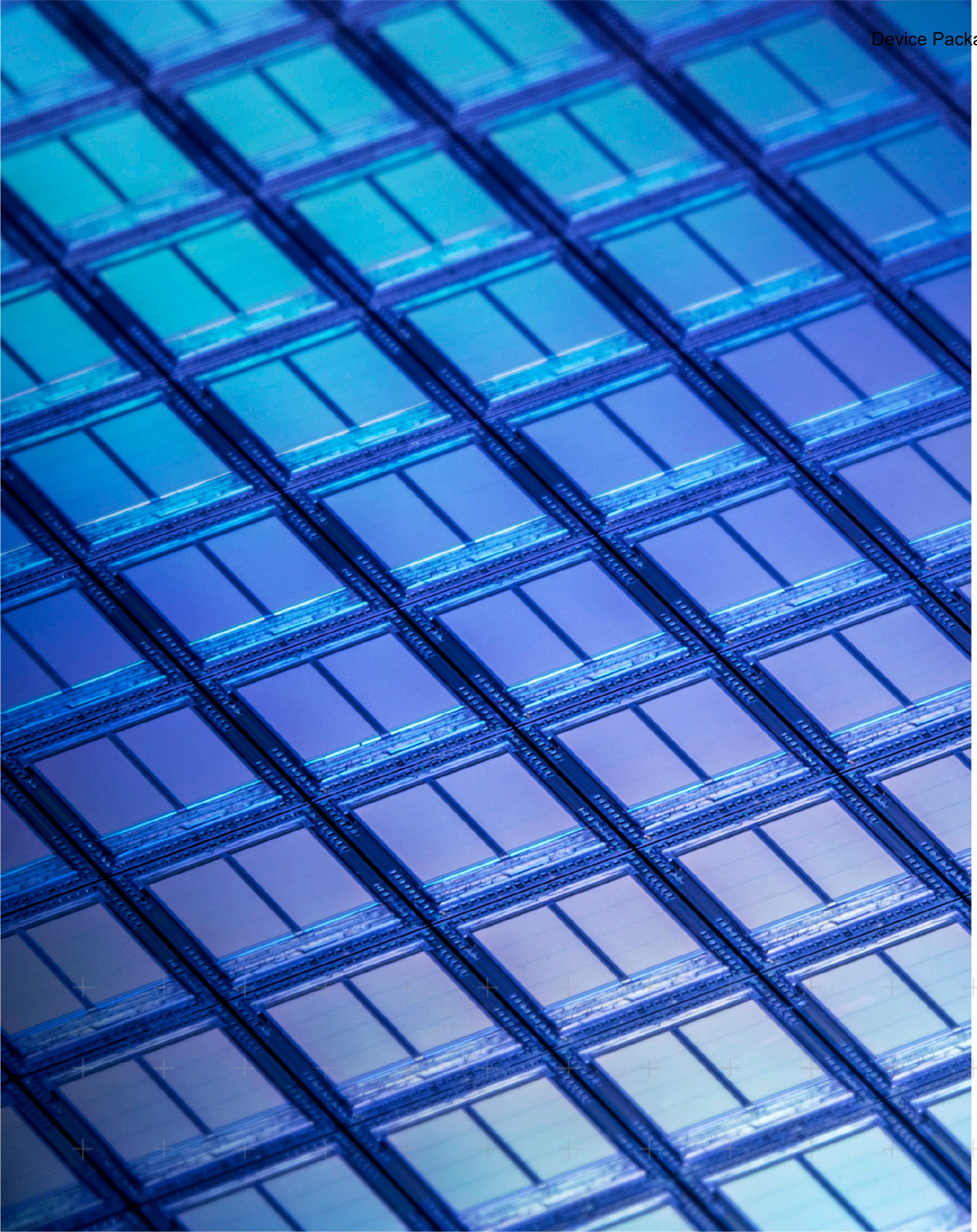

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Analysis and Management of the Effects of Fluorinated Gases during Plasma Dicing

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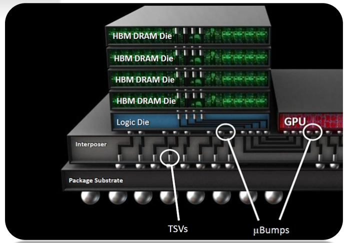
April 2020

