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NASA Goddard

Issues and Concerns with Cu Bond Wire PEMs

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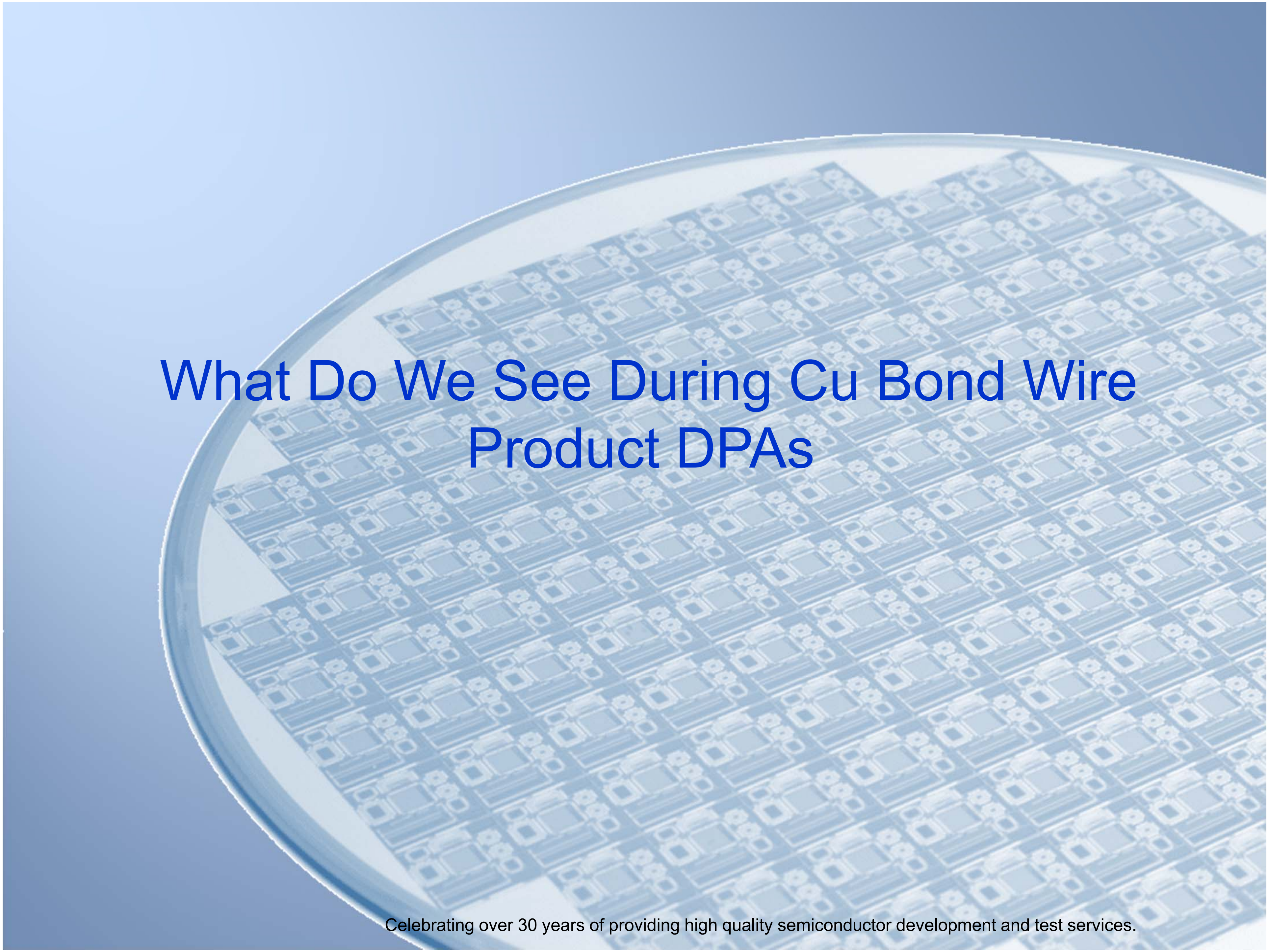
INTEGRA
TECHNOLOGIES

TECHNOLOGY QUALITY
OVER 35 YEARS
ON-TIME DELIVERY

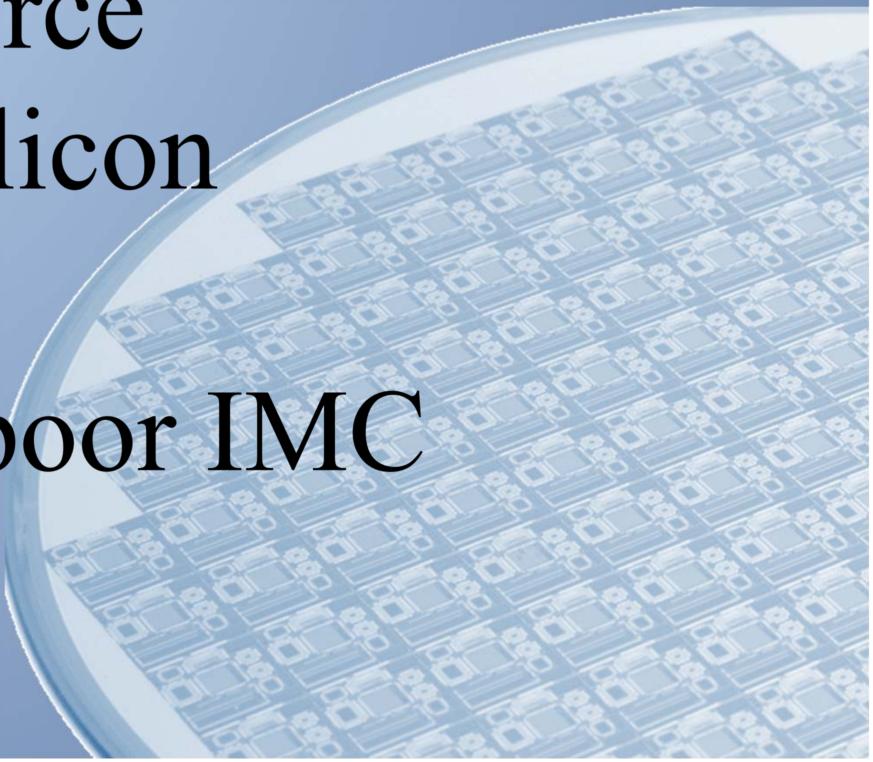


What Do We See During Cu Bond Wire Product DPAs

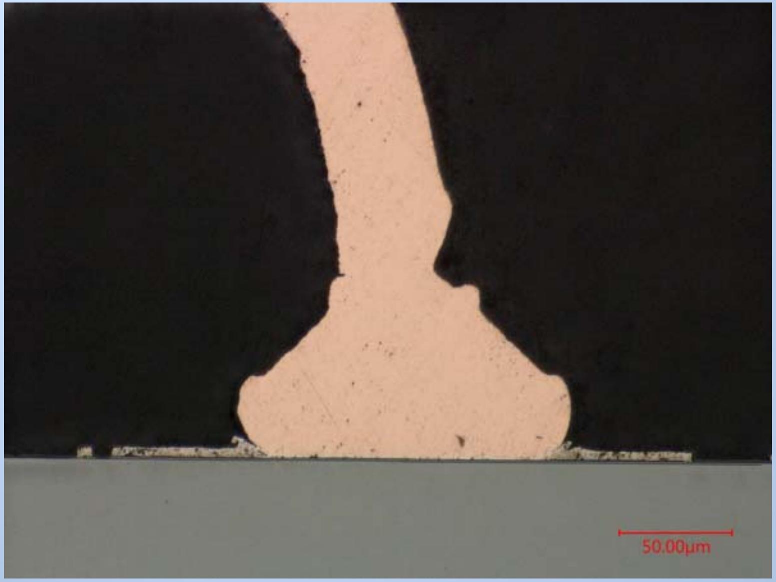
Celebrating over 30 years of providing high quality semiconductor development and test services.

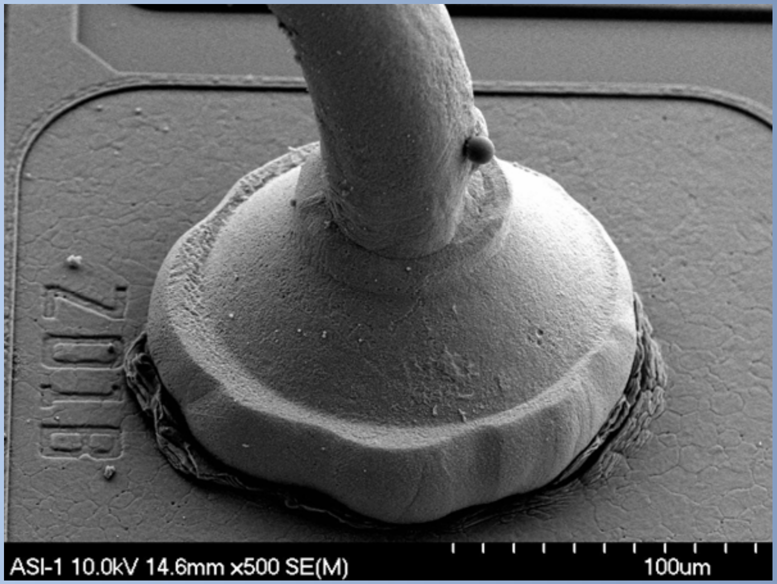
What Do We See During Cu Bond Wire DPA

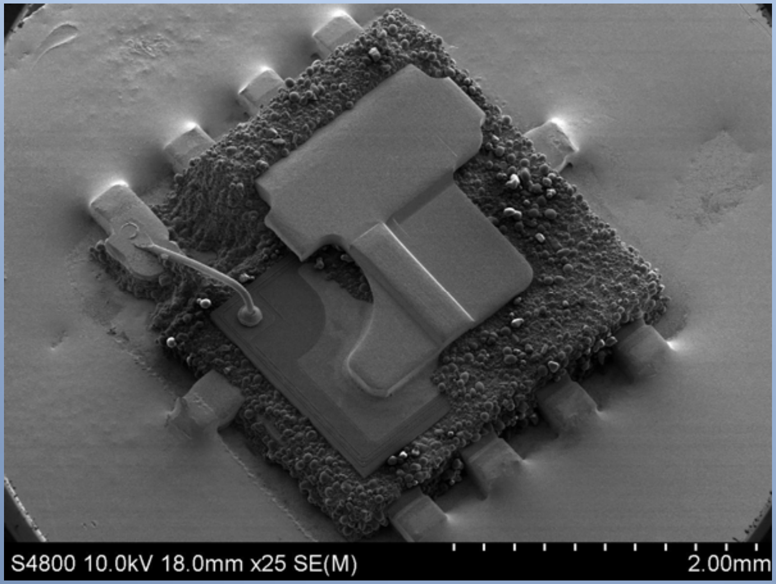
–Bond wire thinning at the neck
–Excessive splash of bond on pad
–Low ball bond force
–Lifted pad and silicon
–Cratering
–Bond lift due to poor IMC

