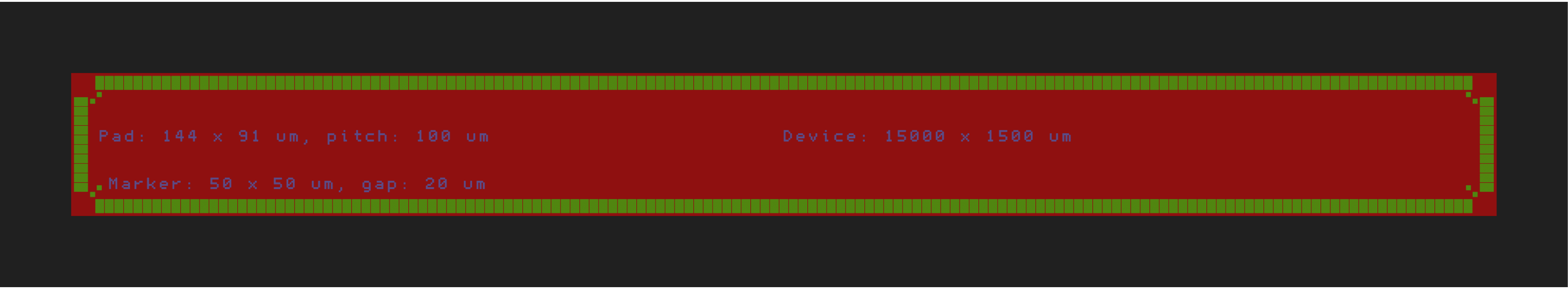
Metalization

- Material: Aluminum (Al) or Copper (Cu) with Ni/Au plating is acceptable
- Thickness: around 1 µm (at least > 500 nm)
- Design complexity
  - Only bondable pads are required, with the following specifications
    - Pad size: 91 µm × 144 µm
    - Pad pitch: 100 µm
    - We can compromise on the pad size/shape
  - In addition to the pads, need a couple of alignment markers on each dummy LAS

Dummy parts – AncASIC

Device Dimensions
- Thickness: 300 µm
- Dicing Requirements:
  - Length: ~15 mm
- Width: ~1.5 mm

Metalization
- The same requirement as the dummy LAS with similar pad size and pitch



Quotes from Nanosystems JP

- Proposed processes
  - Procure Silicon wafer 625um
  - Photomask fabrication
  - 600nm Al patterning and etching
  - Backgrinding to 50um
  - Dicing & Chip tray packing
  - Shipping

- **Option 1**: 50 5RSU LAS + 500 AncASIC = 19900 + 11900 = 31800 USD
  - 20 5RSU LAS: 12900 USD
  - **50 5RSU LAS: 19900 USD**
  - 20 5RSU LAS + 20 6RSU LAS: 19900 USD
  - 50 5RSU LAS + 50 6RSU LAS: 27900 USD
  - **500 – 800 AncASIC: 11900 USD**
- **Option 2:** 41400 USD → 41400 – 31800 = 9600 USD for additional 50 babyLAS
  - ~50 5RSU LAS + ~50 1RSU babyLAS
  - 500 – 600 AncASIC
- **Option 3:** 46390 USD
  - ~50 6RSU LAS + ~50 5RSU LAS + ~30 1RSU babyLAS (possibly a few more)
  - 500 – 600 AncASIC

