CMSE Los Angeles

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Cu Bond Wire Reliability and Decapsulation Process

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Cu Bond Wire Study at Integra and ASI

Phases of Cu Wire Study Project

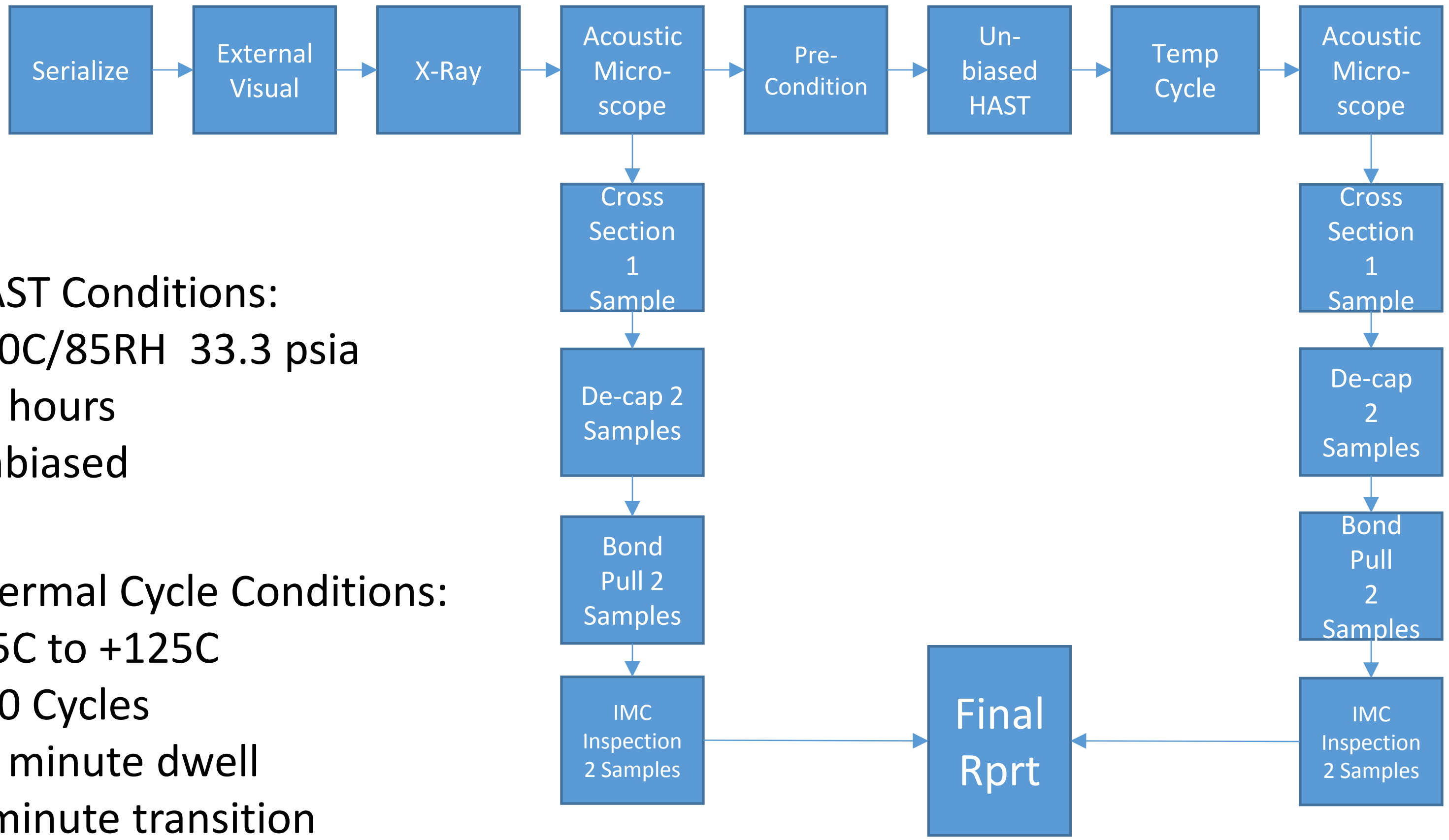
Phase 1

- Perform evaluation of Cu Wire without bias stresses
- Intended to gather some basic information
- Stresses utilized were unbiased and were common for typical qualifications for package changes

Phase 2

- Perform evaluation of Cu Wire with bias stress
- Utilizes biased HAST to more rapidly age the intermetallic bond.
- Temp Cycle utilized to stress the bonds and accelerate the process of work hardening and intermetallic bond issues.
- Increased Sample size

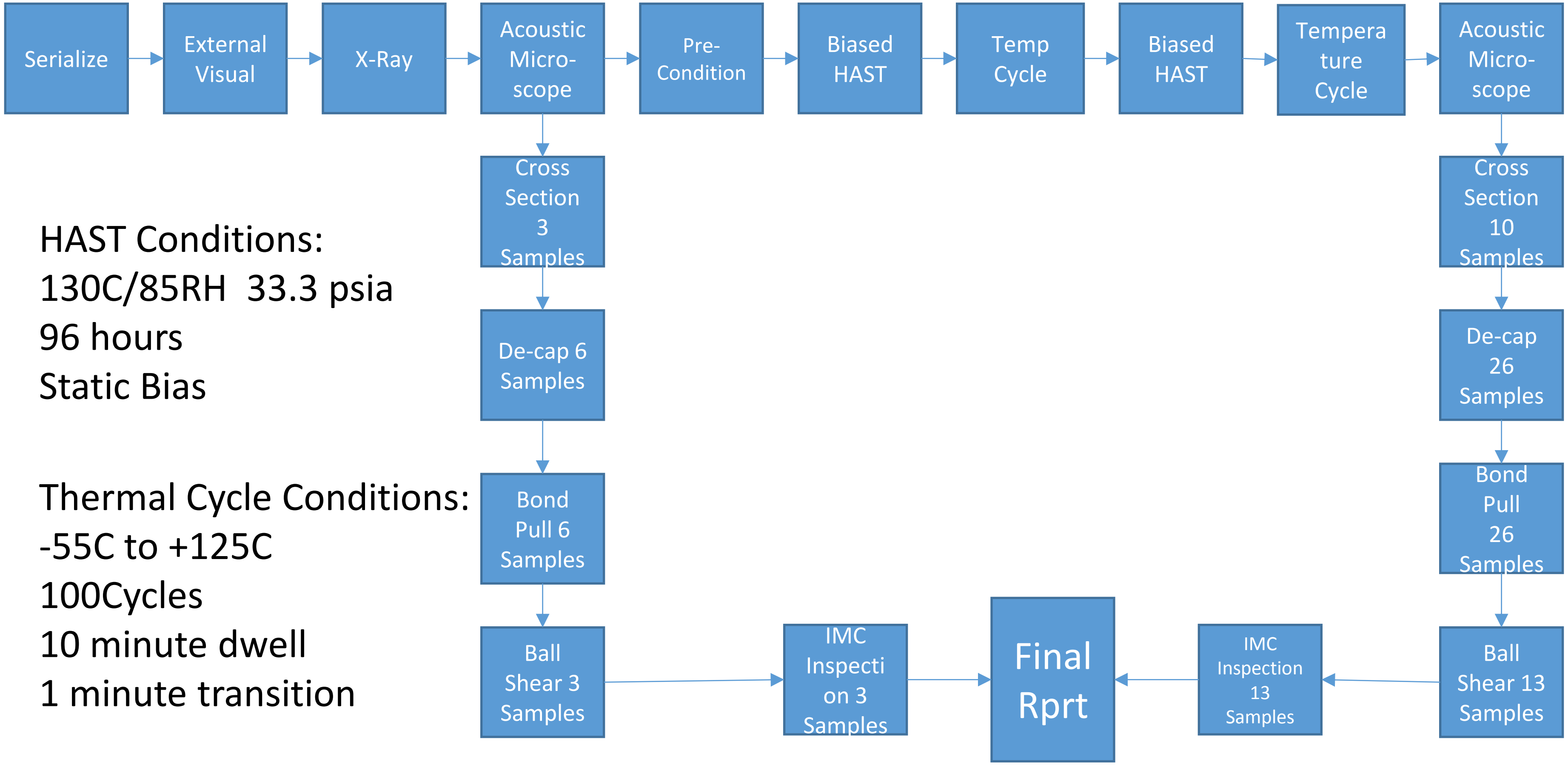
Process Flow for Phase 1



HAST Conditions:
130C/85RH 33.3 psia
96 hours
Unbiased

Thermal Cycle Conditions:
-55C to +125C
100 Cycles
10 minute dwell
1 minute transition

Process Flow for Phase 2



HAST Conditions:
130C/85RH 33.3 psia
96 hours
Static Bias

Thermal Cycle Conditions:
-55C to +125C
100Cycles
10 minute dwell
1 minute transition

Sample Devices

Part Number	Manufacturer	Date Code	Bond Material	Bond Pad Material
74FCT162245ATPVG	IDT	1402	Cu	Al
TPS51116RGET	Texas Instruments	1038	Cu	Cu/Ni/Pd
M74VHC1GT50DFT1G	On Semiconductor	1421	Cu	Al
BAS70-04LT1G	On Semiconductor	1448	Cu	Al

It has been observed during analysis that PCN data is not always accurate for determining when parts actually transition to copper. Because of this, all devices were chosen base on historical analysis data indicating that the manufacturer had transitioned their product to copper.

Two additional devices were candidates, however, the date codes received were prior to the manufacturer's transition to copper.

Phase two devices was performed on TPS51116RGET and M74VHC1GT50DFT1G.
Completed full phase 2 on TPS51116RGET only

Summary of Results on all 4 lots – Phase 1

Lot Numbers	Ext. Vis	Pre- X-ray	Pre-SAM	Pre-Bond Pull	Pre-IMC	Post-SAM	Post Bond Pull	Post-IMC	Comparative Analysis
74FCT162245ATPVG	Pass	Pass	Pass	*	Pass	Pass	*	Pass	No significant degradation or growth of IMC.
TPS51116RGET	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	No significant degradation or growth of IMC.
M74VHC1GT50DFT1G	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	No significant degradation or growth of IMC.
BAS70-04LT1G	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	No significant degradation or growth of IMC.

Bond lifts were identified for part number 74FCT162245ATPVG. One pre-stress and one post-stress device exhibited bond lifts on pins 12 and 15. Minor cratering was seen.

Phase 1 Summary

With limited data on sample sizes and stress level:

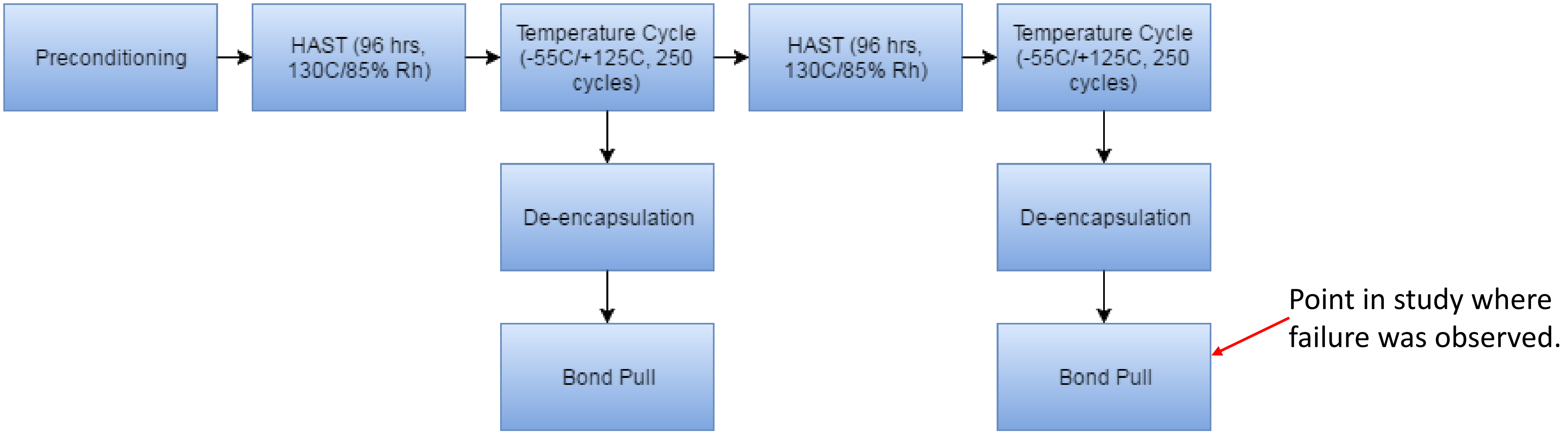
1. No electrical rejects post stress
2. IMC was found to be 6% greater pre to post stress
3. Aluminum Splash was observed
4. Bond lifting was observed with location dependency
5. IMC
   a. Au/Pd IMC was much thinner than Au/Al – IMC was not measurable due to thickness and slow diffusion with this metal stack
   a. IMC seen on all other devices

Phase 2 -With Biased HAST

IMC Data

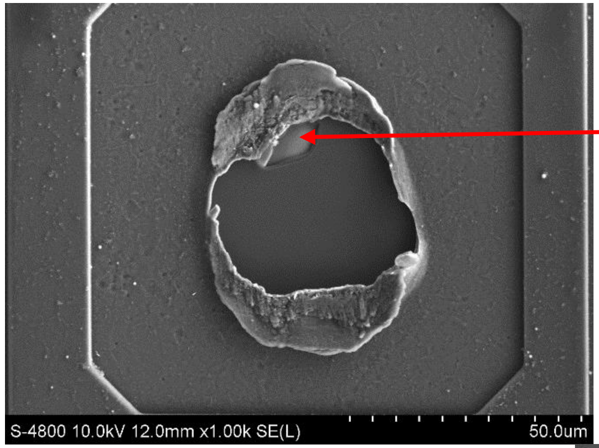
TPS51116RGET (Ball)						TPS51116RGET (IMC)					
Pre		**Post**		**Post Phase 2**		**Pre**		**Post**		**Post Phase 2**	
Min	2.45	Min	2.43	Min	2.59	Min	1.88	Min	1.93	Min	1.98
Max	2.82	Max	2.89	Max	2.88	Max	2.57	Max	2.9	Max	2.62
Mean	2.65	Mean	2.63	Mean	2.74	Mean	2.19	Mean	2.24	Mean	2.35
STDev	0.08	STDev	0.08	STDev	0.06	STDev	0.14	STDev	0.21	STDev	0.1
Number of bonds	50	Number of bonds	50	Number of bonds	174	Number of bonds	48	Number of bonds	49	Number of bonds	94
Average Area	5.59	Average Area	5.44	Average Area	5.91	Average Area	3.77	Average Area	3.94	Average Area	4.33
								% IMC area Change Pre-to-Post	15%		

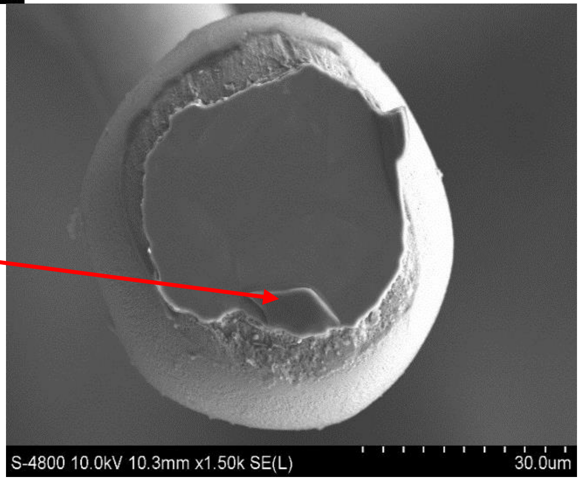
Failure Data (Damage to passivation and active circuitry)



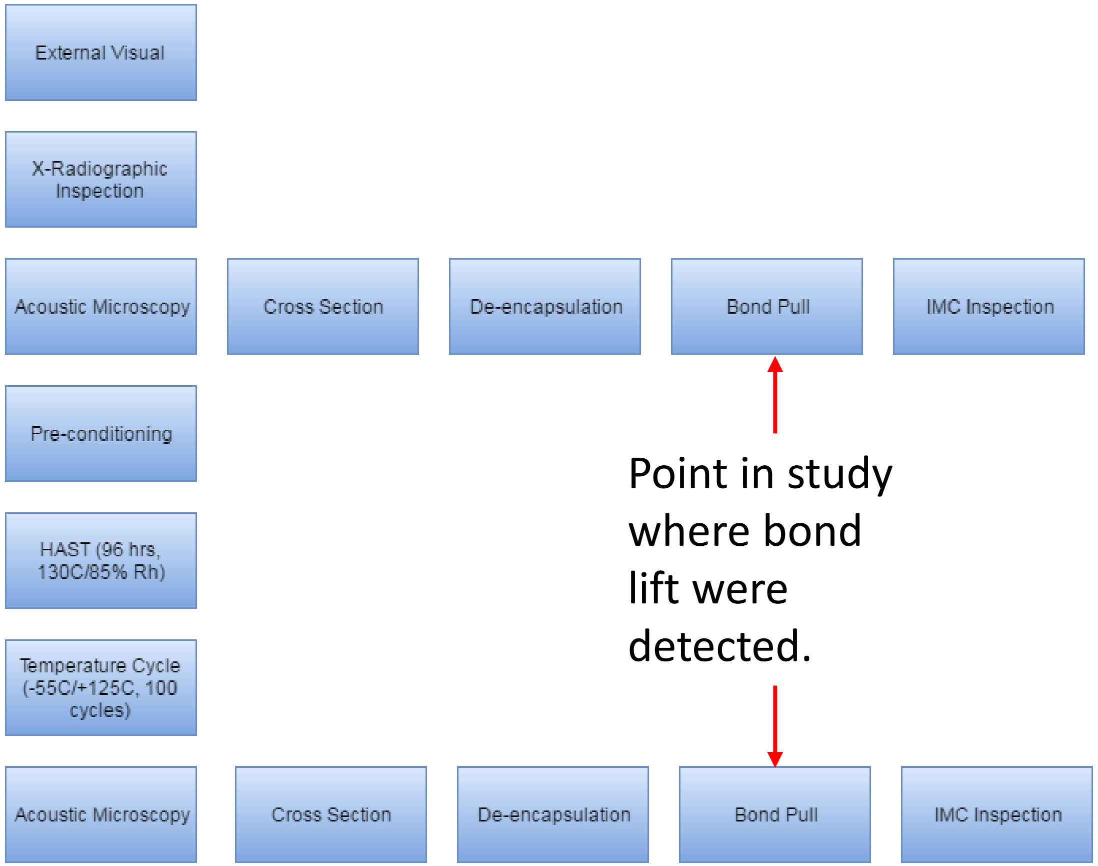
Failure Data (Damage to passivation and active circuitry) – Phase 1 – 74FCT162245ATPVG – Observed at both pre and post stress – Pins 12 and pins 15

- Contributing Factors
  - **Thin aluminum bond pad**.
  - Location Dependent, non-Optimized bonding process.