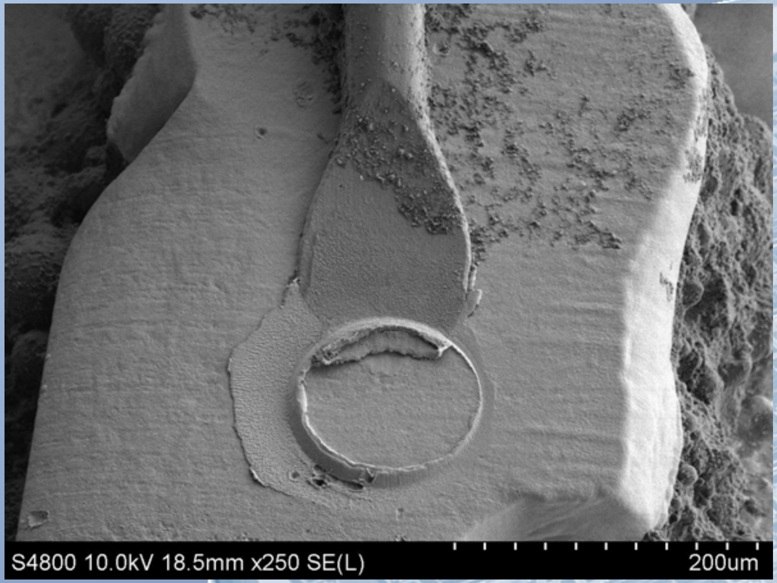


Seen at DPA: thinning at the neck down area of a copper bond

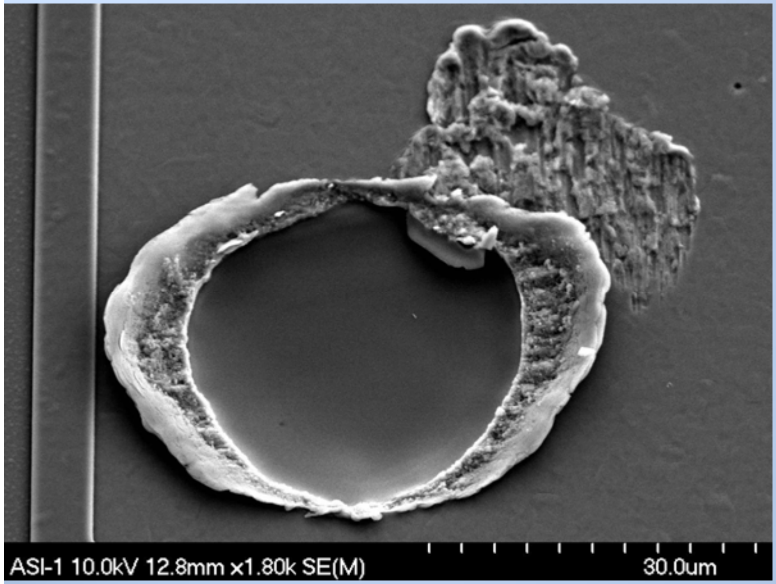


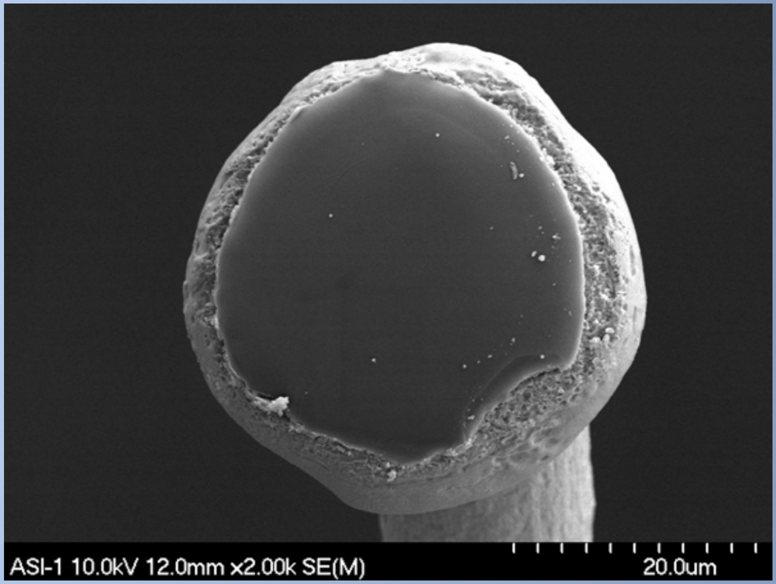


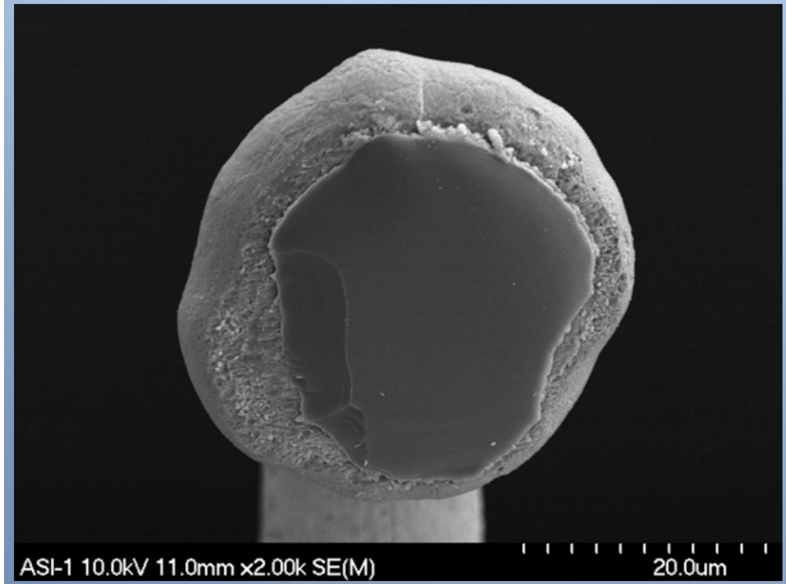


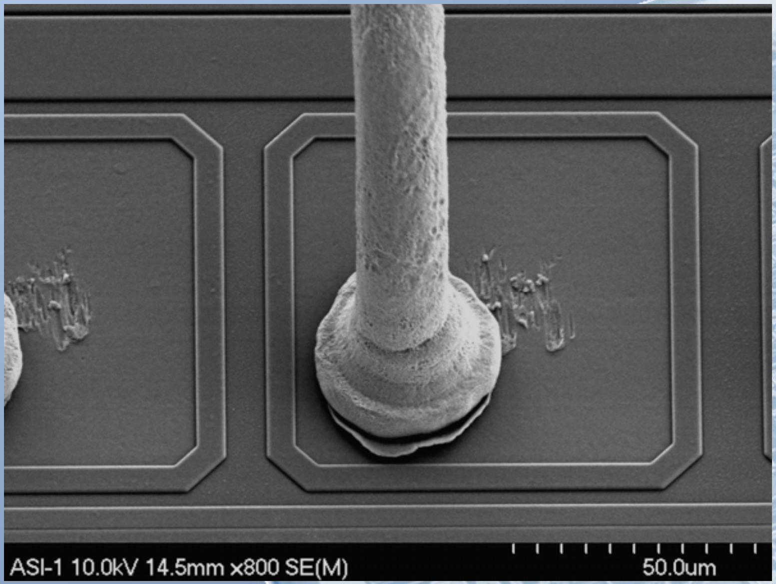


Seen at DPA: Low bond force (1.5gm) / Lifted pad and silicon





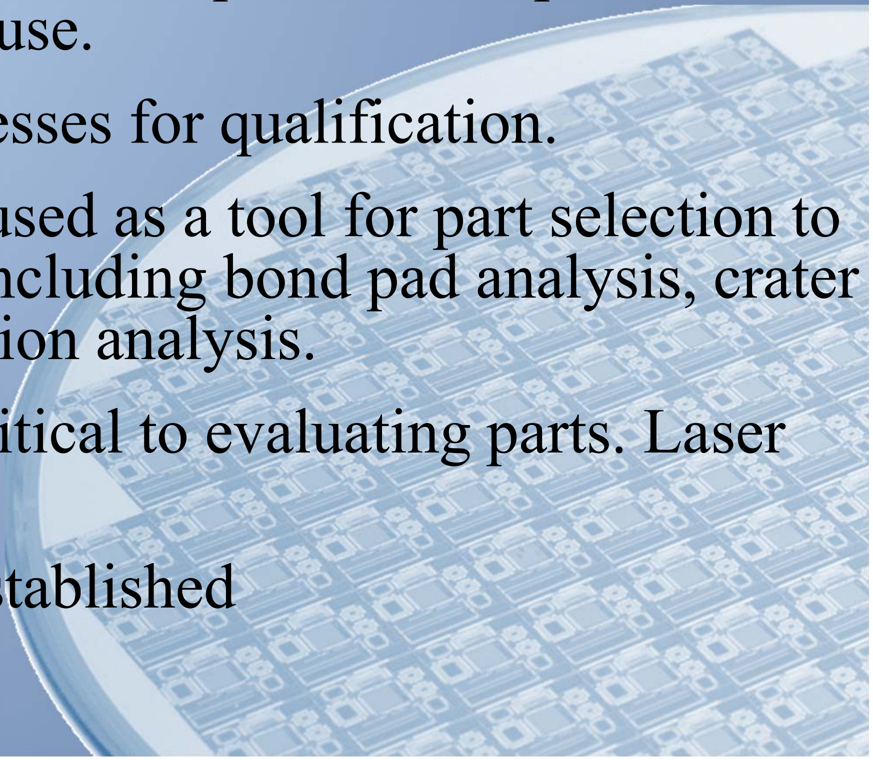




Industry Trends The Way We Are Seeing It

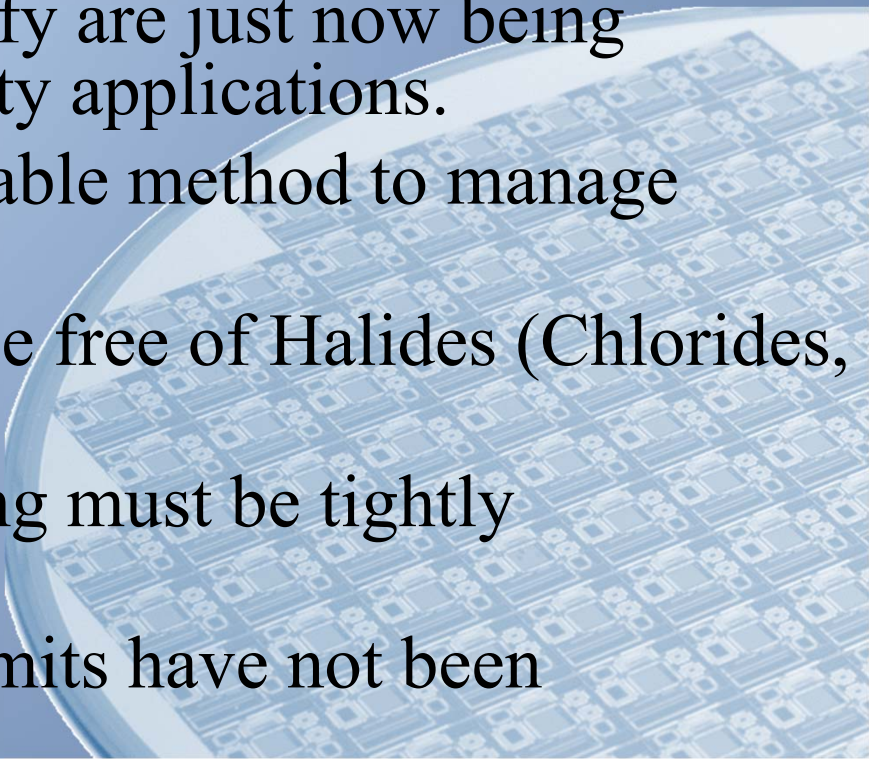
Cu Bond Wire – Integra's Work and Assessment

- Industry learning about Cu wire bonds and how to mitigate risk
- Some industry qualifications plans have now been released but not a lot of sequential testing
- Need for a risk mitigation plan that includes a list of acceptable manufacturers, device quality levels and qualification plans that are relevant to the application of use.
- Recommend using sequential stresses for qualification.