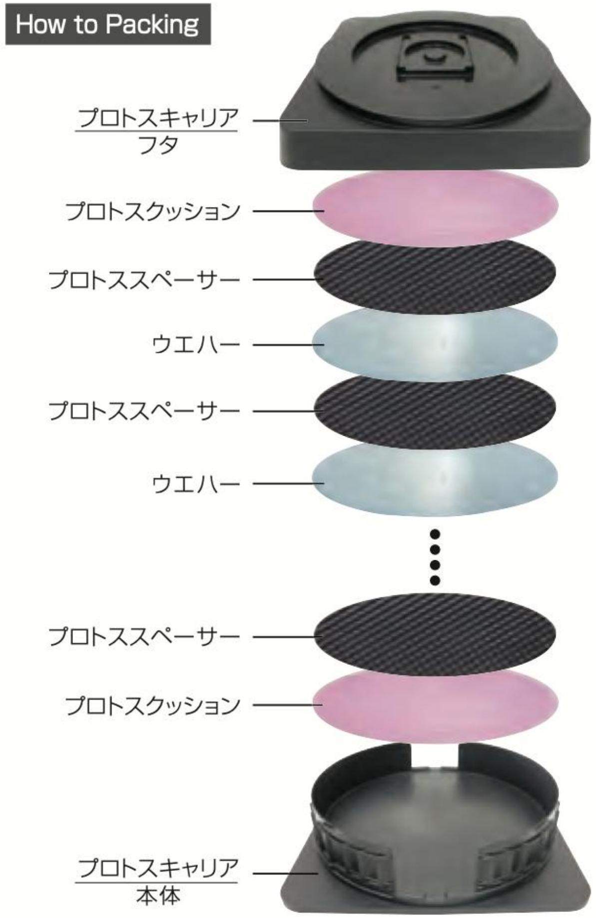
- Comments from the supplier
  - First order requires mask fabrication and other startup engineering costs, subsequent ordered chips will be comparatively cheaper
  - Manufacturing larger quantities in a single batch is more cost-effective than producing them separately
- Lead time
  - Approximately 2 to 2.5 months
  - Their production schedule is filling up, so early confirmation would help secure a favorable slot
  - They propose moving the order to July or August to enable a faster turnaround

- Is it possible to place the order for AncASIC in July/August?
- Is it possible to place the order for LAS in September?

Packaging

- Nanosystems JP packaging details
  - Dummy LAS: “given the three different chip sizes, instead of fabricating a custom case from scratch, we propose a standard method where we will remove the chips from the dicing ring and pack them using a cushioning system as shown below. The pink layer will serve as a cushion, and a black spacer will secure the chips between the layers. This is a standard packaging method we frequently use.”
  - Dummy AncASIC: “a similar-sized chip tray (15 × 1.5 mm) is available, which we will use for packaging.”

- Provide the Gel-Pak trays for LAS packaging and shipment? To be seen based on our test outcomes