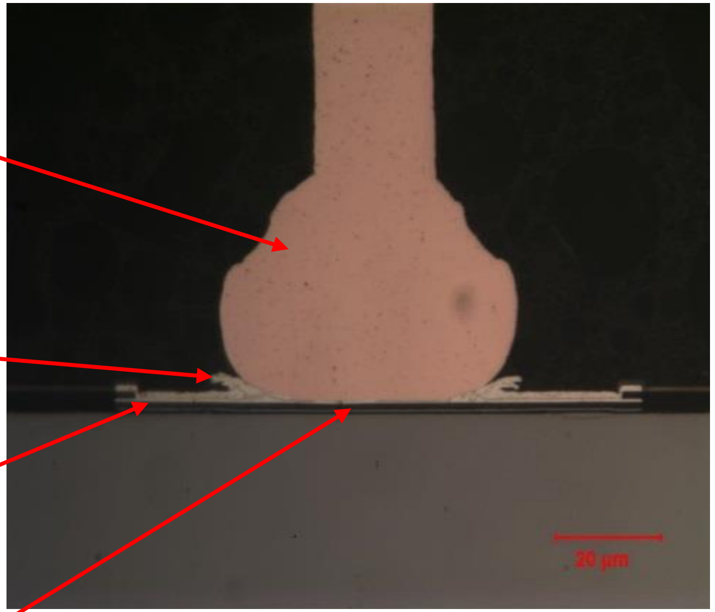




Failure Data (Damage to oxide and active circuitry - 74FCT162245ATPVG - Observed at both pre and post stress – Pins 12 and pins 15)



- Ball bond formation indicates manufacturer tried to optimize for thin bond pad metallization.
- Aluminum splash is expected but appears to be minimal.
- Bond pad is too thin to support.
- Very little aluminum under the ball bond.



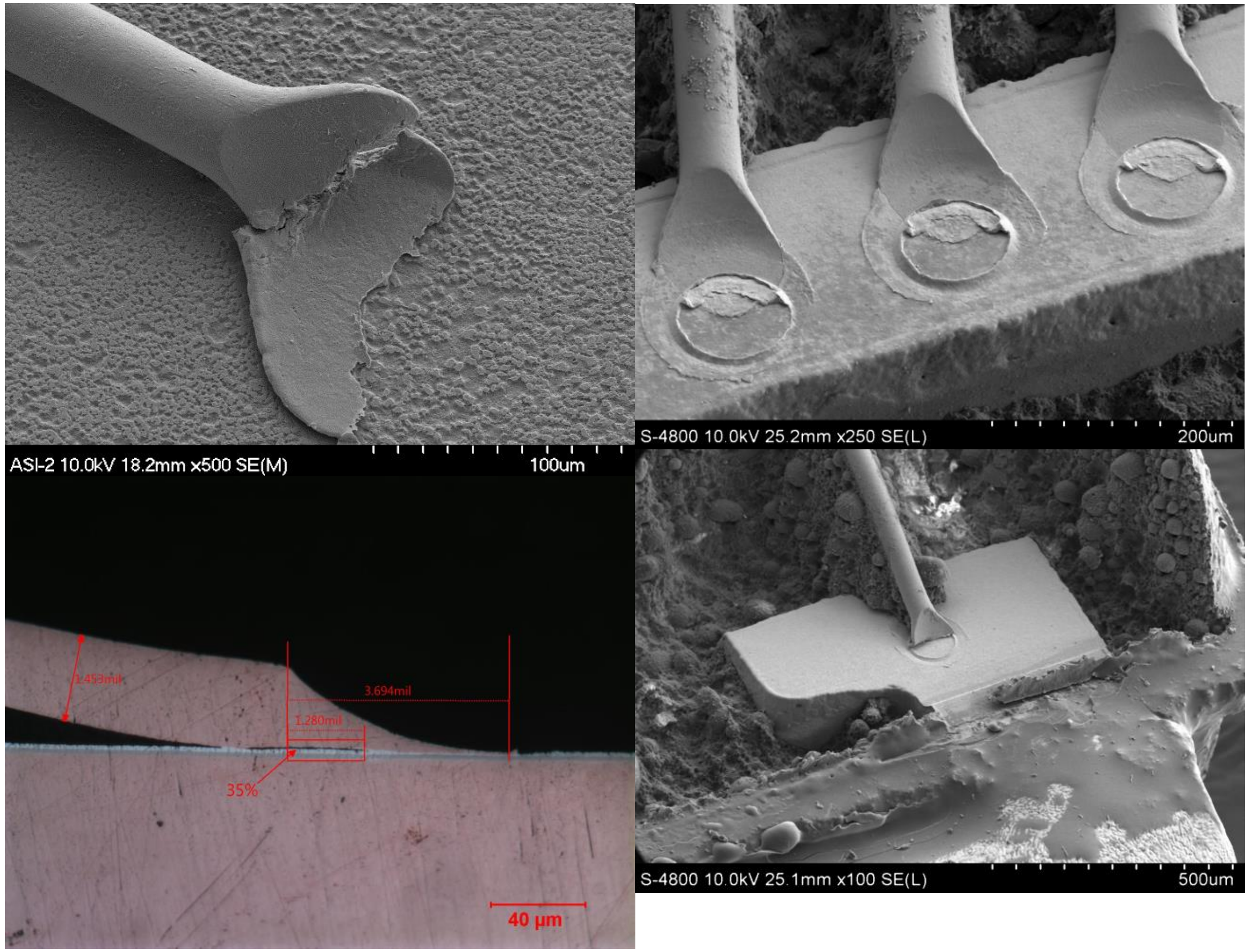
Failure Data (Damage to oxide and active circuitry)

	Pre-Stress	Oxide Pullout?	Post-Stress	Oxide Pullout
Location 12	4.48 grams	No	4.64 grams	No
Location 15	8.29 grams	No	8.83 grams	Yes

- While not every device pulled had bond lifts, two of the thirty devices did.
- While oxide pullout was not noted at location 12, bond pull strengths were notably lower.
- If 2X gold limit were utilized as criteria, these bond lifts would have passed.
- Is pull strength limit the only thing we should look at?

Potential Failure Modes (Cracked/Broken wedge bond heel)

- Contributing Factors.
  - Delamination in the wire bond area as seen in Scanning Acoustic Microscopy.
  - Non-bonded regions in the critical bond interface.
  - Large CTE mismatches.
  - Broken bonds from manufacturing process right two images.
  - Left two images are devices from study.

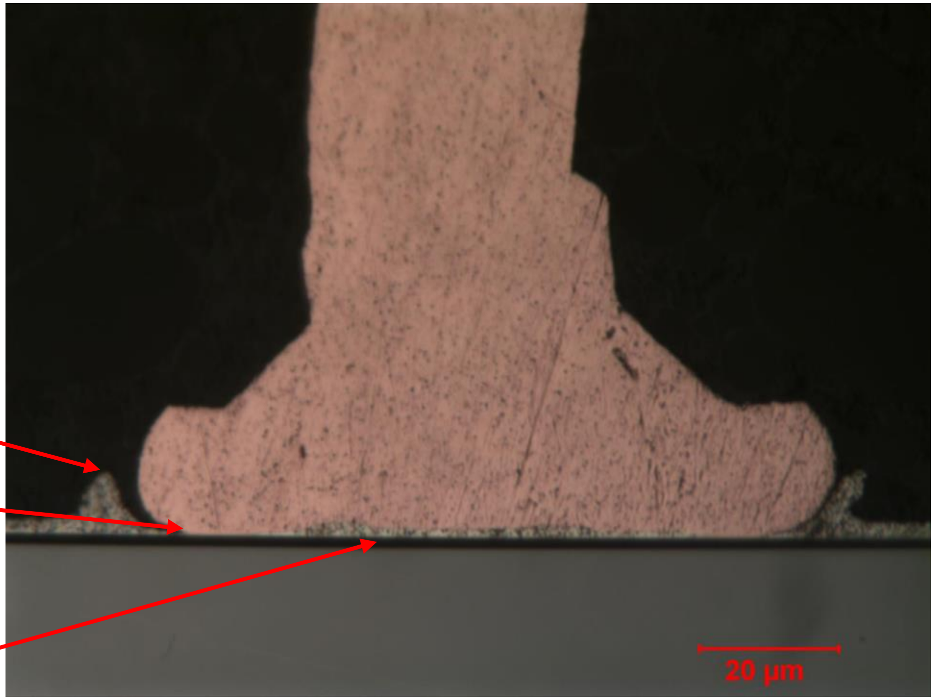


Potential Failure Mode (Wire neck severance)

- Non-ductile fracture of the neck down of a ball bond. Found during bond pull testing.
  - Found on virgin device indicating that the work hardening occurred during manufacturing.

Potential Failure Mode (Insufficient Cu/Al IMC)

- Indicators of possible insufficient Cu/Al IMC.
  - Excessive flash
  - Missing aluminum bond pad under bond.
  - Concave bond formation.



Copper Wire Bond De-Encapsulation

Comparative Analysis of Full Chemical vs Laser Ablation/Chemical de-encapsulation methods.

Note: This data addresses the laser ablation decapsulation process and not necessarily full Cu bond wire qualification

Purpose

- Provide update on laser ablation capability and its release to production.
- Comparison between full chemical de-encapsulation and laser ablation/chemical de-encapsulation process.
  - Provide Pros and Cons for each technique
  - Provide Data for expected outcomes for future projects
- Identify any cautions about the use of laser ablation or full chemical de-encapsulation of copper wire bonded parts.

Laser Ablation Capability Update

- Control Laser FALIT equipment was installed at Analytical Solution in early May.
- Proof of Laser de-encapsulation process was developed.
  - Phase 1 – Compare and contrast laser ablation/chemical De-encapsulation with full chemical de-encapsulation. (Complete)
    - Leverage experience from F/A engineer who previously worked with laser ablation equipment.
  - Phase 2 – Develop a complete understanding of variable settings with the laser ablation equipment and how each variable can affect the final outcome. (Ongoing)
    - Equipment Variables (Ongoing)
      - Power
      - Q
      - Duty Cycle
      - Raster Rate
    - Device Variable
      - Mold Compound (Ongoing)
      - Pre vs post environment mold compound changes (Complete)
- Several devices have been successfully de-encapsulated already.

Full Chemical De-encapsulation (Continued)

- Acid Mixture
  - 2 parts 90% Nitric
  - 1 part 96% Sulfuric
- Acid Temperature
  - Room Temp
- Beaker
  - 80 ml graduated
- Stir Plate and Rod
  - Speed of stir plate is adjusted until the vortex of the fluid mixture is approximately ¼ of the mixture in depth.

- Process
  - Mount and Bake Parts
    - Solder on high carbon steel substrate
    - Clean all flux residue
    - Vacuum Bake parts
      - 100C
      - 8 hours minimum
    - Mechanically remove bulk material (S2)
  - Mix Acid
  - Suspend part in acid 4 minutes
    - Inspect Device for damage
    - Not all molding compound will be removed from around the wire bonds at this point.
  - Dispose of Acid and mix new batch
  - Suspend part in acid 1 minute
    - Inspect Device for damage and completeness of de-encapsulation.
      - If de-encapsulation is not complete reduce acid exposure time to 15 seconds and repeat until full de-encapsulation is obtained.

Laser/Chemical De-encapsulation

- Acid Mixture
  - 2 parts 90% Nitric
  - 1 part 96% Sulfuric
- Acid Temperature
  - Room Temp
- Beaker
  - 80 ml graduated
- Stir Plate and Rod
  - Speed of stir plate is adjusted until the vortex of the fluid mixture is approximately ¼ of the mixture in depth.

- Process
  - Mount and Bake Parts
    - Solder on high carbon steel substrate
    - Clean all flux residue
    - Vacuum Bake parts
      - 100C
      - 8 hours minimum
  - Laser Ablate Device
    - Power setting: 30%
    - Q: 30
      - 4 passes over entire area to be opened.
      - 5 passes excluding area over the die
  - Mix Acid
  - Suspend part in acid 1 minute
    - Inspect Device for damage and completeness of de-encapsulation.
      - If de-encapsulation is not complete reduce acid exposure time to 15 seconds and repeat until full de-encapsulation is obtained.