Analysis and Management of the Effects of Fluorinated Gases during Plasma Dicing

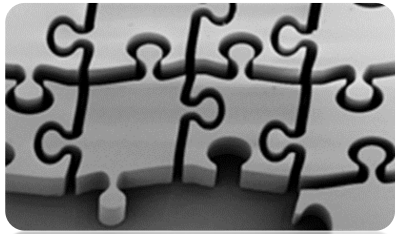
- Introduction
  - Plasma dicing benefits
  - Integration
- Coatings and post plasma treatment
- Wirebonding evaluation
- Conclusions

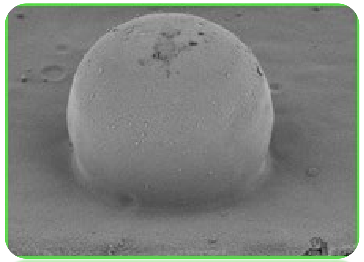
Introduction

- Rate of plasma dicing (PD) adoption continues to build momentum
  - Key benefits of plasma being applied across device spectrum
  - Small RFID chips through to D2W Hybrid Bonding schemes for HBM

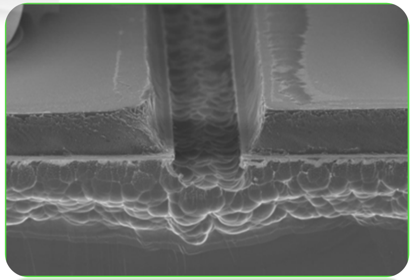


- Barriers to adoption have been removed, one by one…
  - Handling of framed substrates
  - Process Integration
  - Patterning of thinned wafers



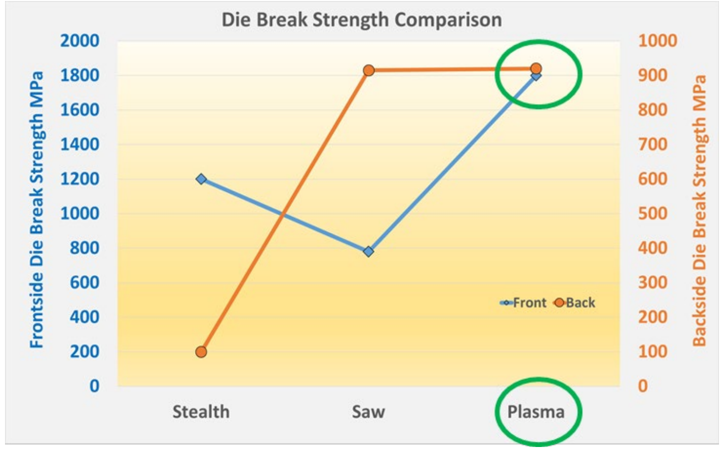


- The final barrier has now also been removed
  - PD uses Fluorine based chemistry for Si etch
  - Solutions are now available that remove any risk that F* poses
  - Compatible with Al Bondpads, solder bumps, etc



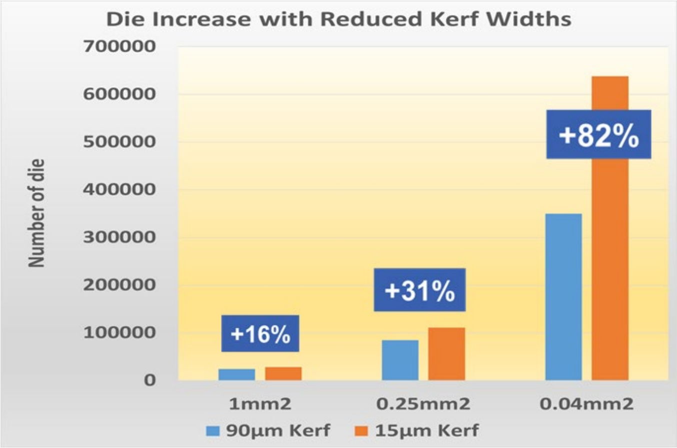
Benefits of Plasma Dicing

No Damage = Increased Die Strength



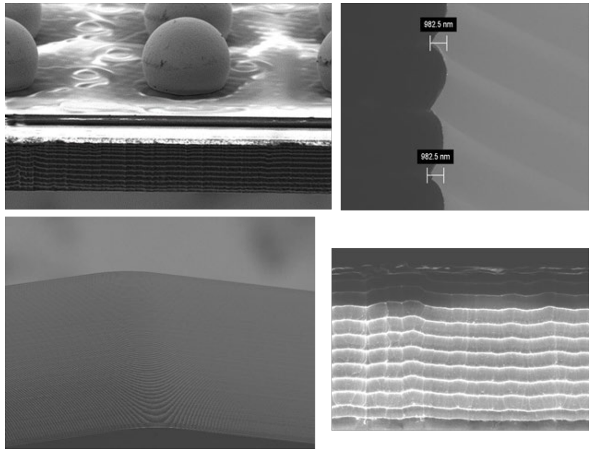
- Chemical etching of material
- Process control protects substrate
- Compatible with <50µm wafers
- MEMS, D2W bonding applications