- Construction analysis should be used as a tool for part selection to look at the overall bond system including bond pad analysis, crater bond evaluation and bond formation analysis.
- Successful de-encapsulation is critical to evaluating parts. Laser ablation process is a must
- Bond pull limits have not been established

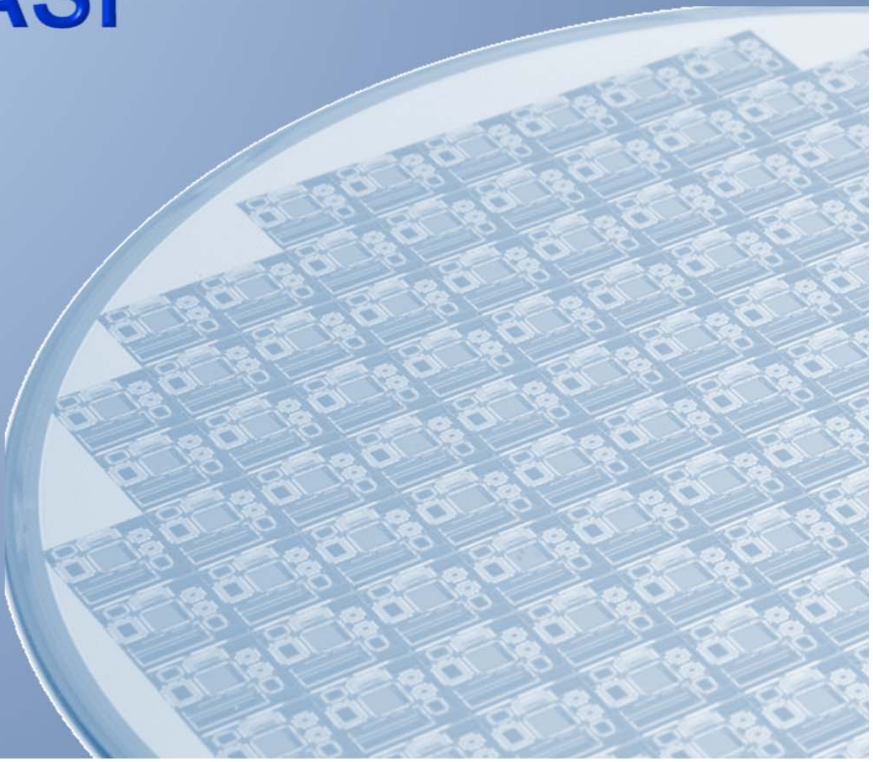


Cu Bond Wire for High Reliability Applications

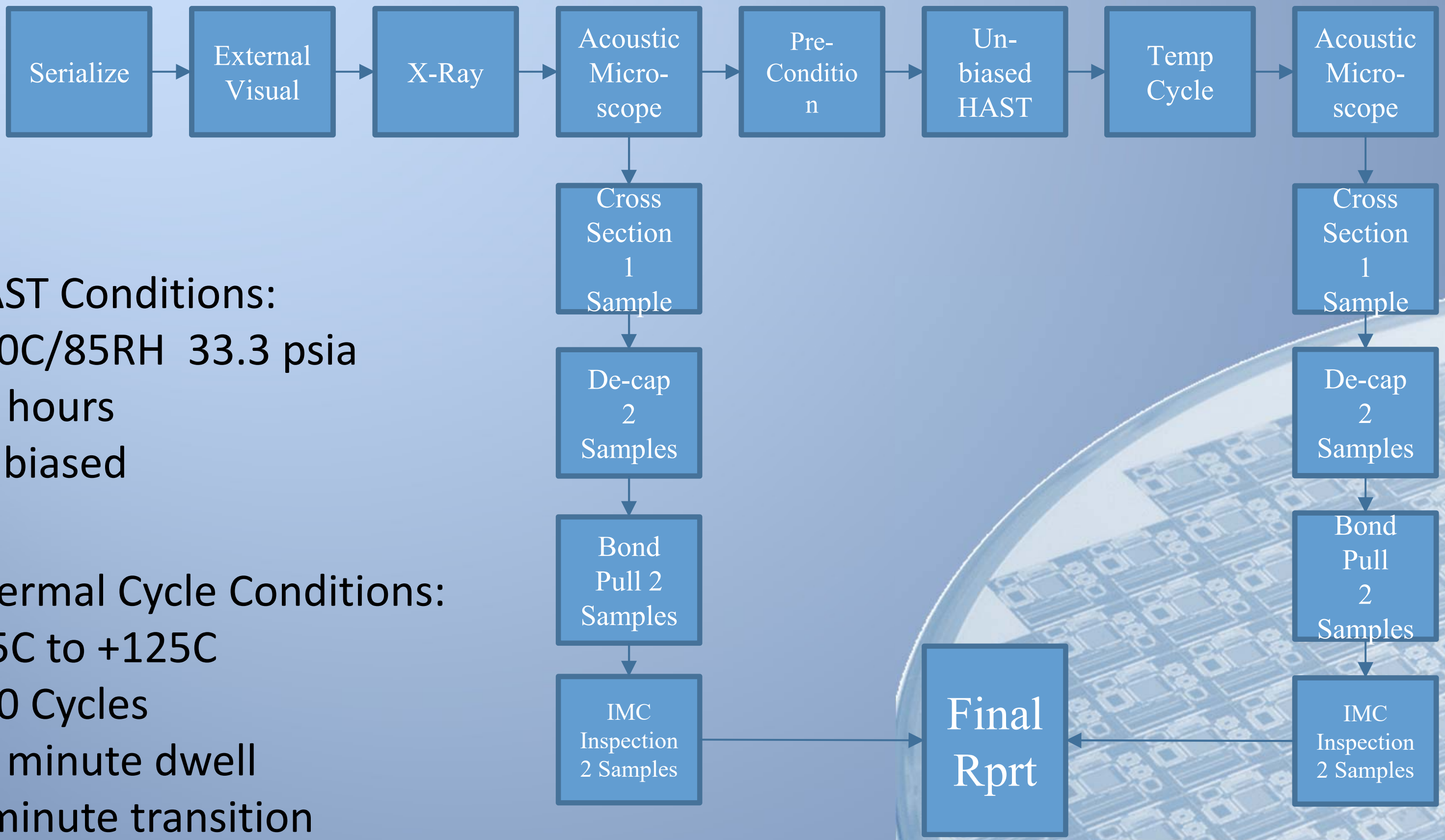
- Copper wire bonds are not well understood by users.
- Failure modes and frequency of failure can be different than devices utilizing other bond material.
- Processes to evaluate/qualify are just now being addressed for high reliability applications.
- PCNs are not always a reliable method to manage transitioning part numbers.
- Molding compound must be free of Halides (Chlorides, Bromide, Fluoride).
- Process window for bonding must be tightly controlled.
- Bond pull and ball shear limits have not been established.