Phase 1

- Obtain Devices
- Mount Devices
- Bake Devices
  - Full Chemical Decap
    - Visual and SEM Inspection
    - Document Worst Case Bond on Die
    - Document Worst Case Bond on Lead Frame
    - Document Worst Case Wire
    - Bond Pull
  - Laser Ablate Entire Device
    - Chemically Remove Residual Molding Compound
    - Visual and SEM inspection
    - Document Worst Case Bond on Die
    - Document Worst Case Bond on Lead Frame
    - Document Worst Case Wire
    - Bond Pull

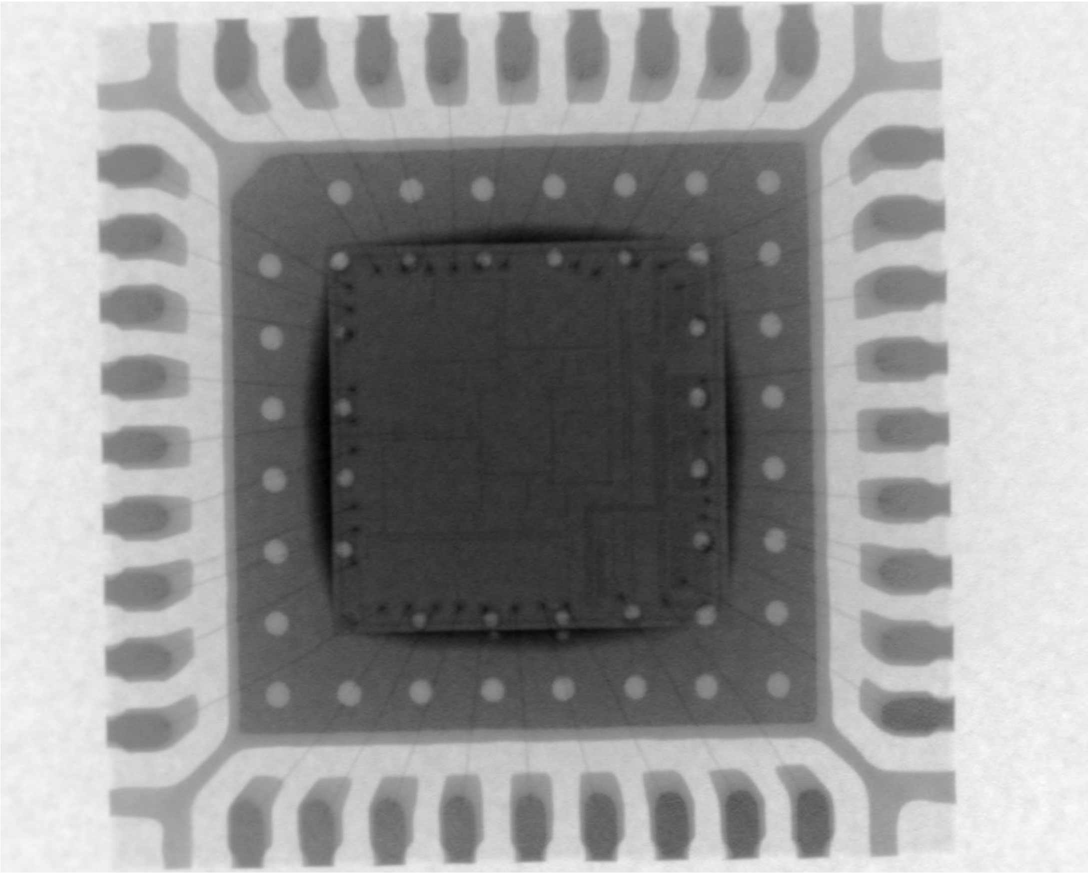
Device Information

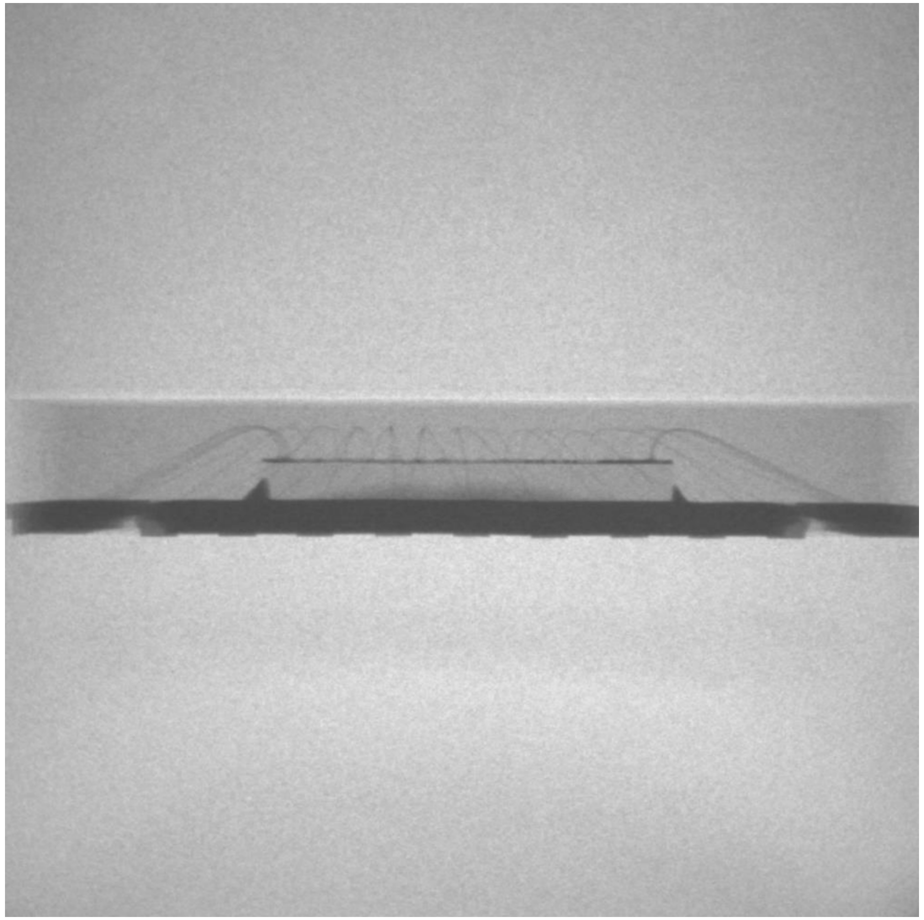
- Part Number: S1
- Device Description: Dual or 2-Phase, Stackable Controller
- Package: VQFN 36
- Wire Bond Material: 1 mil Copper
- Number of Wire Bonds: 38
- All Devices used for this study were from a single lot.
- Chosen based on previous data about the unique bond stack.

Device Information

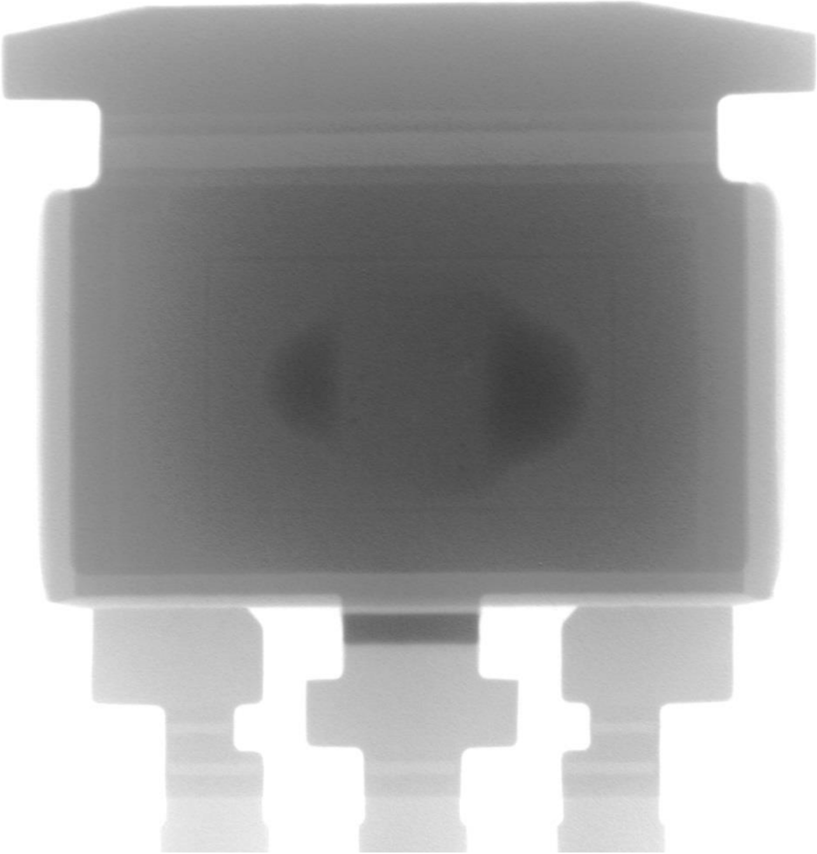
- Part Number: S2
- Device Description: LDO Regulator
- Package: DDPAK/TO-263
- Wire Bond Material: 1.5 mil Copper
- Number of Wire Bonds: 7
- All Devices used for this study were from a single lot.
- Chosen to highlight the differences between full chemical and laser chemical process on devices with large feature height differences.

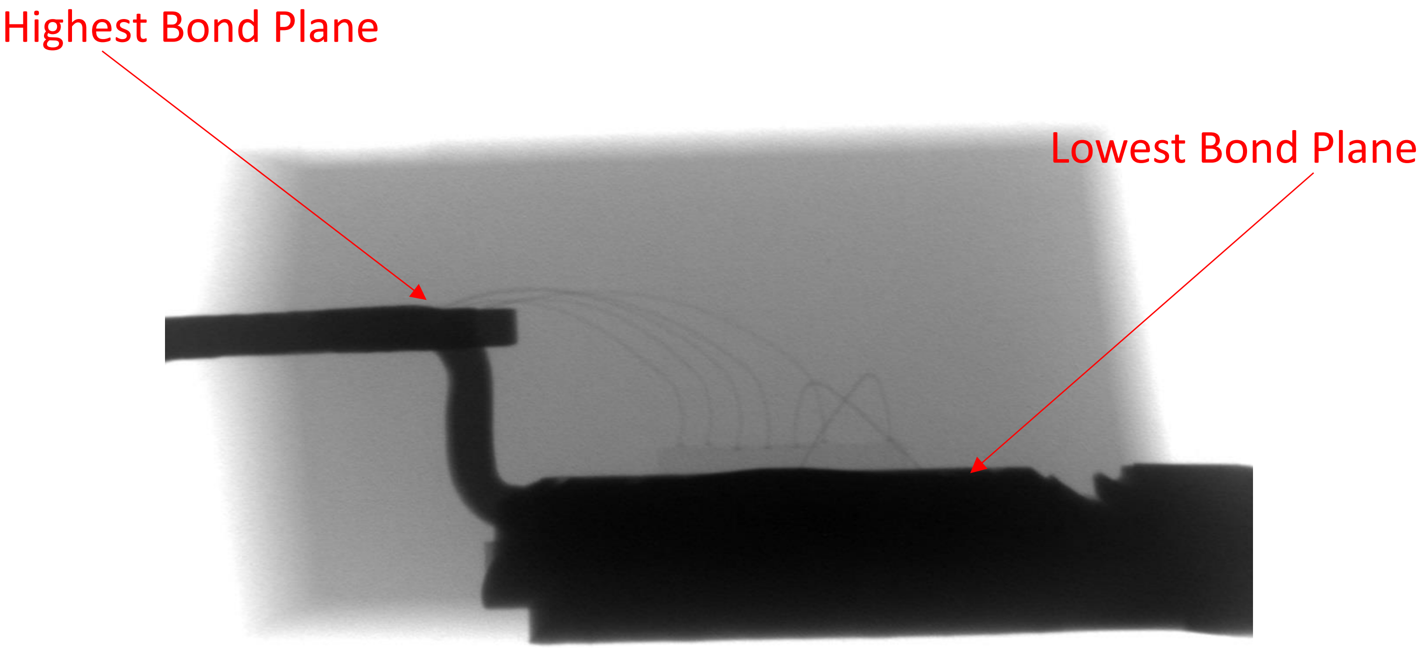
X-Ray image of a typical Device (S1)



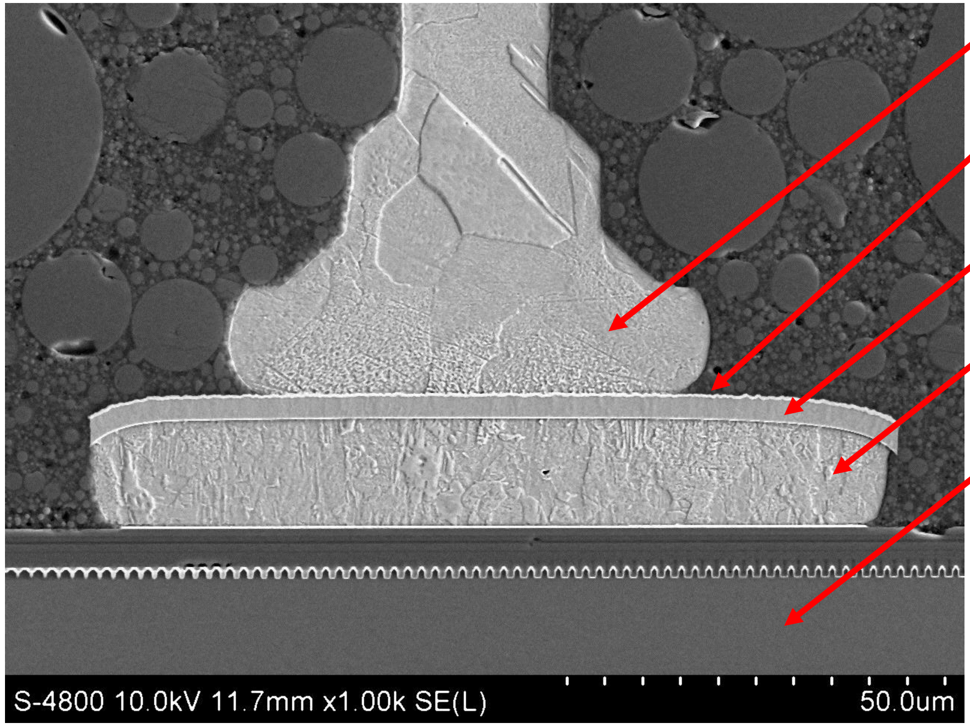


X-Ray image of a typical Device (S2)



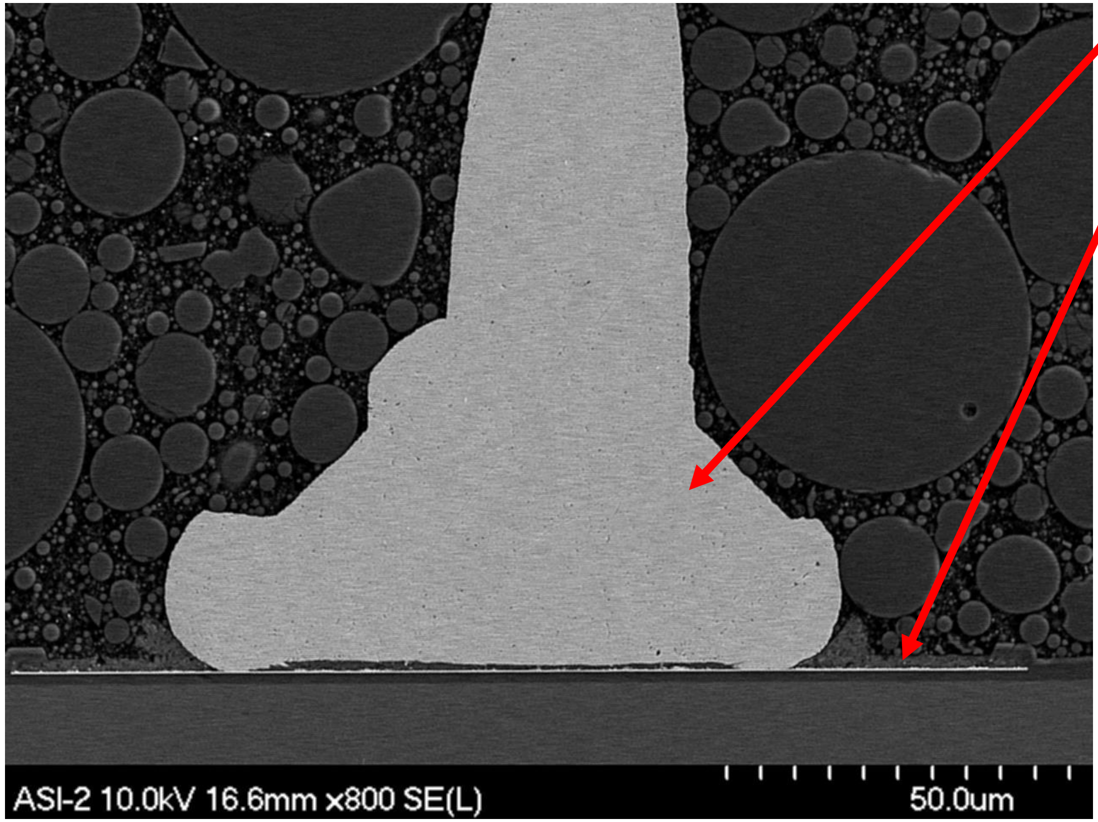


Bond Stack on Die(S1)



- Copper Wire Bond
- Palladium Finish
- Nickle Barrier
- Copper Bus
- Die

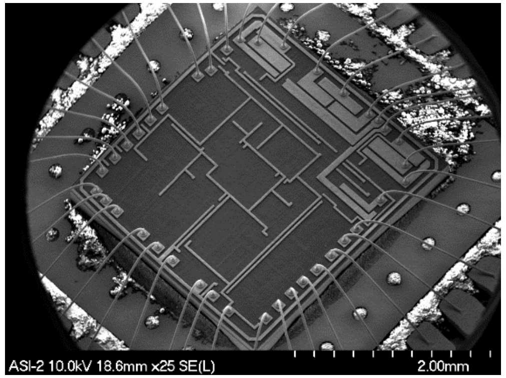
Bond Stack on Die(S2)