Reduced Kerf = More die per wafer



- Releases wafer real estate for product
- Can remove/reduce seal ring areas
- Significant gains for smaller die
- Particularly effective for RFID, TVS die

Particle Management



- Chemical etch does not create particles
- All by-products are pumped away
  - During etch, cleans or post-treatment
- Critical for successful void-free bonding

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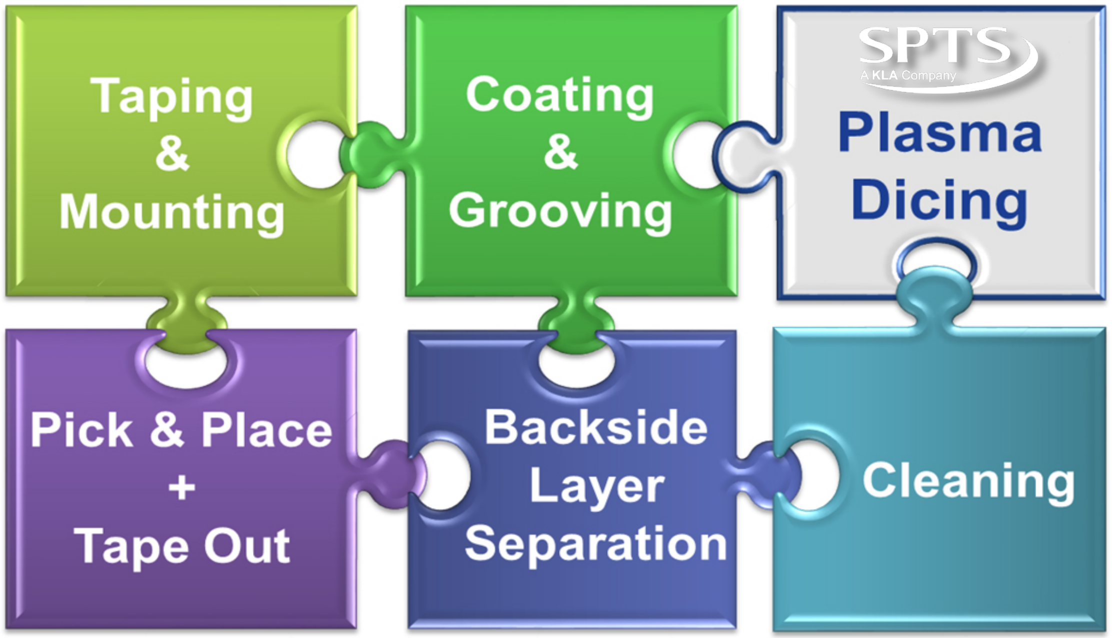
Integration is Key for successful PD adoption

- **Plasma Dicing step cannot be considered in isolation**



Off-The-Shelf tapes from leading vendors characterised

Working with all groove options used by customers

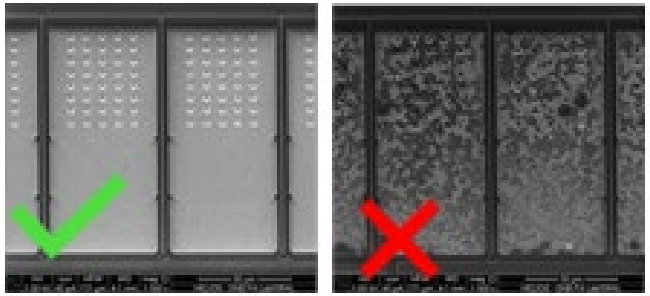
Collaborating on coating developments

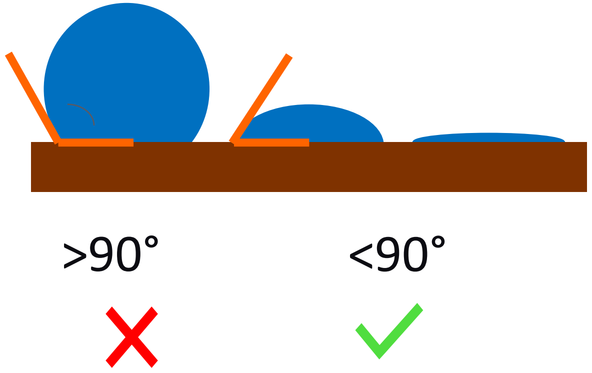
- Collaborations & co-working across back-end community is critical for successful integration
  - Tapes : Characterisation of tape behaviour under plasma etch conditions; Close co-operation with Lintec
  - Patterning options: Including Photo, FE Flow, LASER Coating/Grooving
  - Post-etch treatments for final cleanliness: **Development of Defluorination solutions**