Cu Bond Wire Study at Integra and ASI



Process Flow for Phase 1 Unbiased HAST



Serialize

External Visual

X-Ray

Acoustic Micro-scope

Pre-Condition

Un-biased HAST

Temp Cycle

Acoustic Micro-scope

Cross Section 1 Sample

De-cap 2 Samples

Bond Pull 2 Samples

IMC Inspection 2 Samples

Cross Section 1 Sample

De-cap 2 Samples

Bond Pull 2 Samples

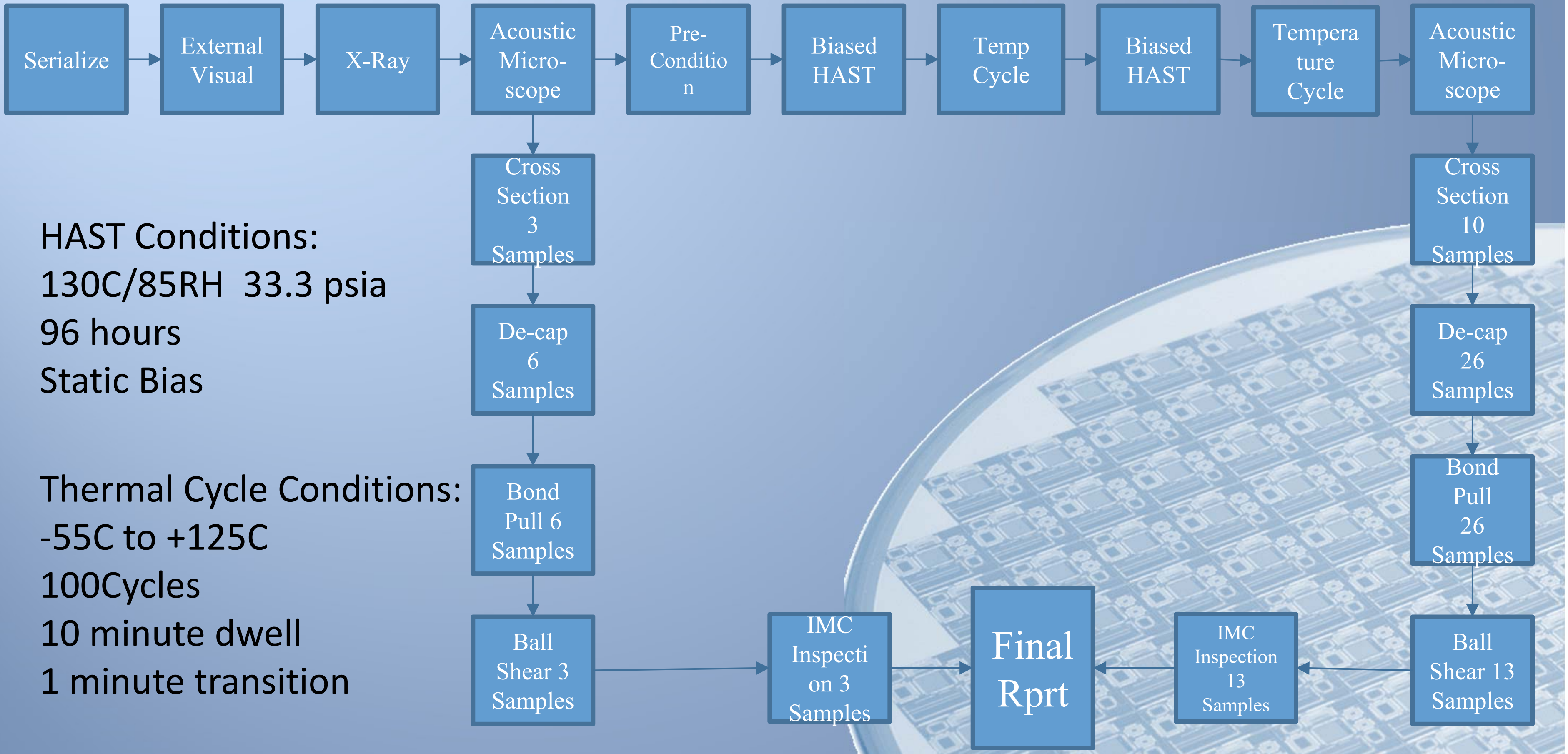
IMC Inspection 2 Samples

Final Rprt

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
Biased HAST



Serialize

External Visual

X-Ray

Acoustic Microscope

Pre-Condition

Biased HAST

Temp Cycle

Biased HAST

Temperature Cycle

Acoustic Microscope

Cross Section 3 Samples

De-cap 6 Samples

Bond Pull 6 Samples

Ball Shear 3 Samples

IMC Inspection 3 Samples

Final Rprt

IMC Inspection 13 Samples

Ball Shear 13 Samples

Bond Pull 26 Samples

De-cap 26 Samples

Cross Section 10 Samples

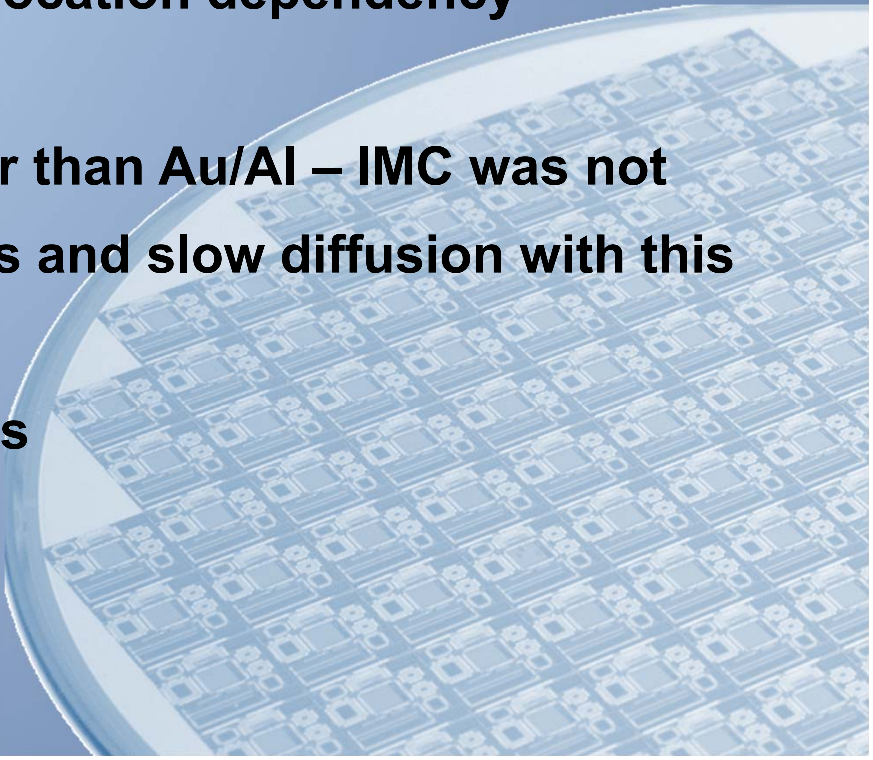
HAST Conditions:
130C/85RH 33.3 psia
96 hours
Static Bias

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

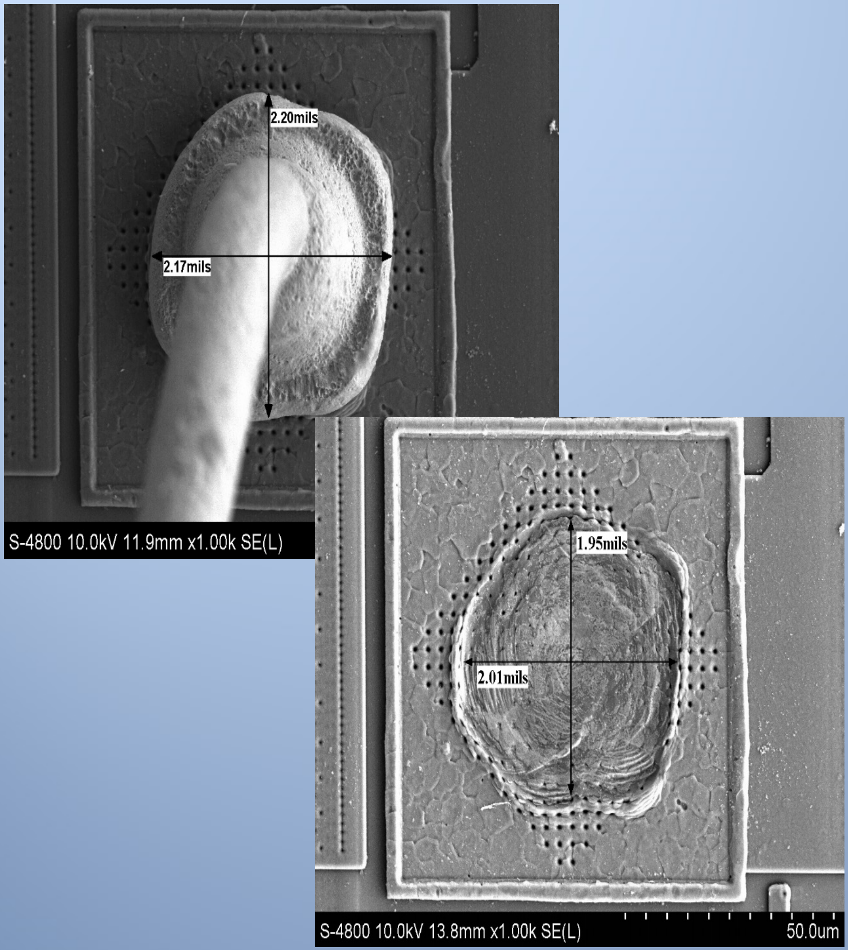
Summary

With limited data on sample sizes and stress level:

1. **IMC was found to be 6% greater pre to post stress (unbiased) and 15% with biased HAST**
1. **Aluminum Splash was observed**
2. **Bond lifting was observed with location dependency**
3. **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**



IMC Inspection Etched

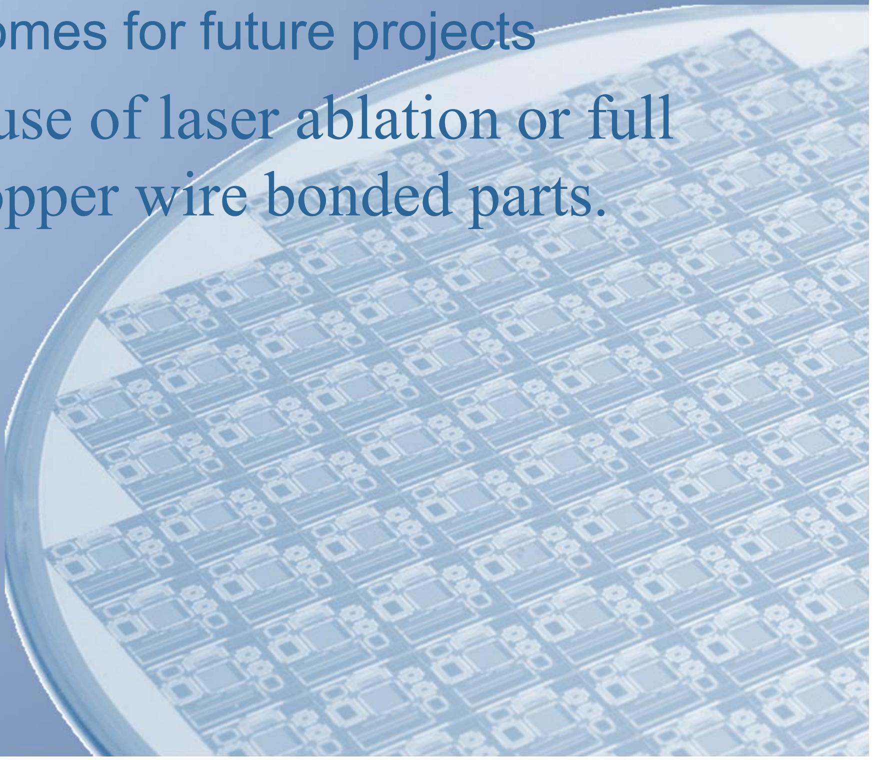


- Method used to remove copper wire bonds was a proprietary process developed at Analytical Solutions.
- Exposure time of the etch varied between 1 and 5 seconds.
- Not all bonds were removed but greater than 80% of bonds removed from each device.
- Area of intermetallic in relation to the ball bond was compared between pre and post stress and was determined to be between 2% and 15% greater on post stress devices.

Copper Wire Bond De-Encapsulation

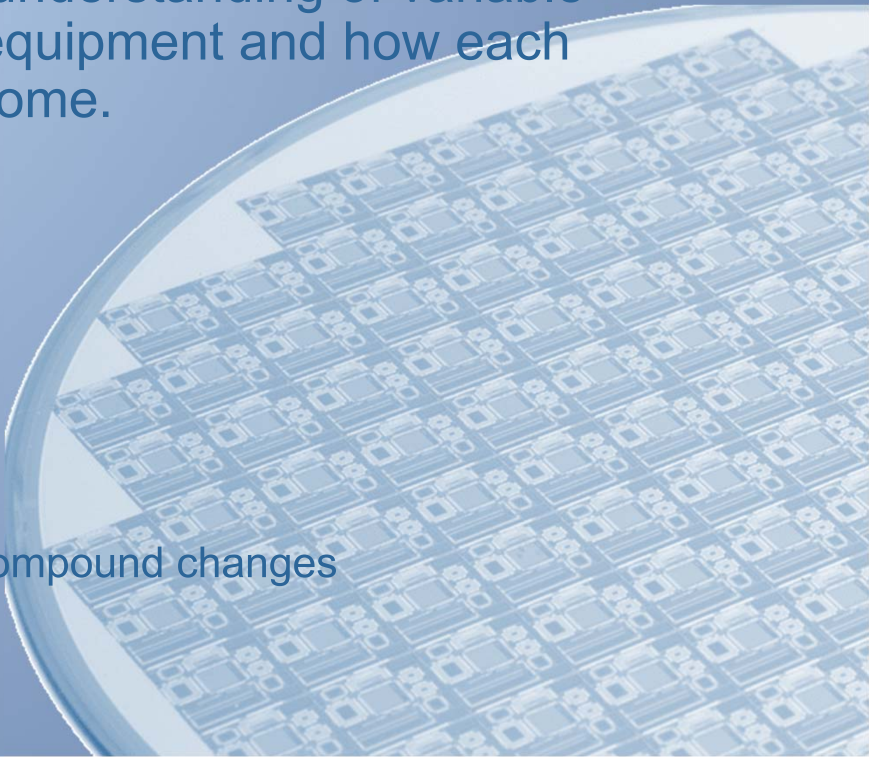
Purpose

- Provide update on laser ablation capability
- 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 Decap Process at ASI

- Equipment: Control Laser FALIT
- Laser de-encapsulation process was developed from scratch
  - Phase 1 – Compare and contrast laser ablation/chemical de-encapsulation with full chemical de-encapsulation.
  - Phase 2 – Develop a complete understanding of variable settings with the laser ablation equipment and how each variable can affect the final outcome.
    - Equipment Variables
      - Power
      - Q
      - Duty Cycle
      - Raster Rate
    - Device Variable
      - Mold Compound (Ongoing)
      - Pre vs post environment mold compound changes



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 (No Environmental Stress)

Obtain Devices

Mount Devices

Bake Devices

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

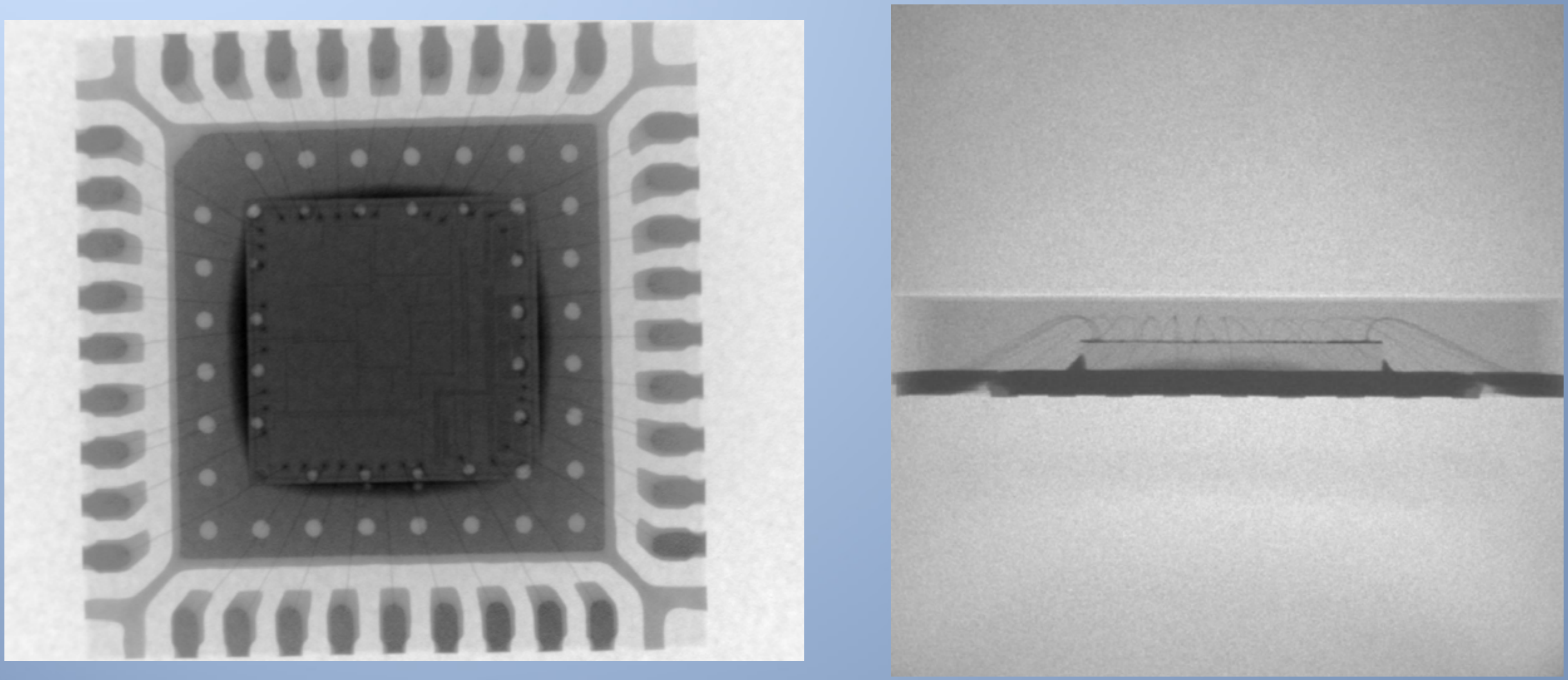
Device Information

- Part Number: Device Type 1
- 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.