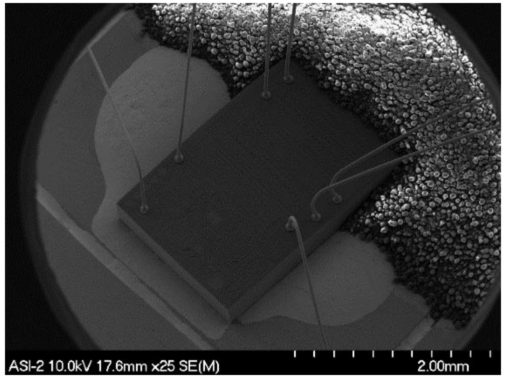


- Copper Bond Wire
- Aluminum Bond Pad

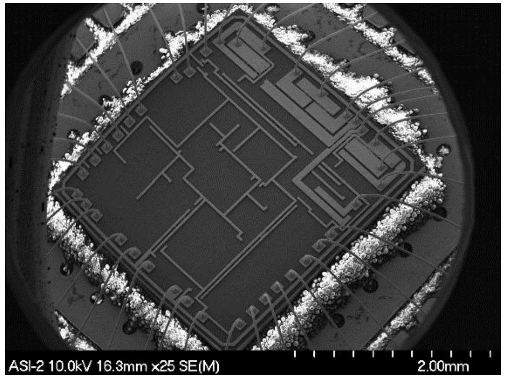
Executive Summary Phase 1

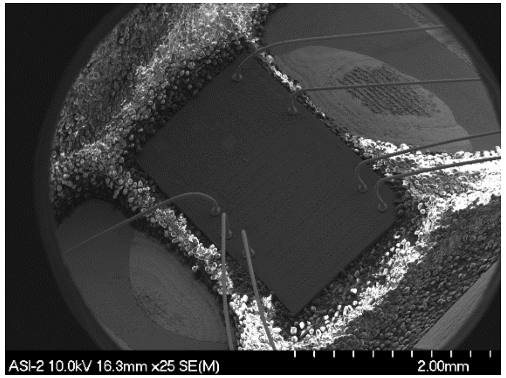
Full Chemical De-encapsulation





Laser/Chemical De-encapsulation

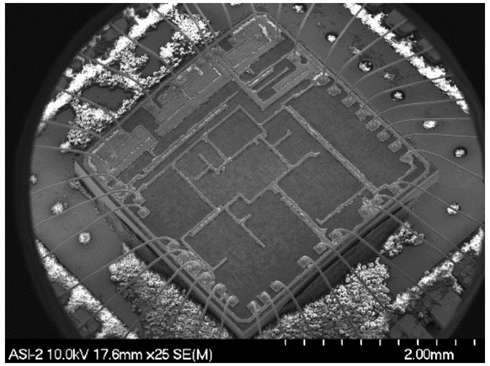


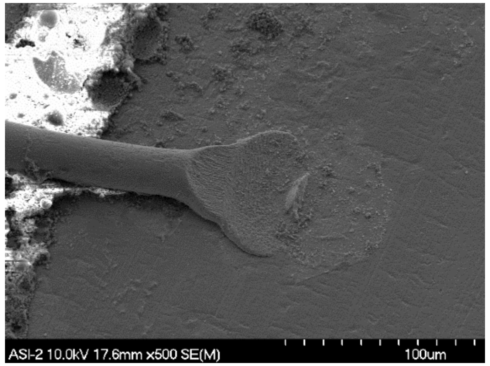


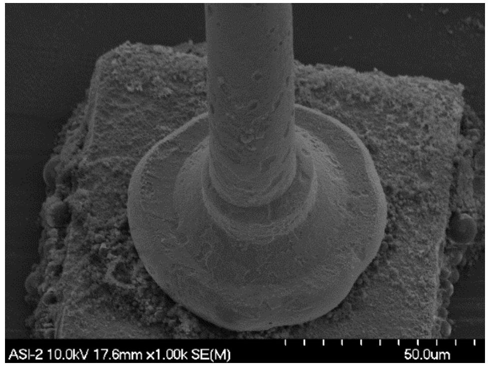
- Both methods yielded similar values for maximum and average bond pull
- Laser/Chemical process improved minimum bond pulls
- Both methods must be tightly controlled to avoid damage to the devices
- Laser/Chemical process is more automated reducing variability

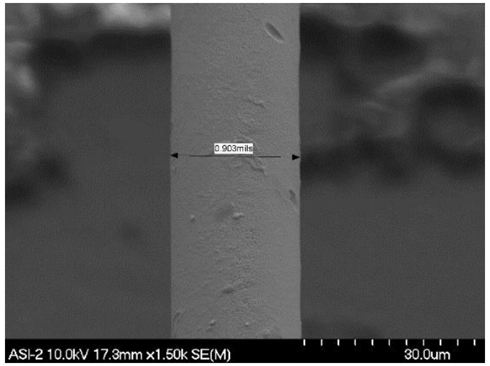
	S1	S2
Total Wire Bond Count:	190	35
Minimum wire pull strength:	6.967	16.715
Maximum wire pull strength:	13.855	28.541
Average wire pull strength:	11.609	22.639
Standard Deviation:	1.1690	2.320

	S1	S2
Total Wire Bond Count:	190	35
Minimum wire pull strength:	8.6953	17.536
Maximum wire pull strength:	13.773	26.518
Average wire pull strength:	11.627	22.523
Standard Deviation:	0.903	2.024









- S1 (Full Chemical De-encapsulation)
- Wire Size Data Post De-encapsulation.

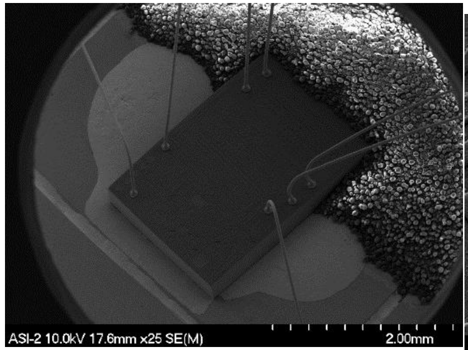
Min	**0.888 mil**
Max	**0.907 mil**
Average	**0.898 mil**
StDev	**0.007 mil**

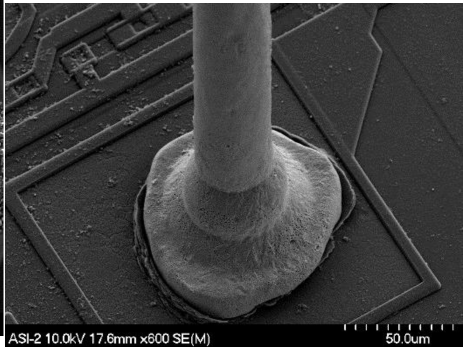
- No lifted bonds were observed on either side of the wire

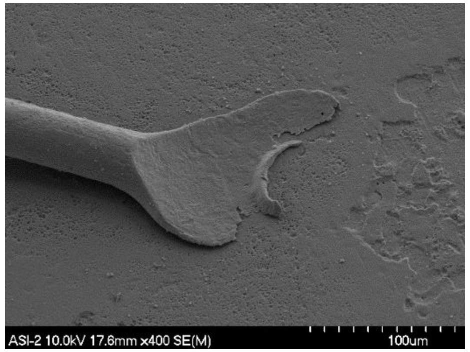
- S1 (Laser / Chemical De-encapsulation)
- Wire Size De-encapsulation

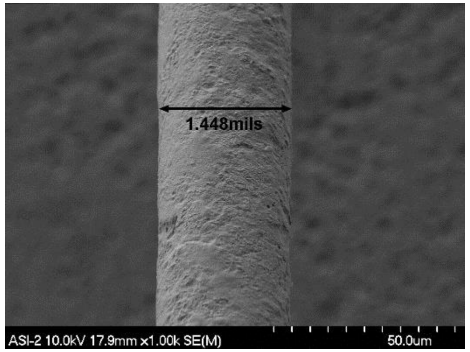
Min	**0.908 mil**
Max	**0.996 mil**
Average	**0.938 mil**
StDev	**0.035 mil**

- No lifted bonds were observed on either side of the wire









- S2 (Full Chemical De-encapsulation)
- Wire Size Data Post De-encapsulation.

Min	**1.403 mil**
Max	**1.448 mil**
Average	**1.423 mil**
StDev	**0.021 mil**

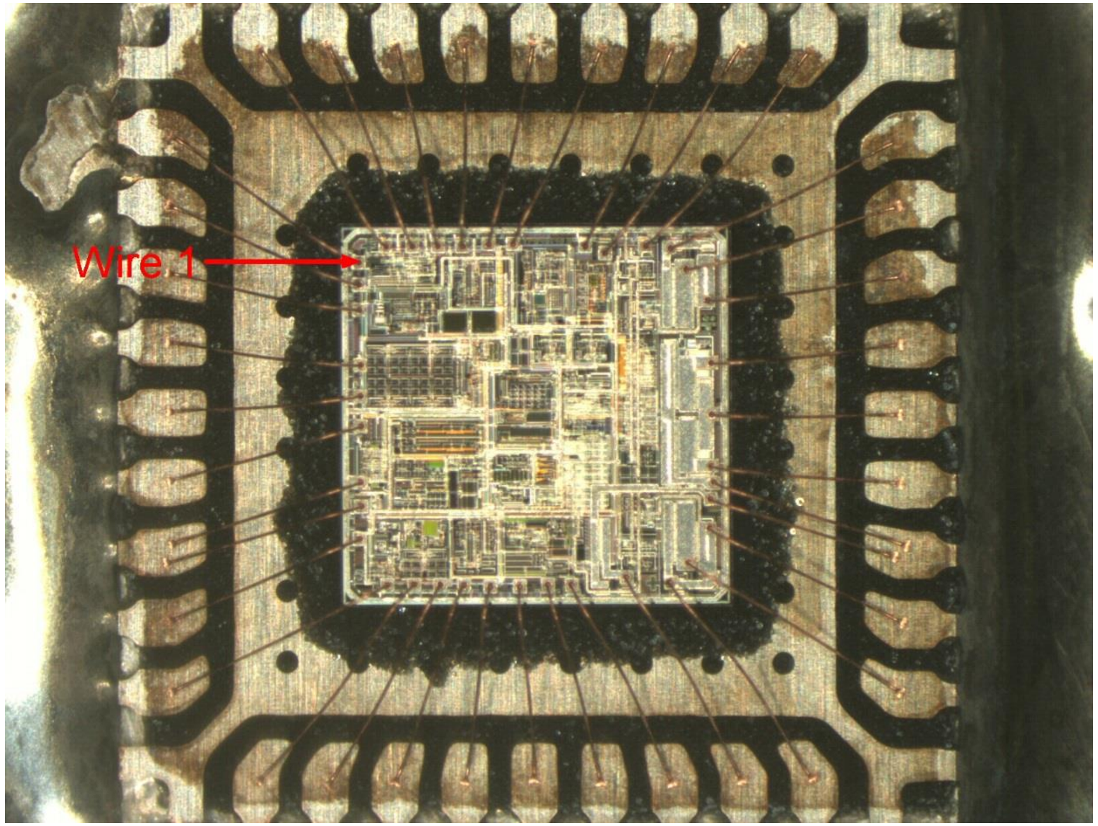
- No life bonds on either side of the wire

- S2 (Chemical / Laser De-encapsulation)
- Wire Size Data Post De-encapsulation.

Min	**1.457 mil**
Max	**1.527 mil**
Average	**1.491 mil**
StDev	**0.025 mil**

- No lifted bond on either side of the wire

S1 Bond Pull Summary



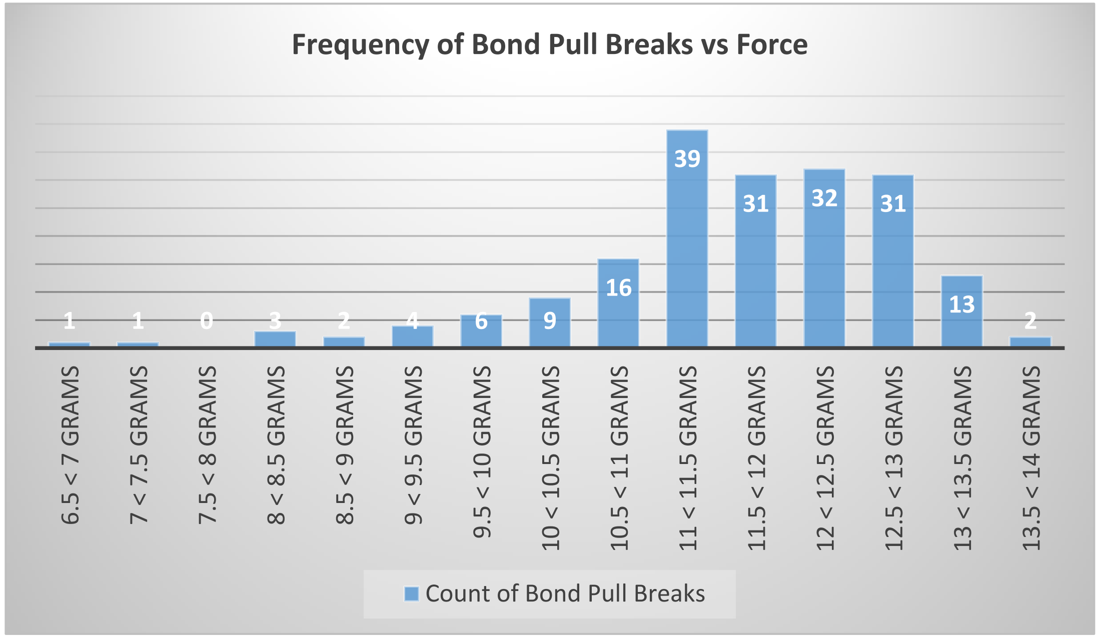
Full Chemical

S/N	Min Pull Force (grams)	Bond Location	Max Pull Force (grams)	Bond Location	Bonds Pulled
1	9.43	38	13.06	26	38
2	6.97	29	12.31	8	38
3	10.43	16	13.86	8	38
4	9.94	27	12.20	28	38
5	9.25	13	13.69	25	38

Chemical / Laser

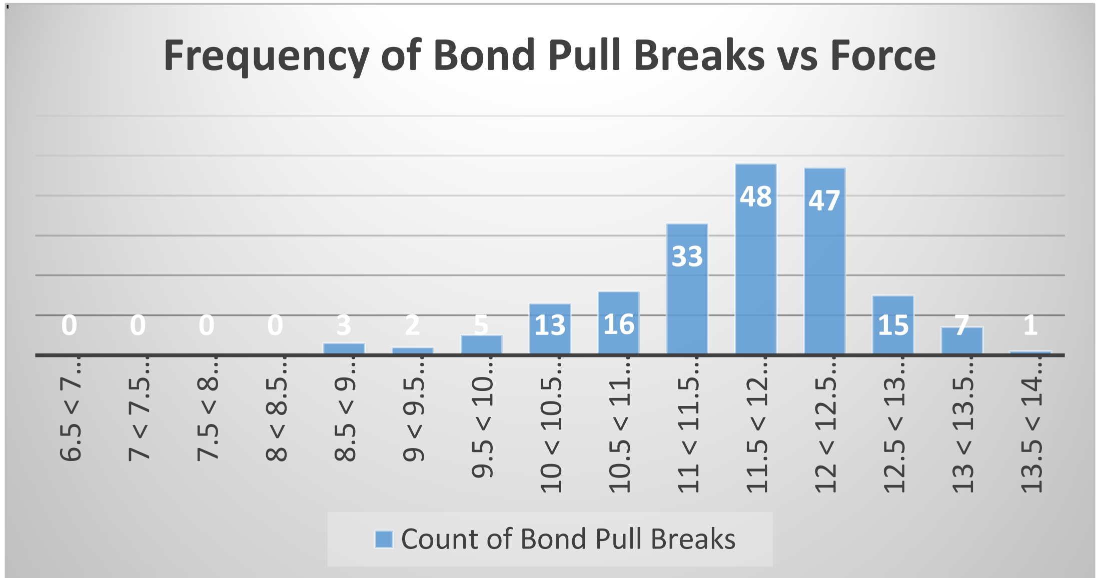
S/N	Min Pull Force (grams)	Bond Location	Max Pull Force (grams)	Bond Location	Bonds Pulled
11	9.05	11	12.97	27	38
12	8.88	18	13.07	5	38
13	9.43	30	13.11	4	38
14	8.70	30	12.48	5	38
15	10.14	38	13.48	23	38

Full Chemical De-encapsulation (S1)



Total Wire Bond Count:	190
Minimum wire pull strength:	6.9672
Maximum wire pull strength:	13.8559
Average wire pull strength:	11.60943
Standard Deviation:	1.169049