Coatings and Post-plasma Treatment Trials

F risks

- Residual F on Al bond pads can result in
  - Corrosion
  - Changes in wettability
  - Wire bond/packaging reliability issues
    - NSOP
    - NSB
    - Metal peel off

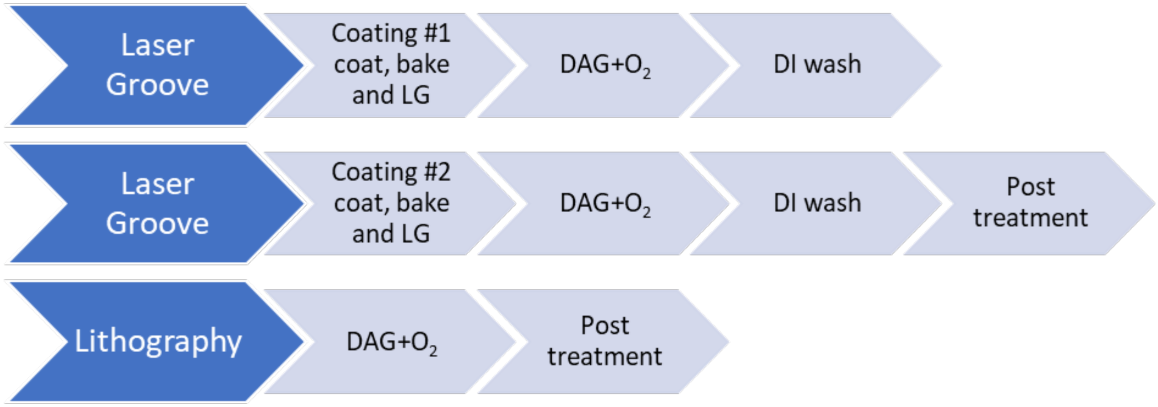




- F present as a result of plasma dicing process
  - C_xF_y (PTFE-like) polymer left of surface and die sidewall
- F can be removed by
  - Post treatment
    - Wet etch
    - Dry etch (Ar sputter)
  - Protection of pads from F during the plasma processing step

Plasma dicing integration schemes

- Depending upon integration scheme, different treatments can be used



- In laser grooving, a coating is used as standard
  - To catch debris from ablated material
  - Trap dust
- Water soluble and washed after grooving process
- In laser groove + plasma dicing, mask has two purposes
  - Protect bond pad
  - Acts as mask for plasma dicing

Coating investigation: Suitability for plasma dicing

- Different coatings were tests for suitability for plasma dicing
  - Selectivity
  - F blocking properties
  - Response to laser
  - Removal post processing
- Coating #1 demonstrated good results

Property	LG industry standard	Coating #1	Coating #2	PR Reference
Selectivity main silicon plasma dicing etch	250:1	1000:1	200:1	1000:1
LASER response	Medium	Excellent	Excellent	Not tested
Adhesion (to Si)	Moderate	High	High	Not tested
Coating removal DI wash	OK	OK	OK	Not Water Soluble
Direct Fluorine Penetration Peel Test F:O	Yes 4.35	No 0.07	Yes 2.09	Not tested

Process Tests

- A series of process splits were carried out to determine the optimum process scheme for F removal
  - Coating#1 gave low F:O with no treatment
  - Coating#2 gave low F:O with a post plasma dicing treatment

Test	EDX measurement At%				
	C	N	O	F	F/O Ratio EDX
Reference (no treatment) M10-24-3-20	15.8	22	57.1	5.2	0.09
Coating#1 no post treatment	35.64	12.42	46.63	5.31	0.11
Coasting#2 no post treatment	16.67	4.61	55.33	23.39	0.42
Coating#2 5min O_2 post treatment	23.74	2.25	69.31	4.7	0.07
Coating#2 Ar sputter + O_2 flash post treatment	49.5	3.7	40	6.9	0.17

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Process Tests: Correlation XPS