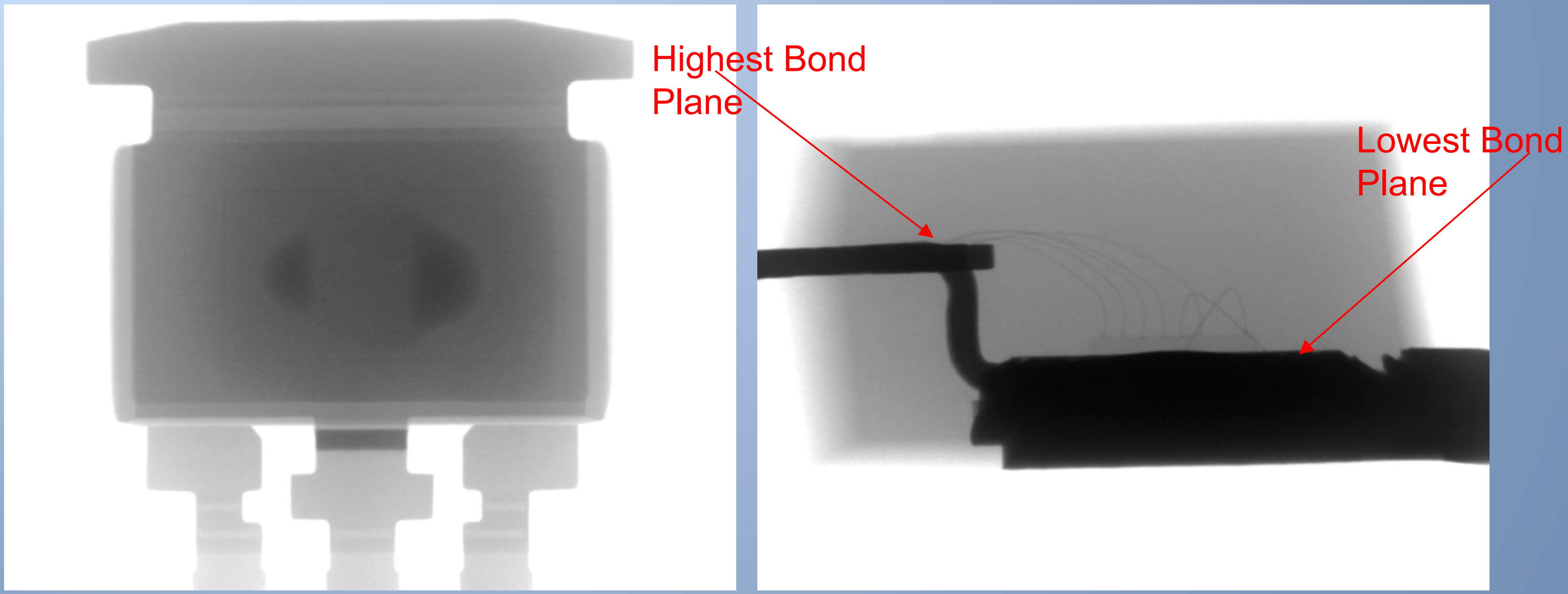
Device Information

- Part Number: Device Type 1
- 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.

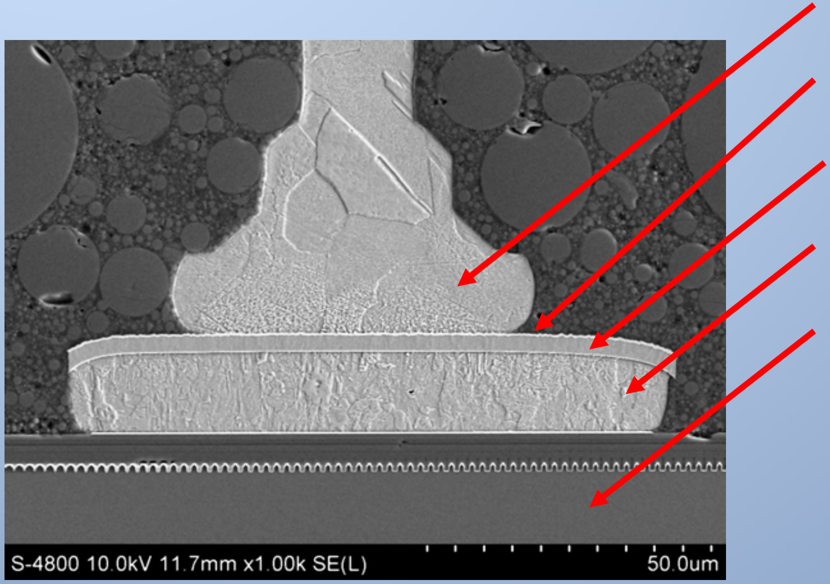
X-Ray image of a typical Device (Device Type 1)



X-Ray image of a typical Device (Device Type 2)

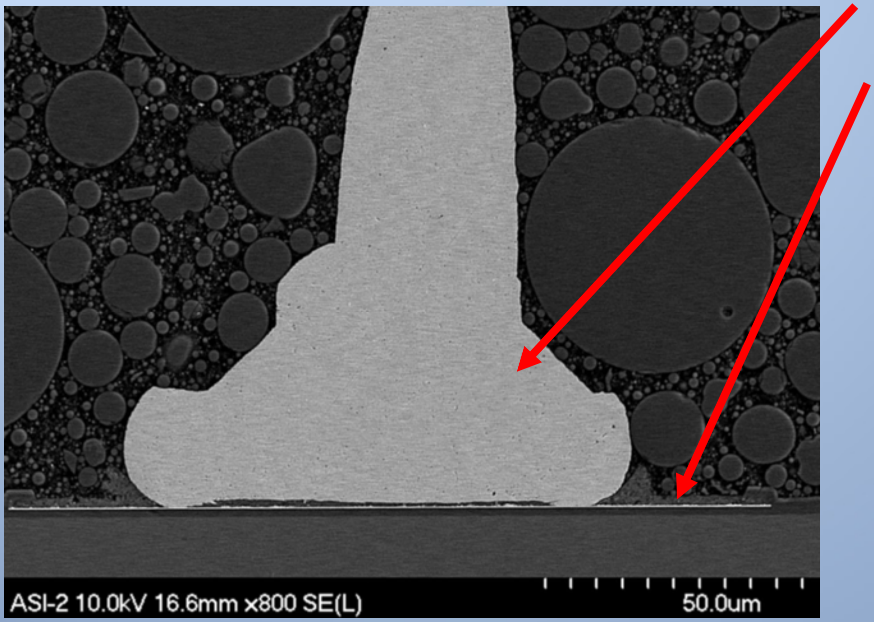


Bond Stack on Die(Device Type 1)



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

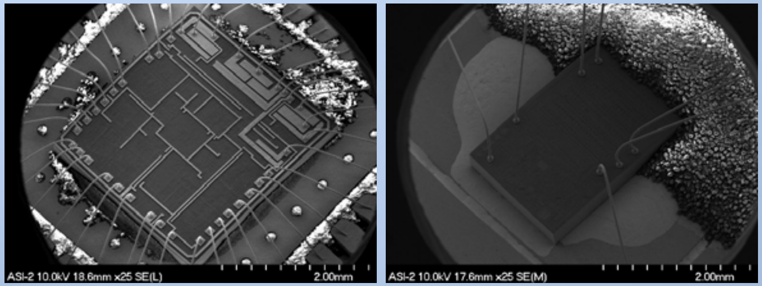
Bond Stack on Die(Device Type 2)



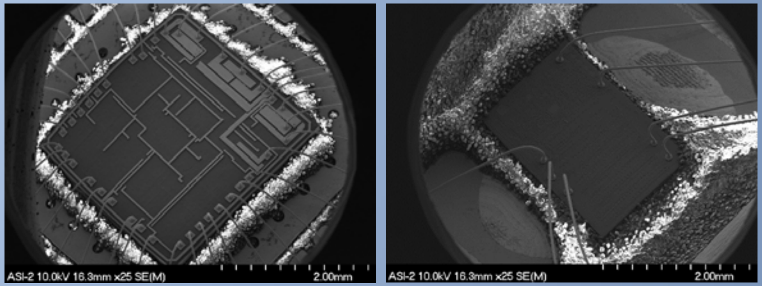
- Copper Bond Wire
- Aluminum Bond Pad

Executive Summary Phase 1

Full Chemical De-encapsulation



Laser/Chemical De-encapsulation

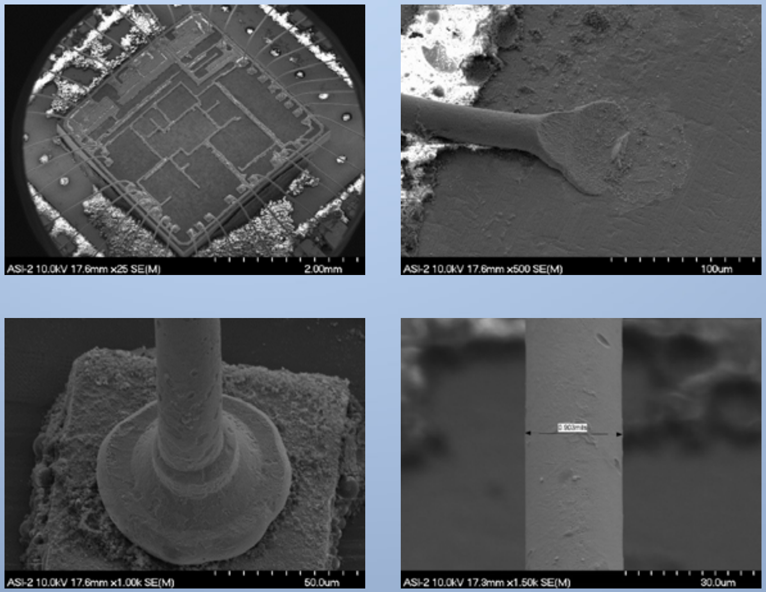


- Both methods yielded similar values for maximum and average bond pull
- Laser/Chemical process improved minimum bond pulls
- Both methods must be tightly controlled to avoid damage to the devices
- Laser/Chemical process is more automated reducing variability

	Device Type 1H	Device Type 2
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