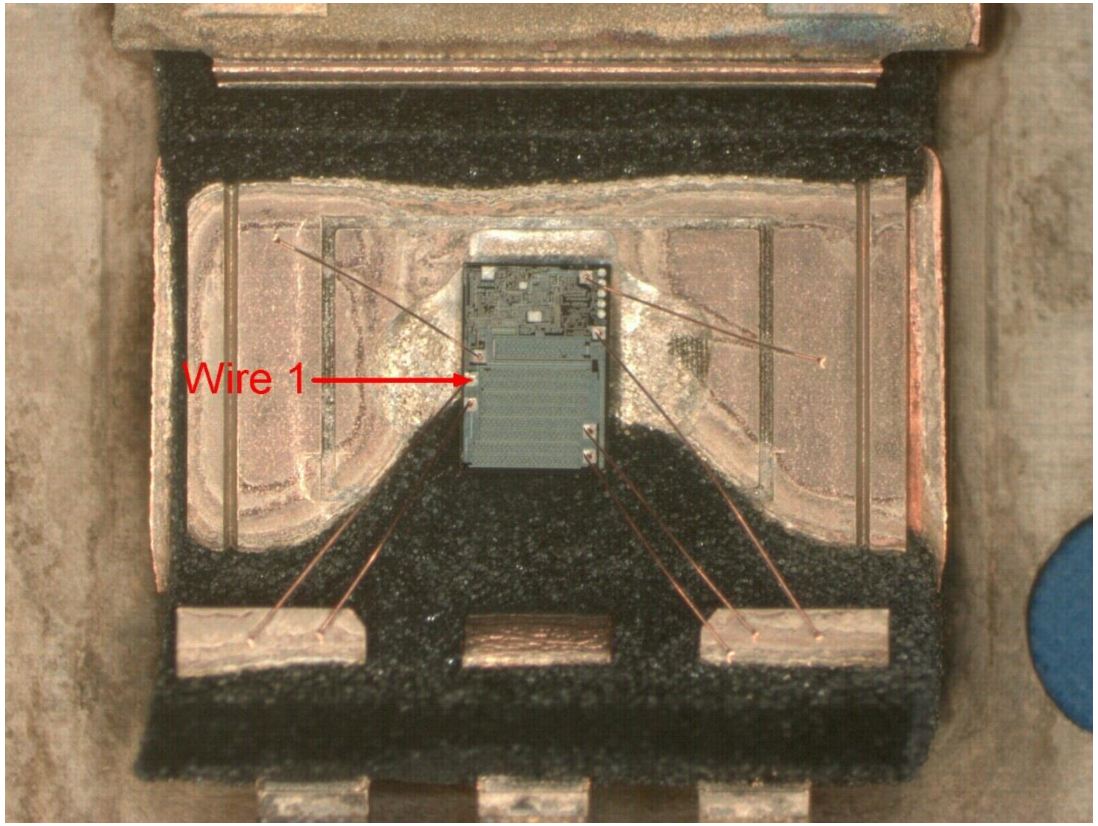
Chemical / Laser De-encapsulation (S1)



Total Wire Bond Count:	190
Minimum wire pull strength:	8.6953
Maximum wire pull strength:	13.773
Average wire pull strength:	11.627
Standard Deviation:	0.903

More normal distribution indicative of controlled process. More repeatable

S2 Bond Pull Summary



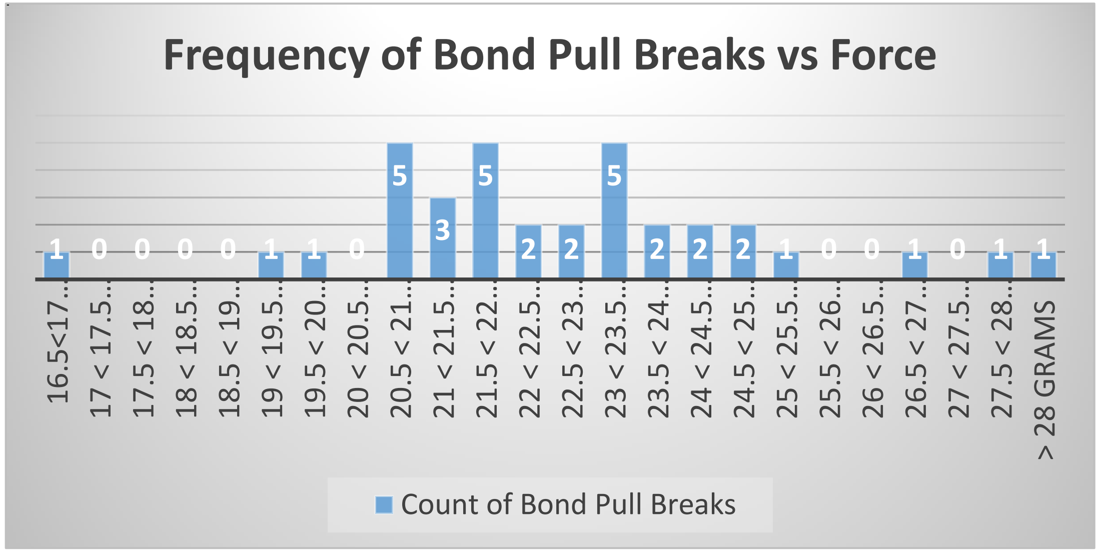
Full Chemical

S/N	Min Pull Force (grams)	Bond Location	Max Pull Force (grams)	Bond Location	Bonds Pulled
6	19.82	3	21.82	1	7
7	16.72	7	24.71	1	7
8	21.58	6	26.71	1	7
9	20.70	6	28.54	1	7
10	20.56	1	24.54	4	7

Chemical / Laser

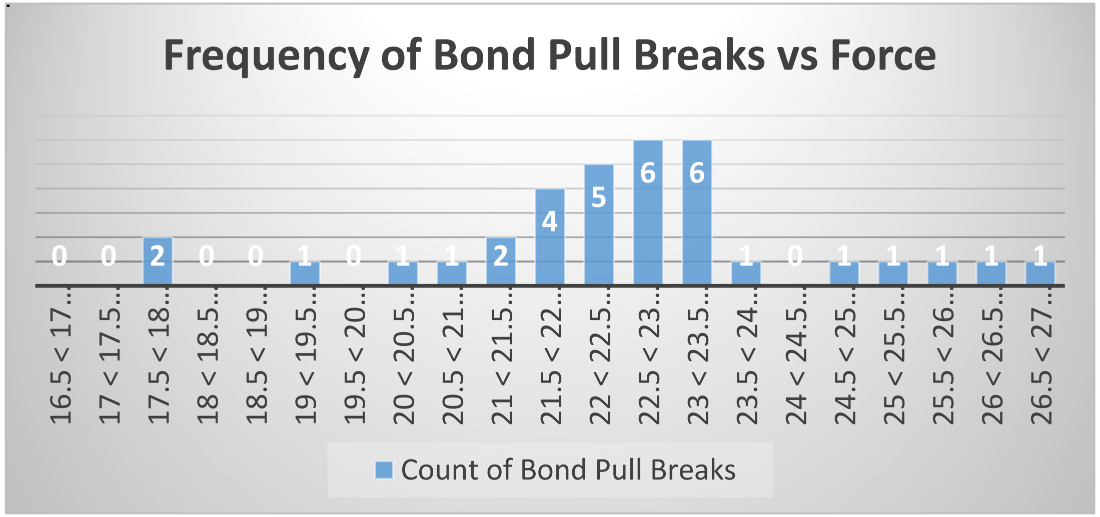
S/N	Min Pull Force (grams)	Bond Location	Max Pull Force (grams)	Bond Location	Bonds Pulled
16	17.54	7	25.05	1	7
17	22.03	6	26.33	1	7
18	20.49	6	26.35	7	7
19	21.08	2	26.52	1	7
20	17.74	7	23.14	4	7

Full Chemical De-encapsulation (S2)



Total Wire Bond Count:	35
Minimum wire pull strength:	16.715
Maximum wire pull strength:	28.541
Average wire pull strength:	22.639
Standard Deviation:	2.32

Chemical / Laser De-encapsulation (S2)



Total Wire Bond Count:	35
Minimum wire pull strength:	17.536
Maximum wire pull strength:	26.518
Average wire pull strength:	22.523
Standard Deviation:	2.024

More normal distribution indicative of controlled process.
More repeatable

Full Chemical De-encapsulation Conclusion

- Full Chemical De-encapsulation is repeatable.
  - Ten devices for this analysis
  - Over 100 copper wire bonded devices over the last month have been successfully de-encapsulated utilizing this method.
  - Wire size due to etching is reduced by approximately 0.1 mils utilizing this method.
- Bond pull data distribution
  - No wire pulled below 2 X gold limit
    - Gold limit for 1 mil wire is 2.5 grams
  - 91 % of bond wires broke at the mid span.
    - All low pull strengths were mid span breaks
  - 7 % of bond wires broke at the neck down of the ball bond.
  - 2% bond wires broke at the bond on lead frame.

Laser/Chemical De-encapsulation Conclusion

- Laser/Chemical De-encapsulation is repeatable.
  - Ten devices for this analysis
  - Bond wire reduction reduced by .07 mils utilizing this method
  - Lead frame plating was noticeably better preserved.
  - Condition of bond pad and overall wire bonds were better preserved.

- Bond pull data distribution
  - No wire pulled below 2 X gold limit
    - Gold limit for 1 mil wire is 2.5 grams
  - 80 % of bond wires broke at the mid span.
    - All low pull strengths were mid span breaks
  - 20 % of bond wires broke at the neck down of the ball bond.
  - No stitch bond breaks observed.

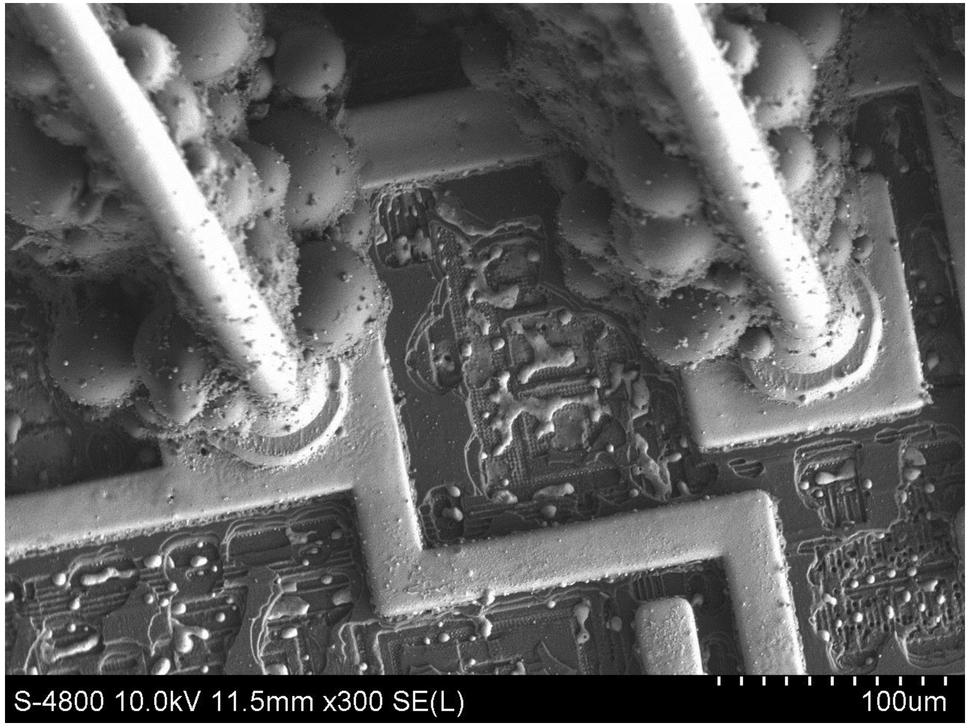
Overall Conclusions

- Laser/chemical process resulted in tighter distribution.
- Average and maximum breaking force was similar for both methods but minimum breaking force was higher when laser/chemical process was used.
- Both methods resulted in bond pull strengths above the 2X limit of gold bond wires.
- Laser/chemical process resulted in cleaner opening with less damage to bond pads, lead frames and overall wire bonds.
- Either process needs setup parts to optimize de-encapsulation.
- Tight controls are needed for either process as both utilize Acid as part of the process which can and will attack the copper wire bonds.

Cautions

- Laser/chemical process is not the be-all-end-all. Parts are still subjected to acid which can etch and damage wire bonds, lead frame or bond pads.
- Laser can cause damage to both the bond wires and the die if performed improperly.
- Either method requires tight controls and active participation of engineering to mitigate damage that may be induced.

Die damage caused by laser overexposure



Phase 2

Preconditioning

HAST (96 hrs, 130C/85% RH)

Temperature Cycle (-55C / +125C) 250 cycles

Pull 20 parts from each part type

Decap

Wire Pull

HAST (96 hrs, 130C/85% RH)

Temperature Cycle (-55C / +125C) 250 cycles

Decap

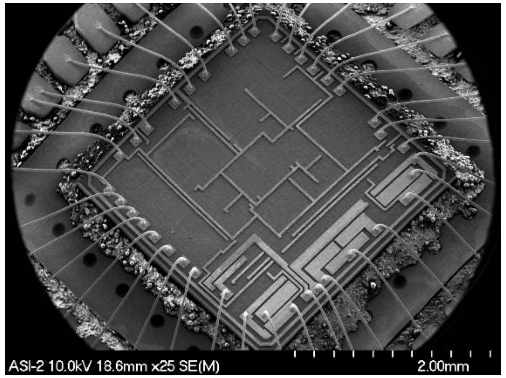
Wire Pull

Purpose of Phase 2

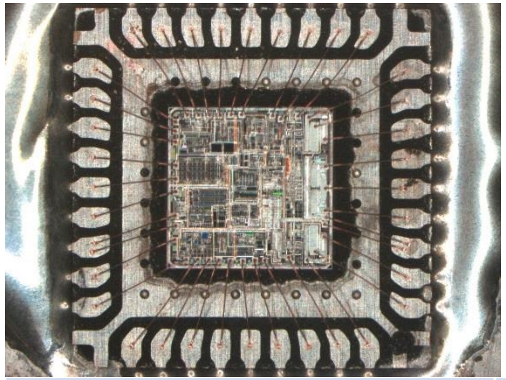
- Refinement of Laser De-encapsulation Process
- Identify differences in Laser De-encapsulation process post environmental stresses
- Show repeatability of Laser De-encapsulation process utilizing the same device types as was used in phase 1

Executive Summary Phase 2

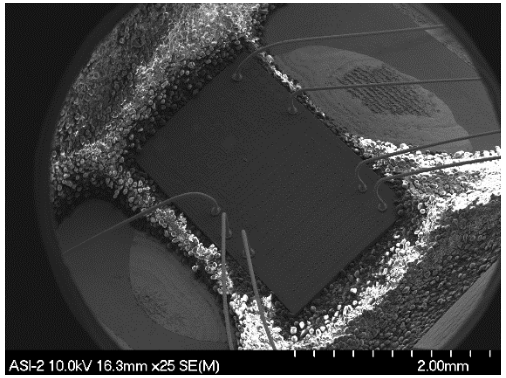
Phase 1 Data	S1	S2
Total Wire Bond Count:	190	35
Minimum wire pull strength:	8.6953	17.536
Maximum wire pull strength:	13.773	26.518
Average wire pull strength:	11.627	22.523
Standard Deviation:	0.903	2.024



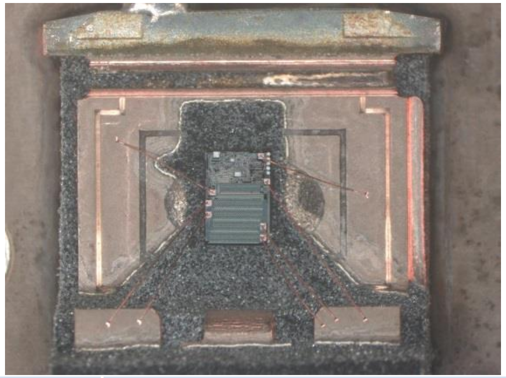
S1



- No changes were required in de-encapsulation process from phase 1 to phase 2.
- Some degradation of the bonds were observed on both devices between phase 1 and phase 2 midpoint with the S2-3.3 showing the most variation.
- Some degradation of the bonds were observed on both devices between the midpoint and endpoint of phase 2.
- Several cracked and broken heals were observed on the S2-3.3 at the endpoint of phase 2 and all low bond breaks between phase 2 midpoint and endpoint were breaks at the heal of the stitch.
- One bond on the S1 cratered resulting in a low bond pull break.
- **No low bond pull breaks were attributed to de-encapsulation quality.**