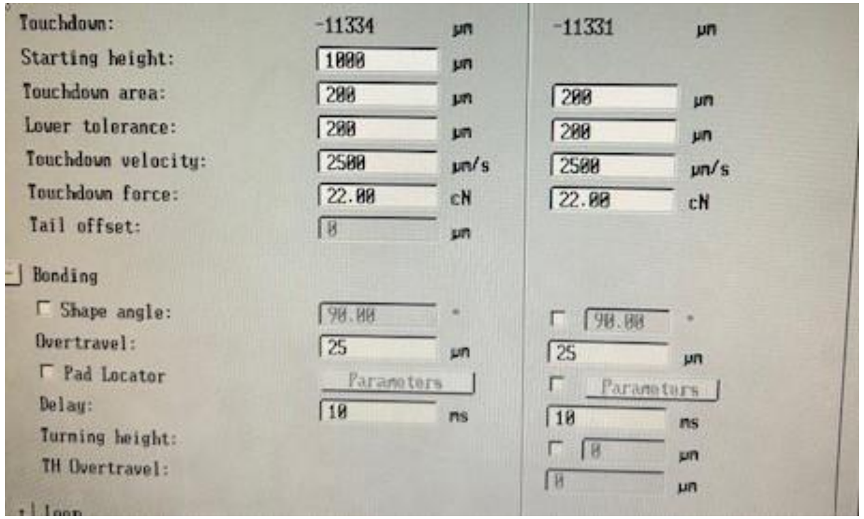


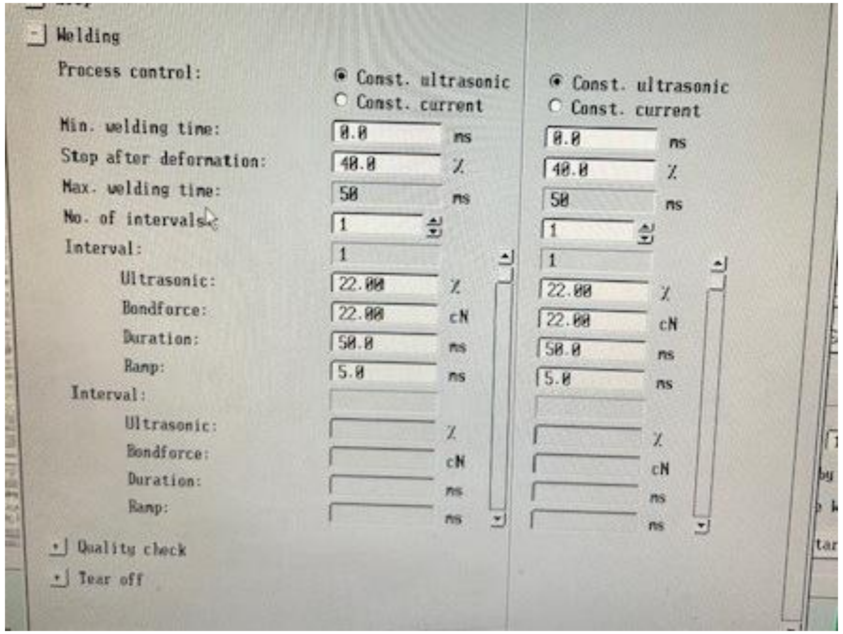
Summary

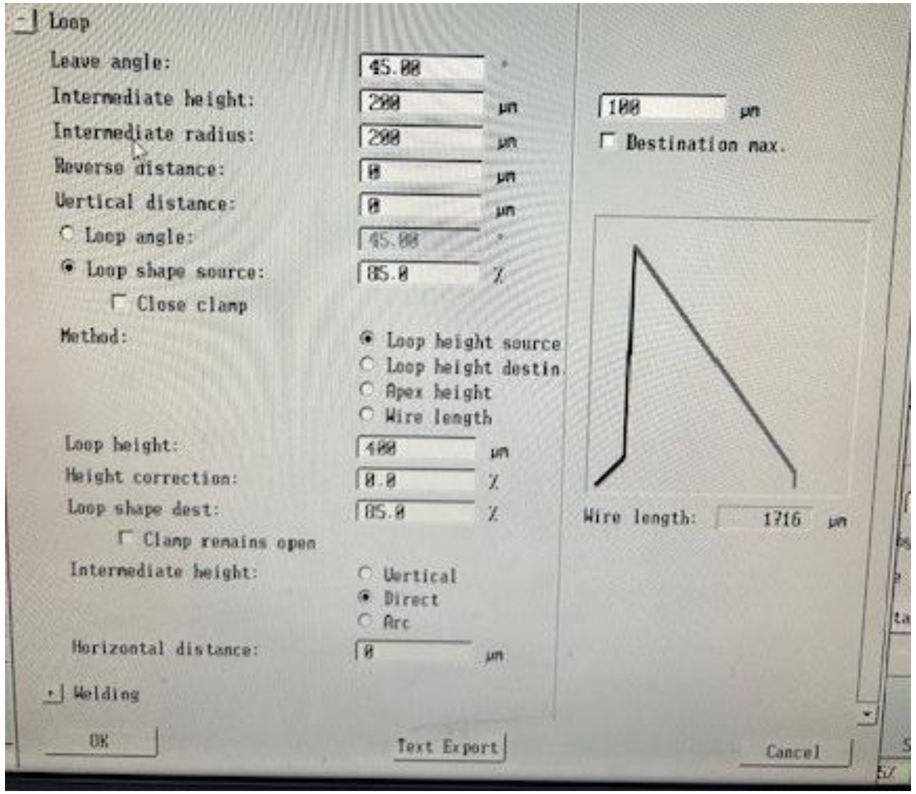
- Based on current requirements, dummy silicon wafers with metal pads are more cost-effective than glass
- Estimated cost: ~30k USD (+ VAT) for 50 5RSU-LAS and 500 AncASIC
- Lead time is about 2.5 months
- Place the order as early as possible, ideally in July/August
- Dummy LAS packaging is still under review

Backup

Standard bonding parameters







spTAB

- spTAB wedge issue
  - The waffle wedge touches the clamp
  - Wedge diameters
    - Waffle Wedge – 1.449 mm
    - Standard Wedge in Liverpool – 1.170 mm → narrower than the ones used in Birmingham of 1/16" diameter (~1.5mm)
      - Contacting Accelonix and asking about getting SPT to make a set of these tool with the narrower shaft diameter