	Device Type 1H	Device Type 2
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

Full Chemical De-encapsulation (Continued)



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

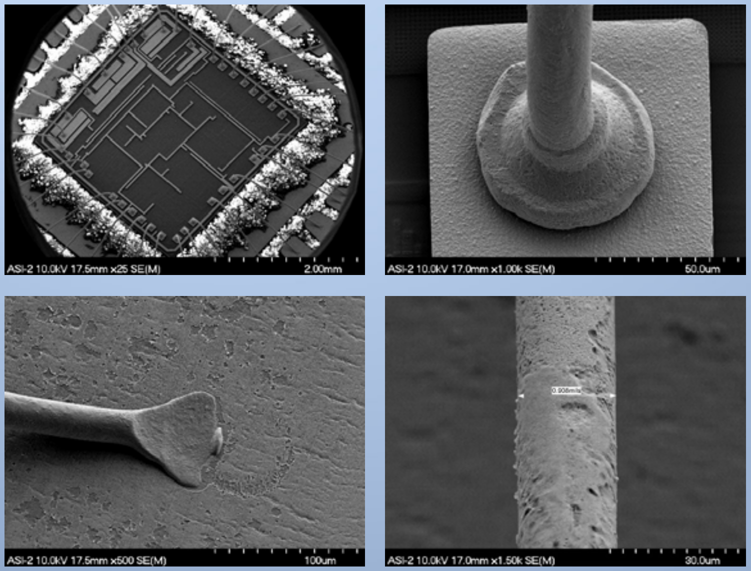
Laser/Chemical

- Device Type 1
- 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.

Laser/Chemical De-encapsulation (Continued)

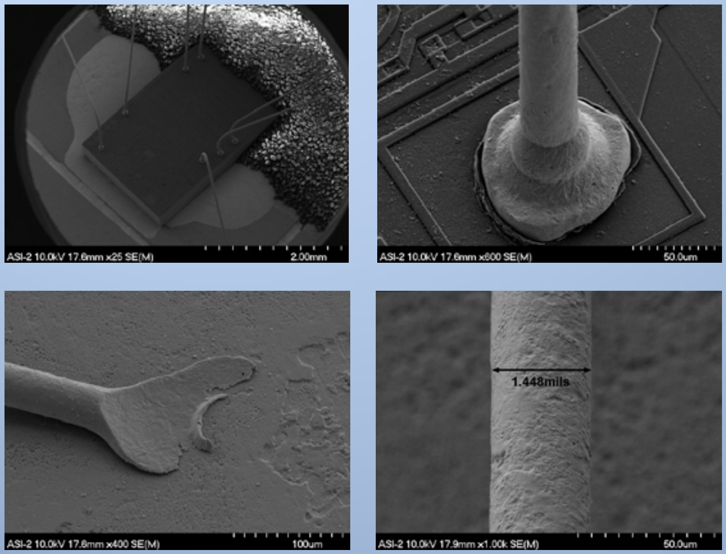


- Device Type 1
- Wire Size Data Post De-encapsulation.

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.

Full Chemical De-encapsulation (Continued)



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

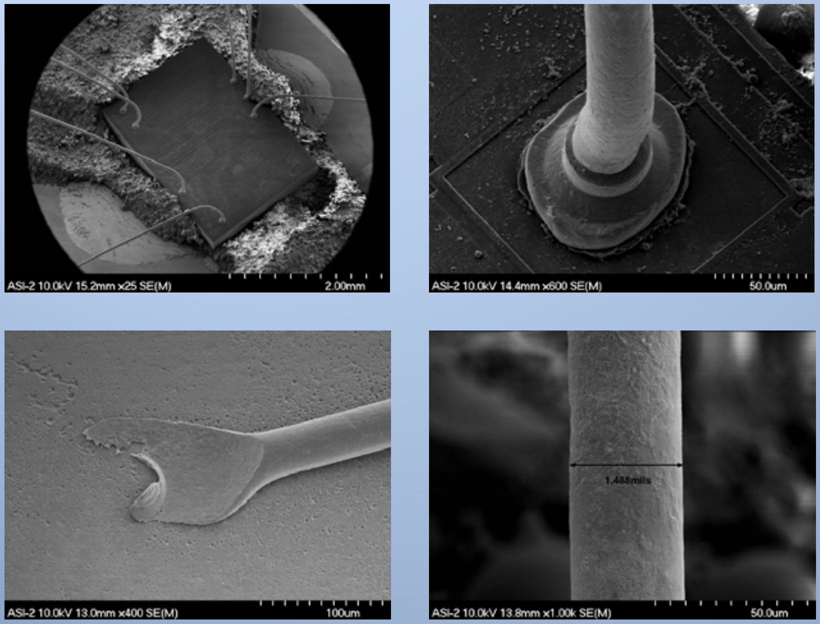
Laser/Chemical

- Device Type 2
- Wire Size Data Post De-encapsulation.

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

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

Laser/Chemical De-encapsulation (Continued)

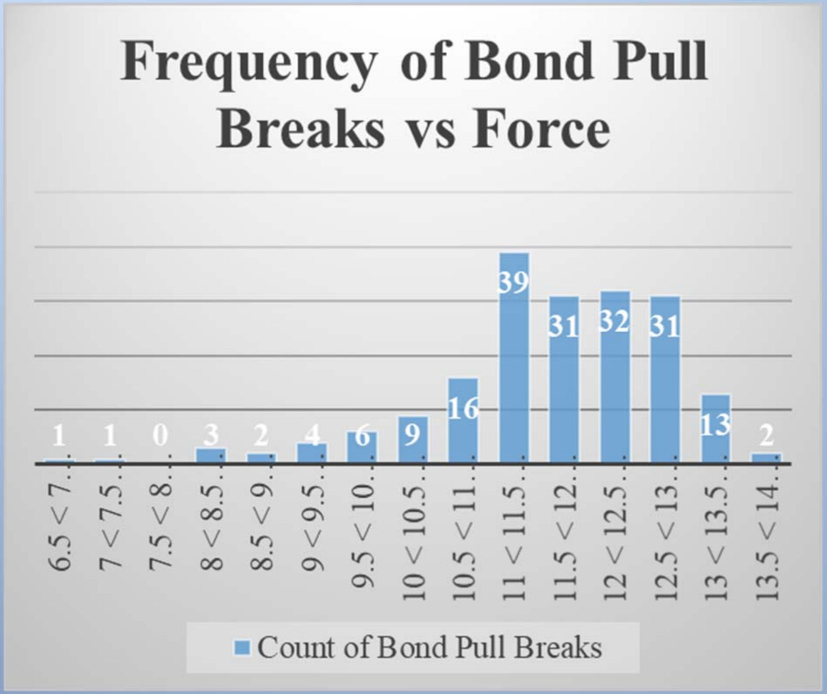


- Device Type 2
- Wire Size Data Post De-encapsulation.

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

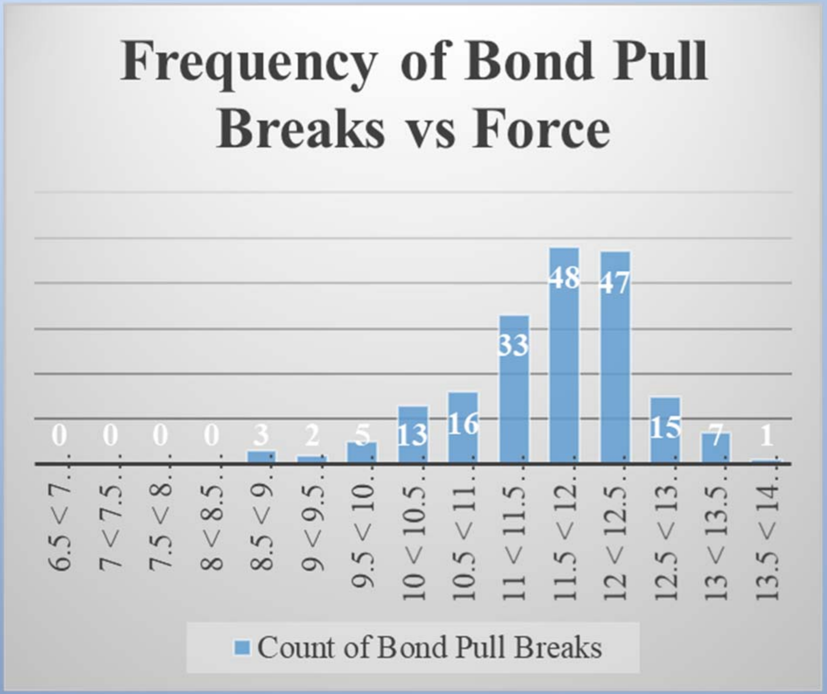
- No lifted bonds were observed on either side of the wire.