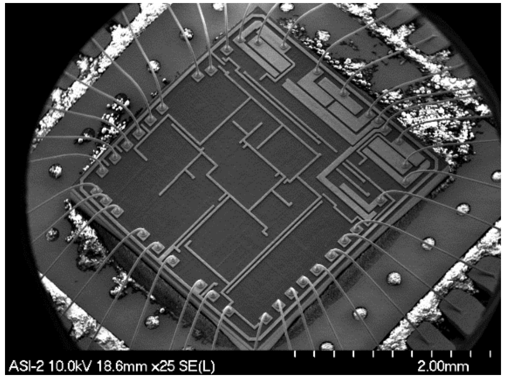
S2-3.3

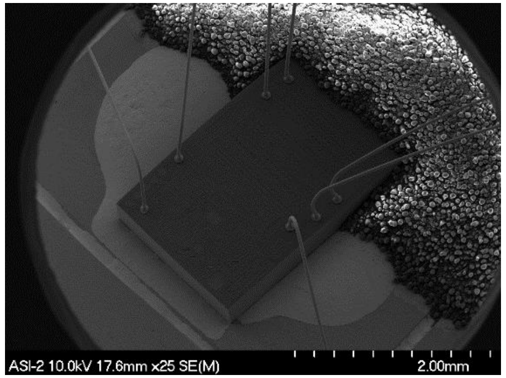


	S1 Midpoint	S1 Endpoint	S2-3.3 Midpoint	S2-3.3 Endpoint
Total Wire Bond Count:	760	760	140	126
Minimum wire pull strength:	6.64 grams	.12 grams	5.92 grams	0.00 grams
Maximum wire pull strength:	13.07 grams	13.23 grams	32.45 grams	30.77 grams
Average wire pull strength:	11.23 grams	11.40 grams	22.40 grams	21.88 grams
Standard Deviation:	0.82 grams	0.87 grams	3.96 grams	5.82 grams

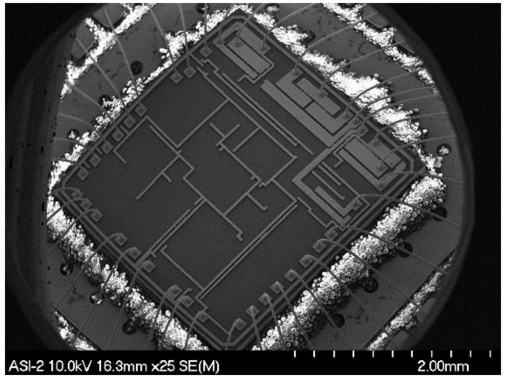
Executive Summary Phase 1

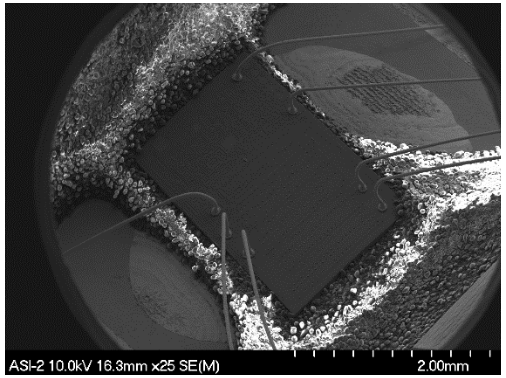
Full Chemical De-encapsulation





Laser/Chemical De-encapsulation



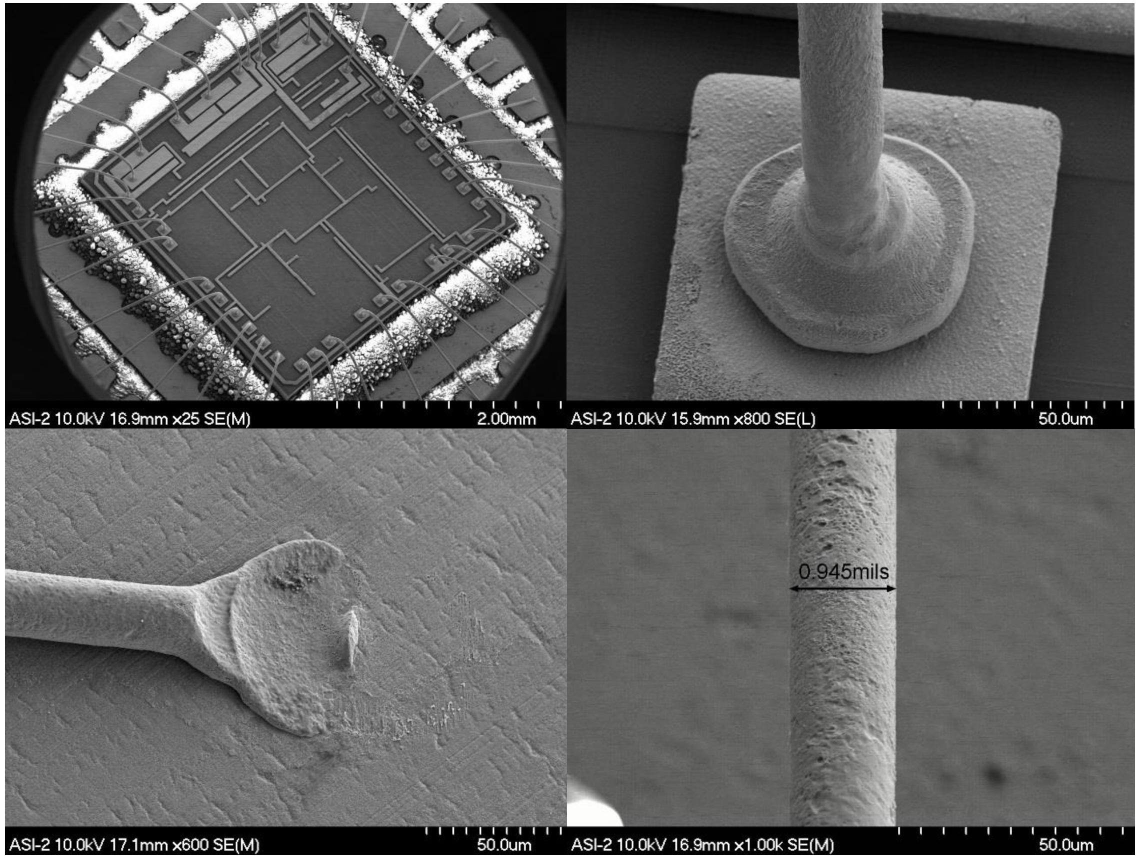


- Both methods yielded similar values for maximum and average bond pull
- Laser/Chemical process improved minimum bond pulls
- Both methods must be tightly controlled to avoid damage to the devices
- Laser/Chemical process is more automated reducing variability

	S1	S2
Total Wire Bond Count:	190	35
Minimum wire pull strength:	6.967	16.715
Maximum wire pull strength:	13.855	28.541
Average wire pull strength:	11.609	22.639
Standard Deviation:	1.1690	2.320

	S1	S2
Total Wire Bond Count:	190	35
Minimum wire pull strength:	8.6953	17.536
Maximum wire pull strength:	13.773	26.518
Average wire pull strength:	11.627	22.523
Standard Deviation:	0.903	2.024

Midpoint and End Point de-encapsulation wire diameter



- S1
- Mid Point:

Min	**0.875 mil**
Max	**1.00 mil**
Average	**0.93655 mil**
StDev	**0.02802 mil**

- End Point

Min	**0.878 mil**
Max	**0.949 mil**
Average	**0.912 mil**
StDev	**0.018 mil**

Midpoint and endpoint de-encapsulation and wire pull

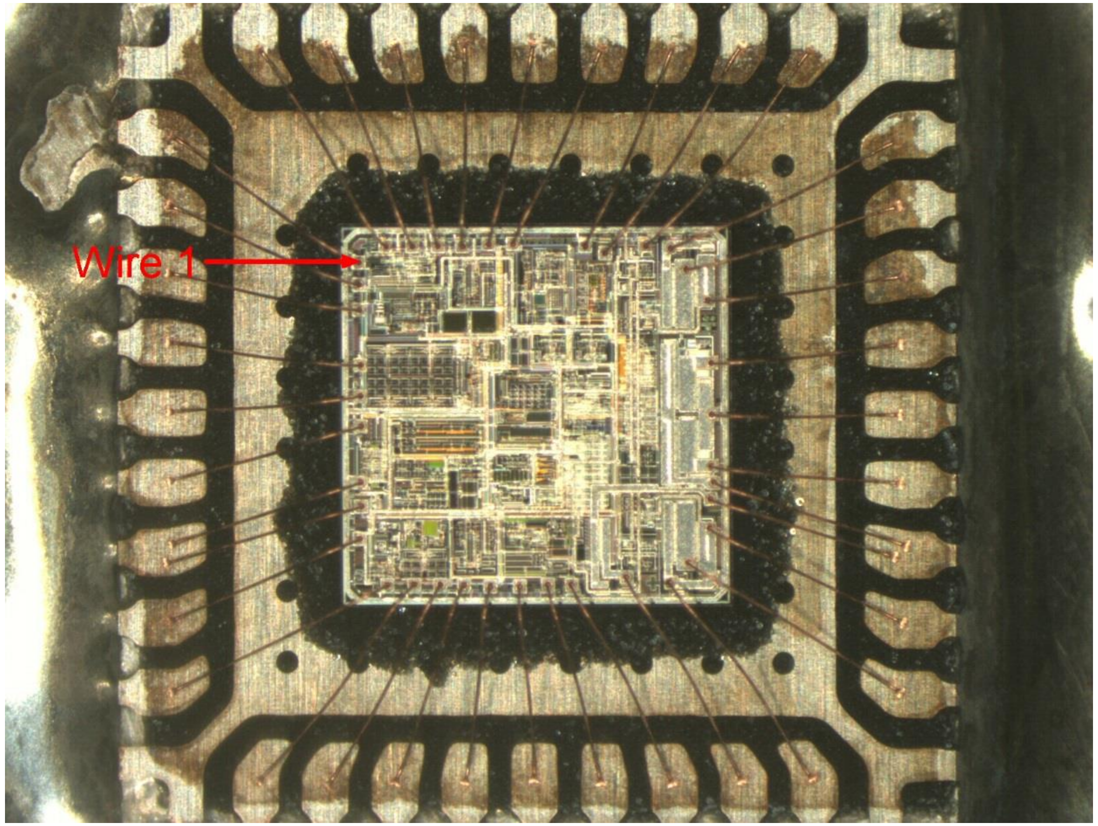
- S1
- Midpoint

Number of Bonds Pulled	760
Min	6.64 grams
Max	13.07 grams
Average	11.23 grams
StDev	0.82 grams

- Endpoint

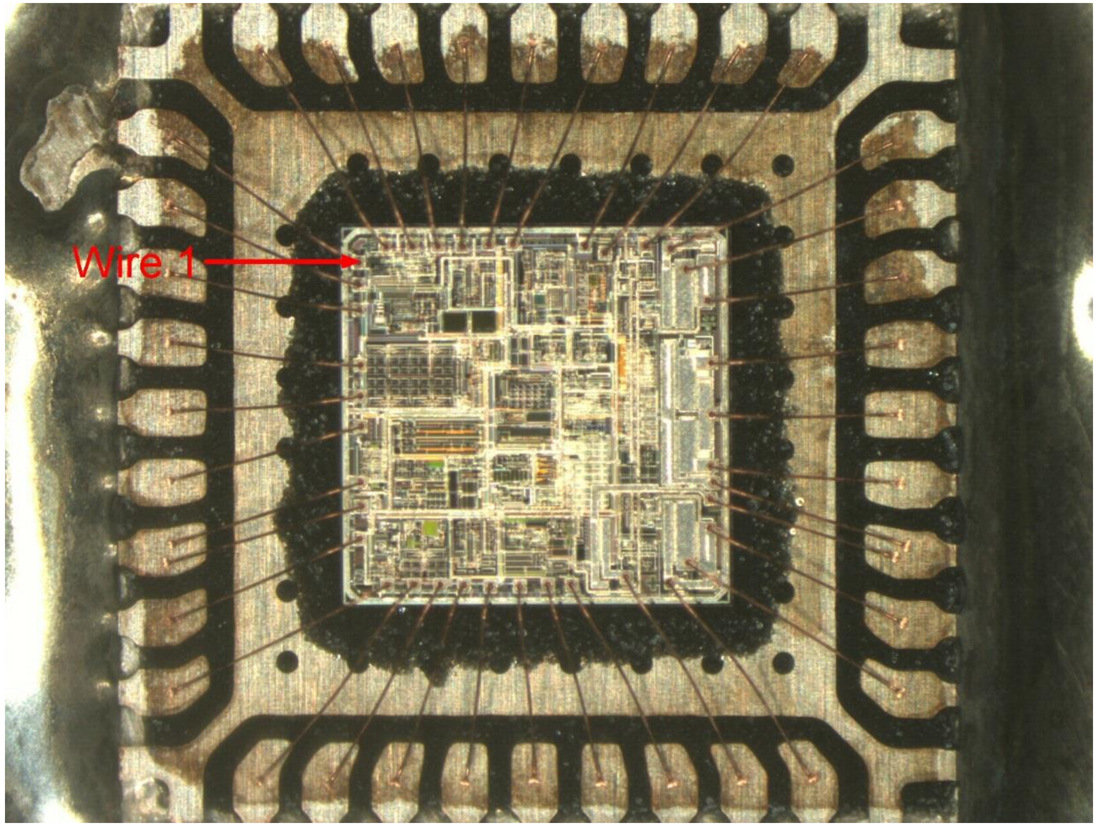
Number of Bonds Pulled	760
Min	.12 grams
Max	13.23 grams
Average	11.40 grams
StDev	0.87 grams

Midpoint Bond Pull Data S1



S/N	Min Pull Force (grams)	Bond Location	Max Pull Force (grams)	Bond Location	Bonds Pulled
1	9.92	17	12.53	24	38
2	6.64	8	12.34	4	38
3	8.45	1	12.57	26	38
4	9.94	29	12.6	4	38
5	8.1	1	12.89	24	38
6	9.65	5	12.03	8	38
7	9.52	11	12.65	15	38
8	9.68	22	12.72	25	38
9	9.63	11	12.43	25	38
10	9.69	20	12.56	15	38
11	9.51	32	12.52	5	38
12	9.46	33	12.31	16	38
13	9.98	10	13	5	38
14	8.45	9	12.76	26	38
15	8.9	33	12.76	22	38
16	9.23	11	12.75	26	38
17	8.42	20	12.4	36	38
18	9.25	20	13.03	26	38
19	9.5	5	12.13	28	38
20	10.54	19	13.07	4	38

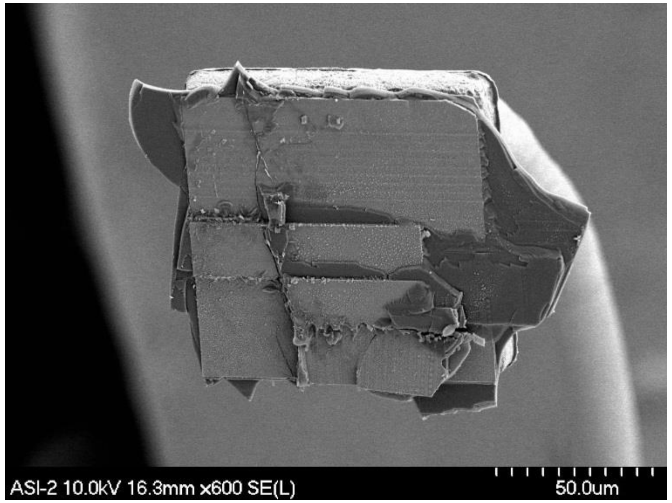
Endpoint Bond Pull Data S1

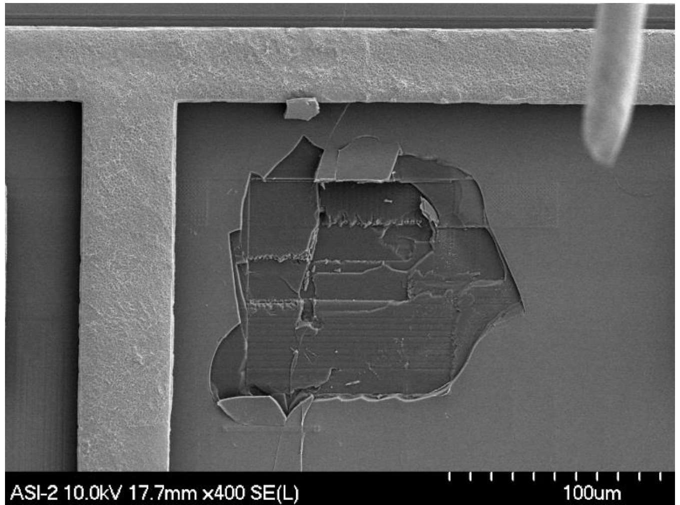


S/N	Min Pull Force (grams)	Bond Location	Max Pull Force (grams)	Bond Location	Bonds Pulled
41	0.12	5	12.24	22	38
42	10.29	18	12.98	35	38
43	9.21	32	12.34	6	38
44	9.94	27	12.20	28	38
45	9.00	6	12.50	4	38
46	9.67	8	12.63	22	38
47	10.13	4	13.07	26	38
48	9.56	1	13.03	23	38
49	10.24	2	12.97	26	38
50	9.87	11	12.32	23	38
51	9.52	7	12.76	34	38
52	9.81	29	12.74	25	38
53	10.69	23	12.81	25	38
54	10.43	19	13.23	14	38
55	8.15	4	12.14	7	38
56	10.26	29	12.60	32	38
57	10.14	3	13.14	2	38
58	9.85	11	12.74	3	38
59	7.34	2	12.45	4	38
60	10.04	1	12.58	36	38

Bond Pull on Pin 5 of S/N 41 resulted in cratering.

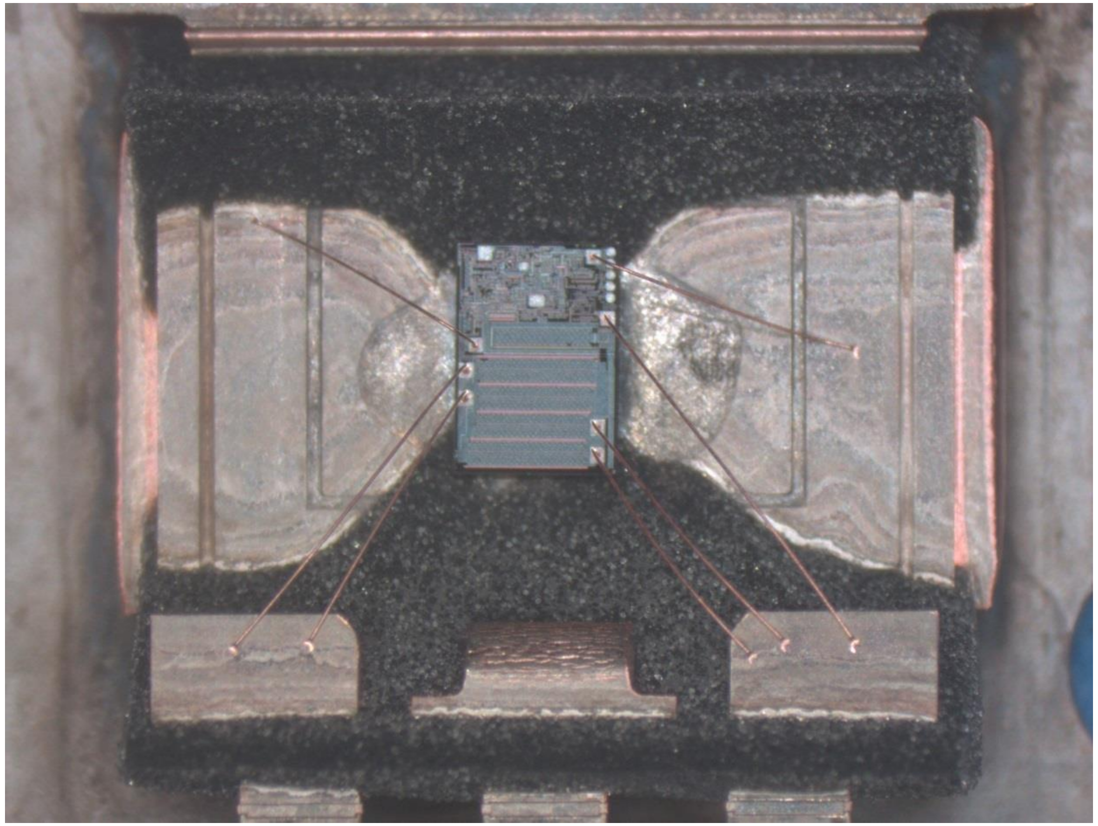
Endpoint de-encapsulation and wire pull





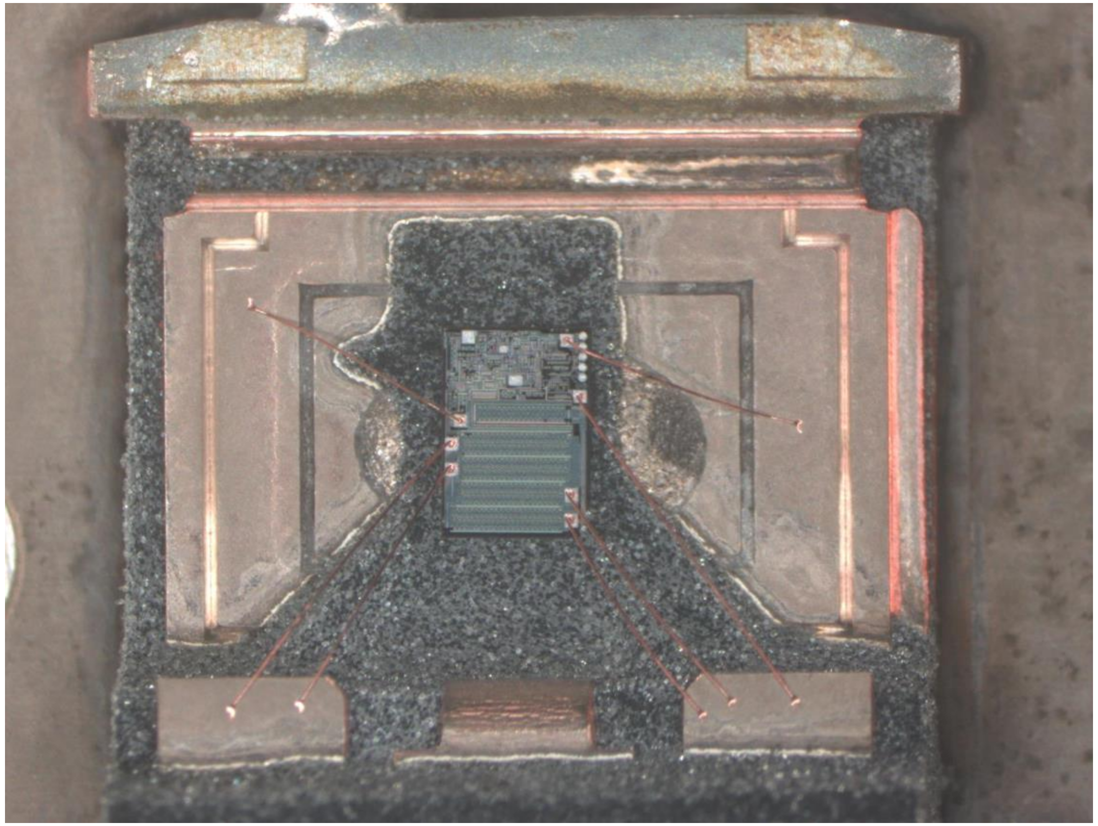
- Bond Pull on Pin 5 of S/N 41 resulted in cratering. Bond pull for this site was 0.12 grams.
- Damage is not indicative of de-encapsulation process.

Midpoint de-encapsulation and wire pull



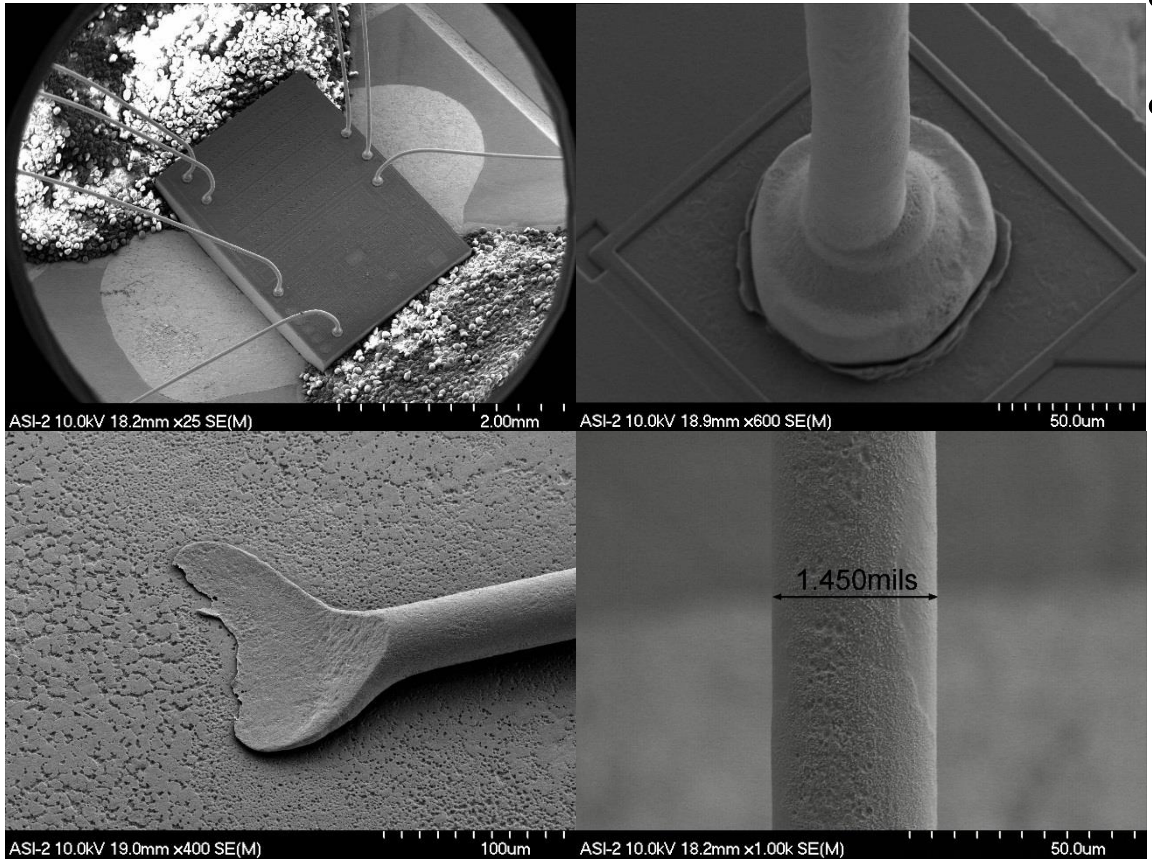
- S2-3.3
- Laser ablation process was identical to the phase 1 process. No adjustments needed.
- Both sides of the bonds were fully exposed.
- Bond Pull Data similar to phase 1.
- All bond breaks below 17 grams were found to be breaks at the heal of the stitch bond.

Endpoint de-encapsulation and wire pull



- S2-3.3
- Laser ablation process was identical to the phase 1 process. No adjustments needed.
- Both sides of the bonds were fully exposed.
- Heal cracks and breaks were observed on several bonds caused by work hardening of the bond wires.
- Heal cracks and breaks are not indicative of the de-encapsulation process.

Midpoint and endpoint de-encapsulation and wire diameter



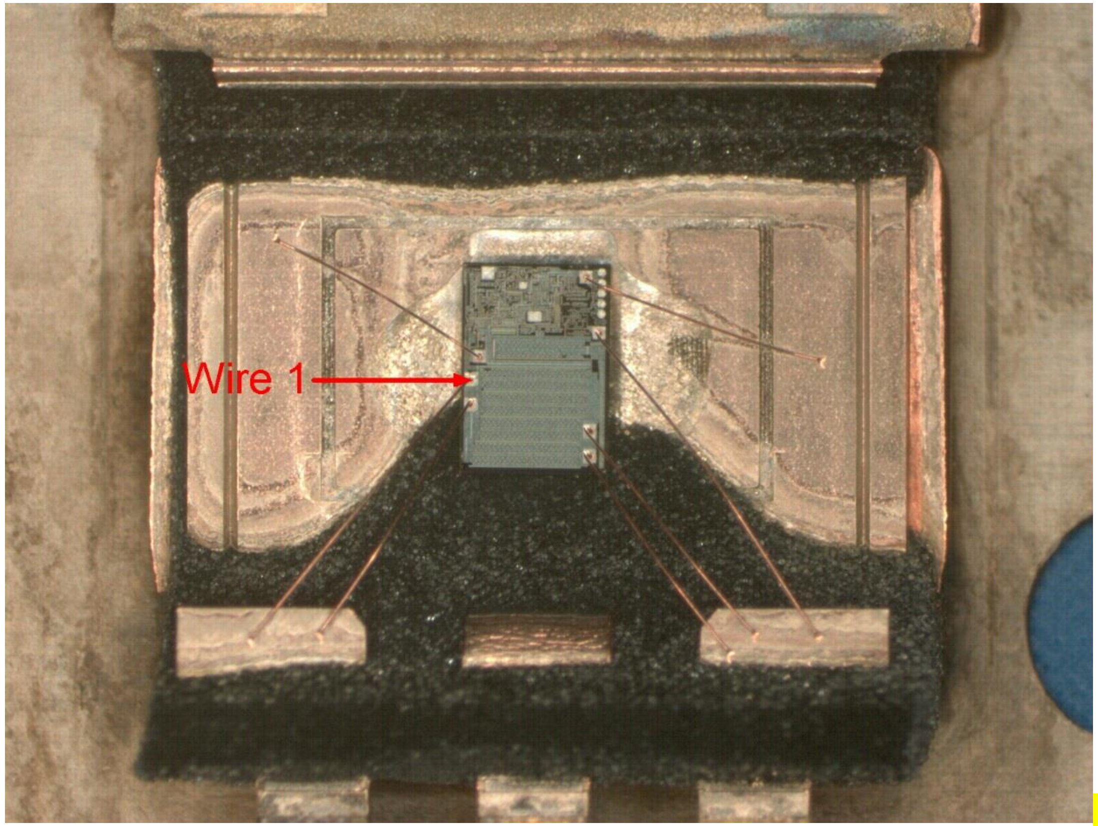
- S2-3.3
- Midpoint

Min	**1.293 mil**
Max	**1.543 mil**
Average	**1.469 mil**
StDev	**0.0516 mil**

- Endpoint

Min	**1.431 mil**
Max	**1.549 mil**
Average	**1.492 mil**
StDev	**0.0302 mil**

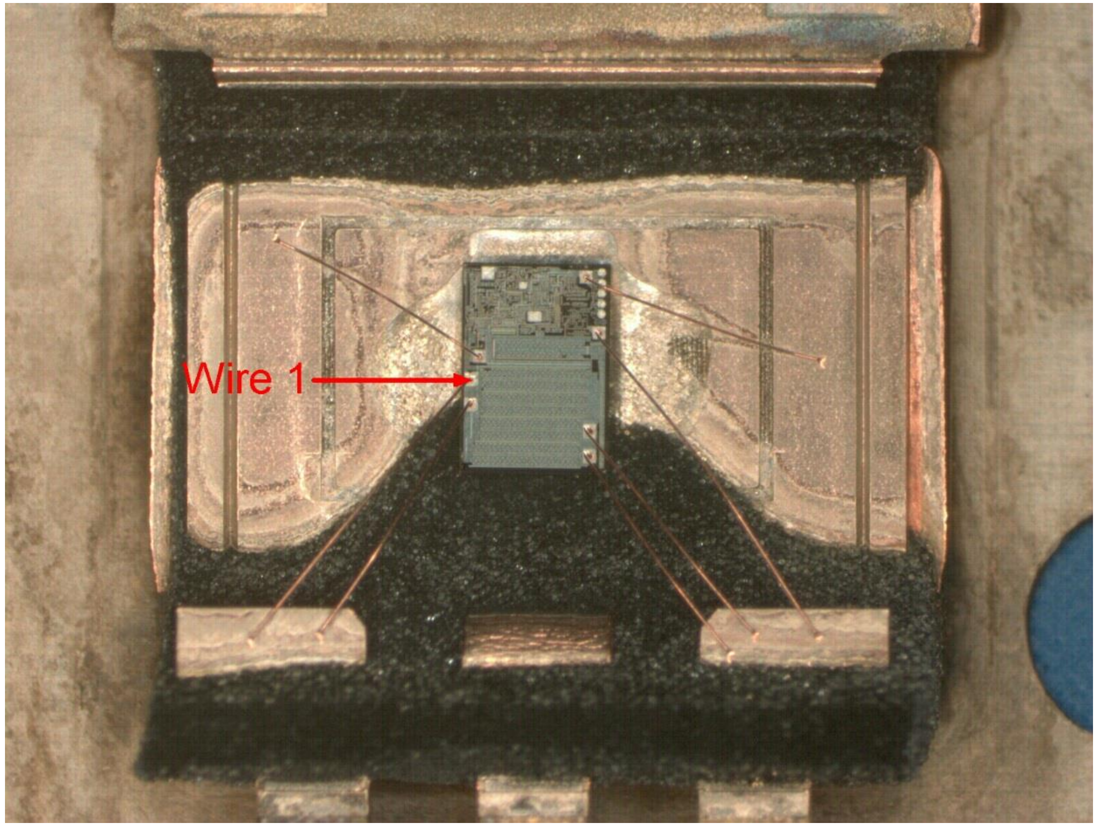
Midpoint Bond Pull Data S2-3.3



S/N	Min Pull Force (grams)	Bond Location	Max Pull Force (grams)	Bond Location	Bonds Pulled
21	11.28	7	24.98	6	7
22	19.91	6	21.76	1	7
23	18.37	4	21.45	6	7
24	6.25	6	22.61	2	7
25	18.63	3	26.7	6	7
26	5.92	6	21.59	3	7
27	19.1	1	25.42	6	7
28	19.36	1	27.39	7	7
29	18.31	6	30.18	7	7
30	21.64	5	27.56	7	7
31	21.15	5	28.37	7	7
32	18.04	5	29	6	7
33	19.68	1	32.45	7	7
34	21.12	4	31.01	7	7
35	21.79	5	29.57	7	7
36	19.77	4	31.97	7	7
37	22.64	3	30.79	6	7
38	20.76	5	30.18	7	7
39	12.25	7	26.5	6	7
40	20.73	3	31.19	7	7

S/N 24 Wire 6 showed excessive etching post bond pull. Wires 5 and 7 of the same device show no etching. S/N 26 Wire 6 was a brittle break of the heal of the stich bond.