Full Chemical De-encapsulation (Device Type 1)



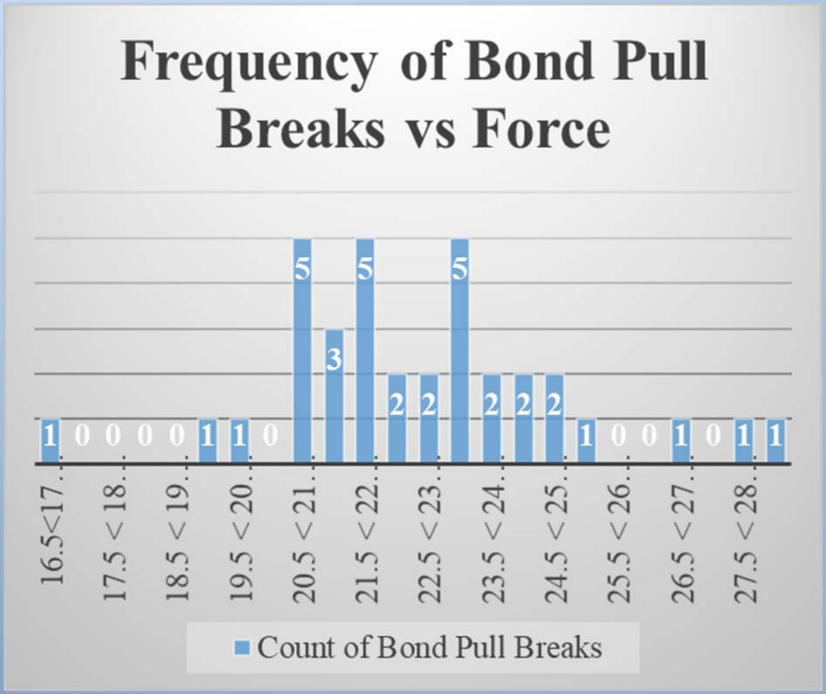
Total Wire Bond Count:	190
Minimum wire pull strength:	6.9672
Maximum wire pull strength:	13.8559
Average wire pull strength:	11.60943
Standard Deviation:	1.169049

Laser/Chemical De-encapsulation (Device Type 1)



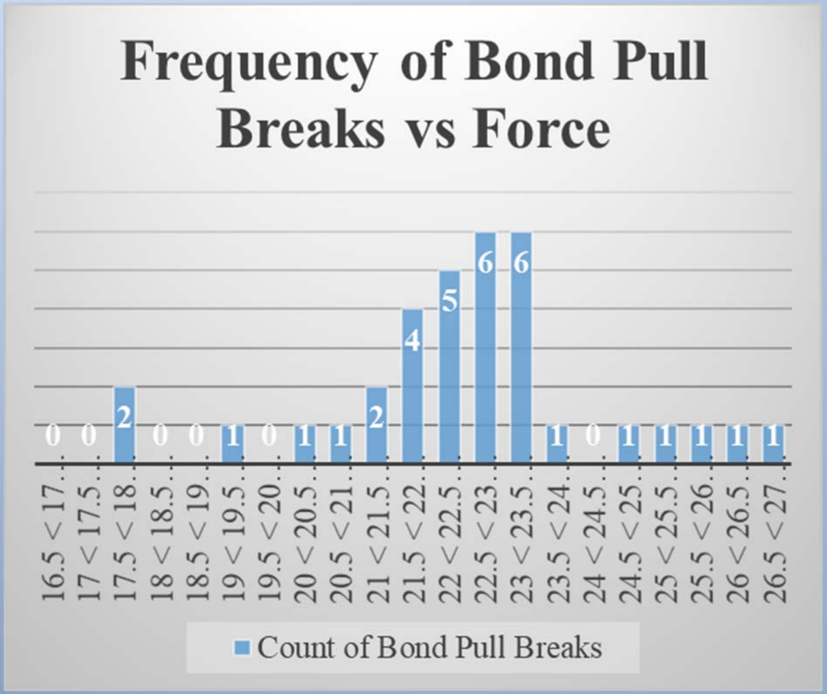
Total Wire Bond Count:	190
Minimum wire pull strength:	8.6953
Maximum wire pull strength:	13.773
Average wire pull strength:	11.627
Standard Deviation:	0.903

Full Chemical De-encapsulation (Device Type 2)



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

Laser/Chemical De-encapsulation (Device Type 2)



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

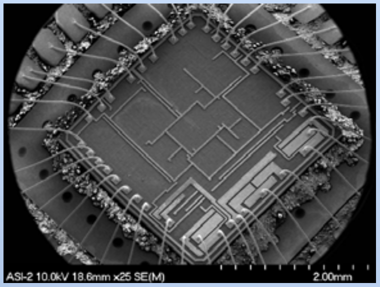
Phase 2 (With Environmental Stress)

- 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

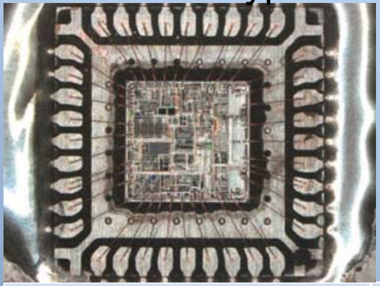
Purpose of Phase 2

- 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

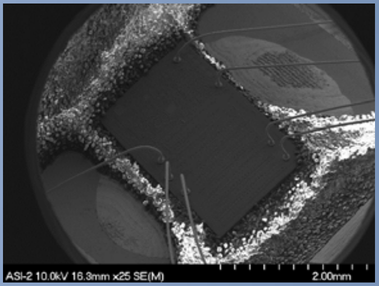
Executive Summary Phase 2



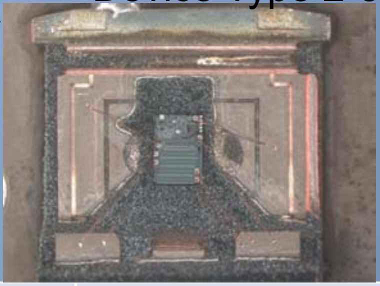
Device Type 1H



- 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 Device Type 2-3.3 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 Device Type 2-3.3 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 Device Type 1H cratered resulting in a low bond pull break.
- **No low bond pull breaks were attributed to de-encapsulation quality.**



Device Type 2-3.3

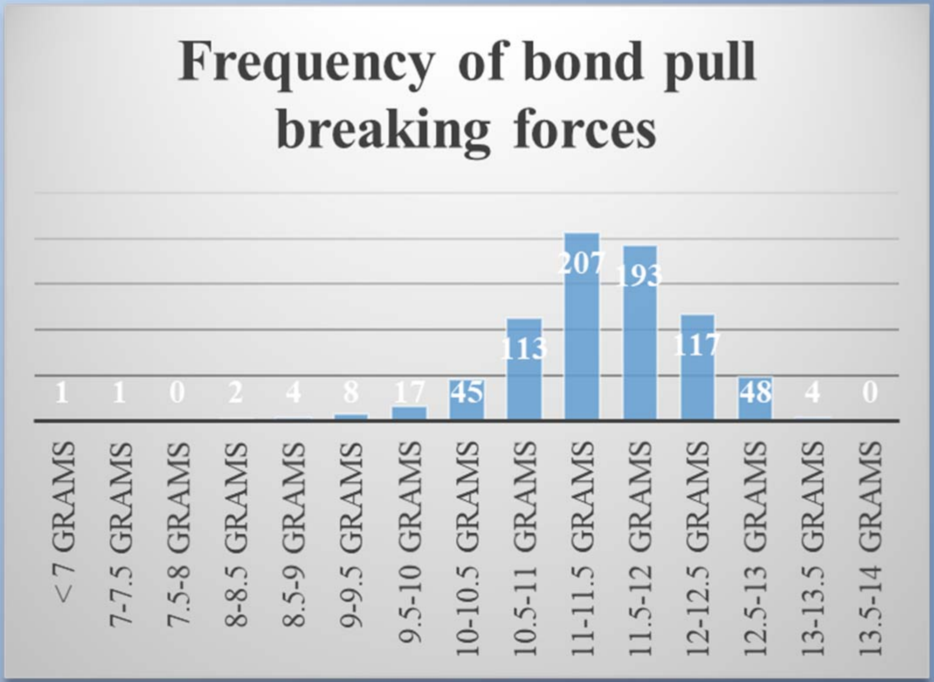


	Device Type 1H Midpoint	Device Type 1H Endpoint	Device Type 2-3.3 Midpoint	Device Type 2-3.3 Endpoint
Total Wire Bond Count:	760	760	140	126
Minimum wire pull strength:	6.64 grams	.12 grams	5.92 grams	0.00 grams
Maximum wire pull strength:	13.07 grams	13.23 grams	32.45 grams	30.77 grams
Average wire 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

Endpoint de-encapsulation and wire pull

- Device Type 1
- Bond Pull Data:

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

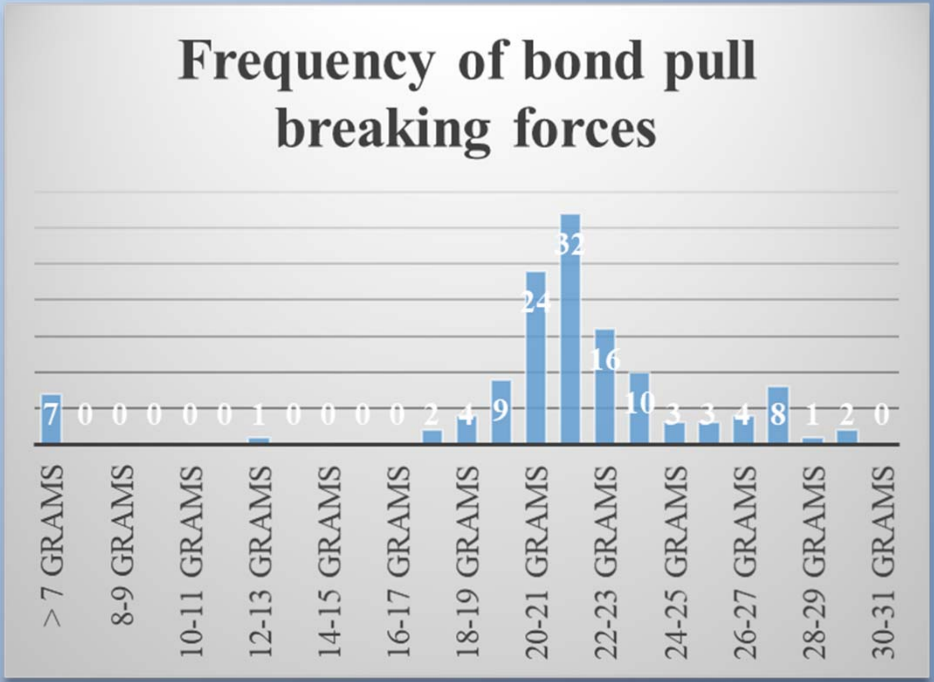


Endpoint de-encapsulation and wire pull

- Device Type 2
- 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.



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