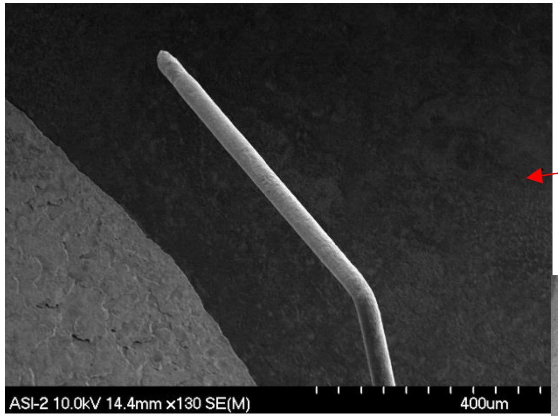
Endpoint Bond Pull Data S2-3.3



S/N	Min Pull Force (grams)	Bond Location	Max Pull Force (grams)	Bond Location	Bonds Pulled
61	22.31	5	28.19	6	7
62	3.22	6	28.35	7	7
63	0.00	6,7	24.46	3	7
64	13.96	7	28.73	6	7
65	21.02	1	28.54	7	7
66	22.38	5	28.96	7	7
67	0.00	6	28.42	7	7
68	21.62	2	30.77	6	7
69	18.82	1	22.42	7	7
70	20.93	2	30.10	6	7
71	0.00	7	24.58	6	7
72	0.00	6	24.79	7	7
73	19.82	5	26.25	7	7
74	20.65	5	22.91	6	7
75	20.62	3	27.54	6	7
76	20.77	2	24.15	6	7
77	0.00	6	29.33	7	7
78	19.17	1	28.22	7	7

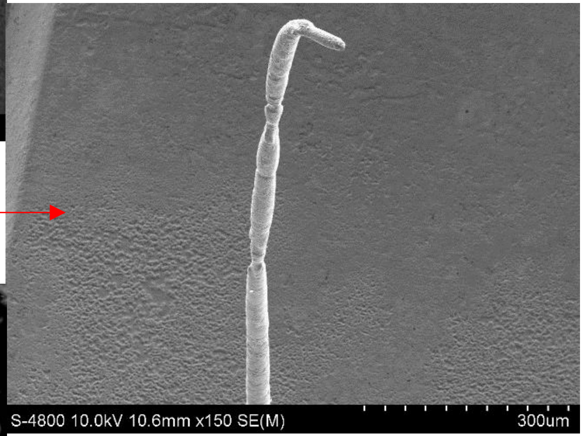
Highlighted serial numbers revealed cracks or breaks
At the heal of the stitch bond that pulled low.

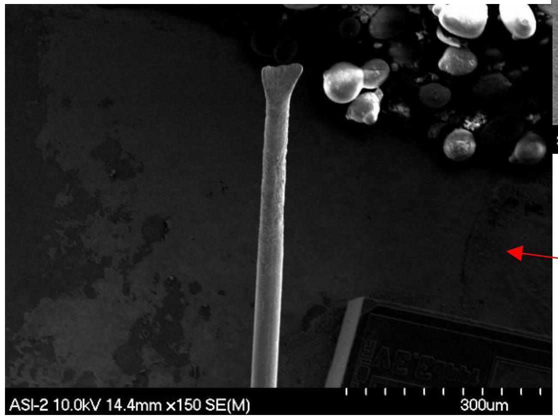
Midpoint Bond Pull Data S2-3.3 S/N 24 Wires 5, 6 and 7 post bond pull.



Wire 5

Wire 6



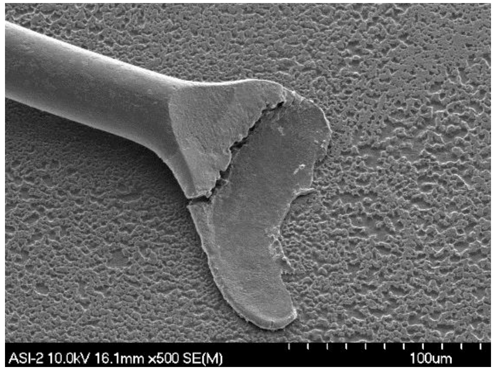


Wire 7

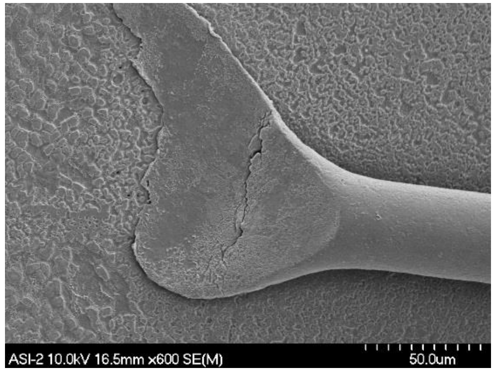
- Wire 5 shows ductile fracture and no etching.
- Wire 6 shows ductile fracture and etching.
- Wire 7 shows break at the heal of the stich and no etching.

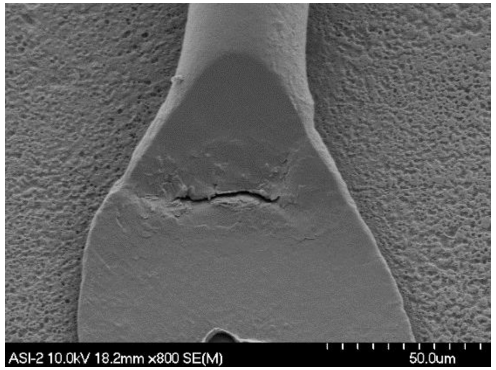
Endpoint de-encapsulation stitch bond heal cracks and breaks examples.

S/N 72 Wire 6

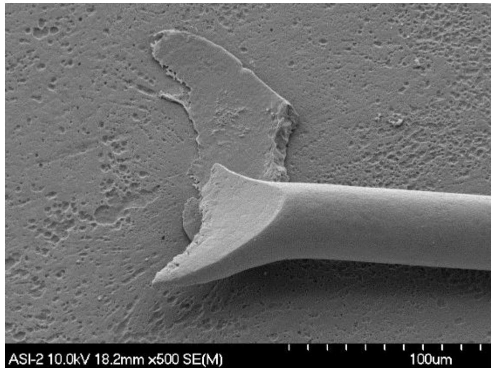


S/N 75 Wire 7





S/N 64 Wire 2



S/N 63 Wire 7

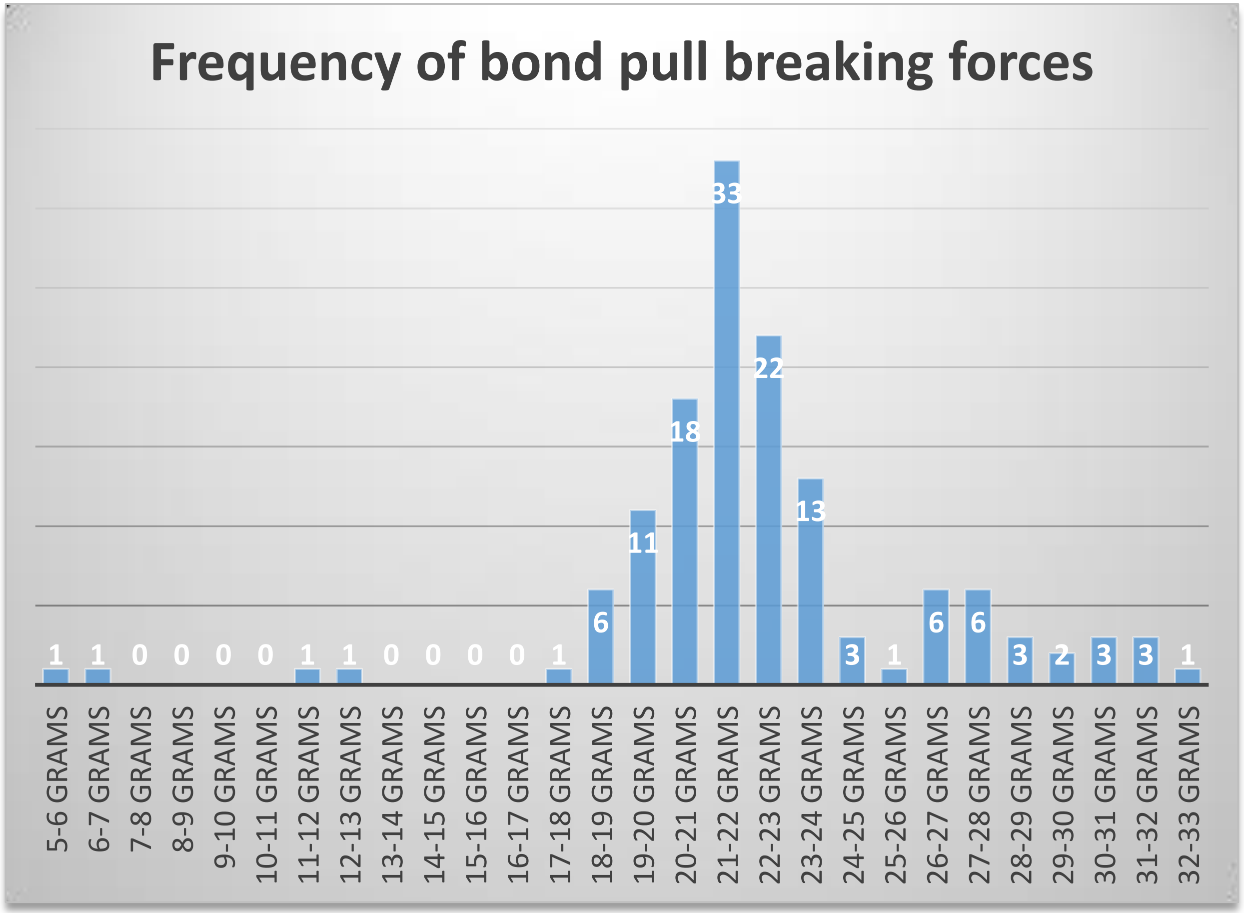
- S2-3.3
- Seven wires were observed to have breaking or cracking at the heal.
- This breaking is indicative of work hardening and no of the de-encapsulation process.
- No wires exhibiting this anomaly show signs of over etching.

Midpoint de-encapsulation and wire pull

- S2-3.3
- Bond Pull Data:

Number of Bonds Pulled	140
Min	5.92 grams
Max	32.45 grams
Average	22.40 grams
StDev	3.96 grams

- All bond breaks below 17 grams were found to be breaks at the heal of the stitch bond.

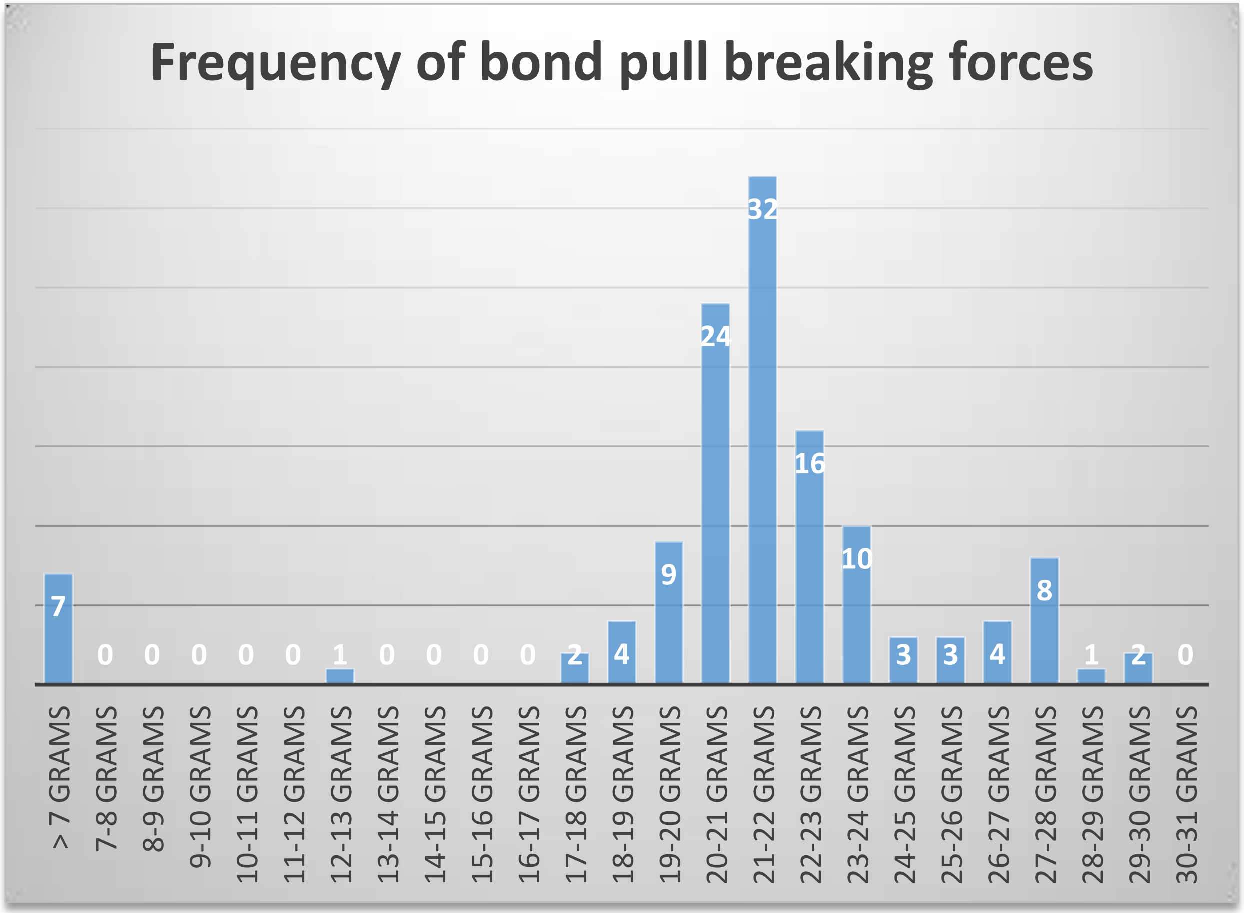


Endpoint de-encapsulation and wire pull

- S2-3.3
- Bond Pull Data:

Number of Bonds Pulled	**126**
Min	**0.00 grams**
Max	**30.77 grams**
Average	**21.88 grams**
StDev	**5.82 grams**

- All bond breaks below 17 grams were found to be breaks at the heal of the stitch bond.



Overall Conclusions

- Sequential testing brings out the worst case reliability
- Product type matters
- Laser/chemical process resulted in cleaner opening with less damage to bond pads, lead frames and overall wire bonds.