- A subset of the tests were cross correlated with XPS
  - EDX 1.5kV to increase surface sensitivity
- Good correlation been data sets
- Specification F:O <0.15 achieved
  - Same specification as used for blade dicing

Test	EDX measurement At%					XPS measurement At%				
	C	N	O	F	F/O Ratio EDX	C	N	O	F	F/O Ratio XPS
Reference (no treatment) M10-24-3-20	15.8	22	57.1	5.2	0.09	35.77	-	40.97	2.64	0.06
M10-21-1-20 LG coating #1	36.1	11.6	47.3	4.9	0.1	54.3	-	36	2	0.06
M10-21-1-20 LG coating #2+PT Ar O2 flash	49.5	3.7	40	6.9	0.17	52.5	-	34.9	5.2	0.15

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Reliability Trials

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Conditions and Test Method for Wire Bonding Reliability

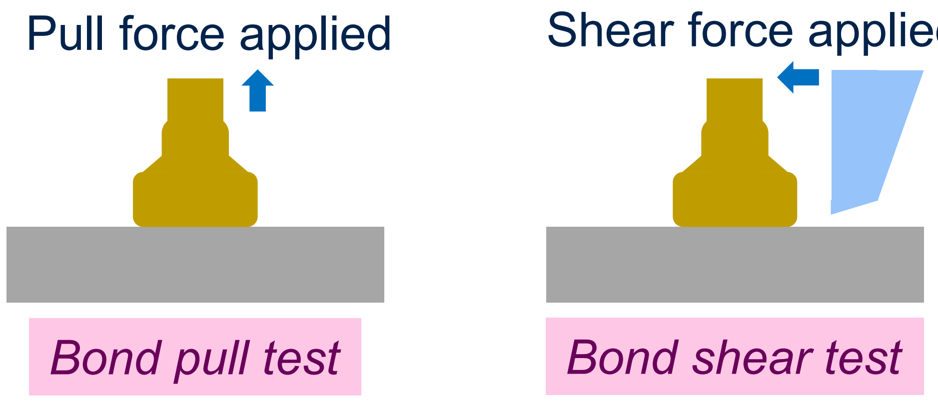
Wire bonding conditions

- 0.8 mil CuPd wire bonded to Aluminum Pad
- Wire bonding performed with thermosonic method as downward force applied to attach ball to pad
- Variables used for bonding trial
  - force (g)
  - ultrasonic energy (current, mA)
- Conditions based on production specification limits

WB Leg	Force	Ultrasonic Energy
LL-10%	LSL - 10%	LSL - 10%
LL	LSL	LSL
NN	Centre	Centre
HH	HSL	HSL
HH+10%	HSL + 10%	HSL + 10%
LH	LSL	HSL
HL	HSL	LSL

LSL: Low specification limit
HSL: High specification limit

Industry typical wire bond pull and shear test method



Reliability Test Conditions

- Initial tests performed directly after bonding (T0)
- Accelerated aging conditions applied before retest

Condition		Temperature	R.H.	Time
High Temperature Stress	Intermediate	175°C	-	108 hrs
	Final	175°C	-	217 hrs
Temperature Humidity Stress	Final	85°C	85%	24 hrs

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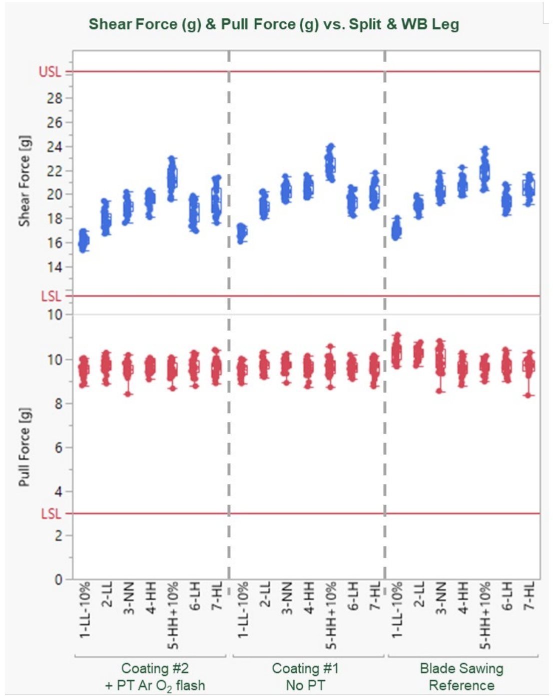
Initial Data After Wire Bonding (T0)



Bond pull and shear forces measured and plotted

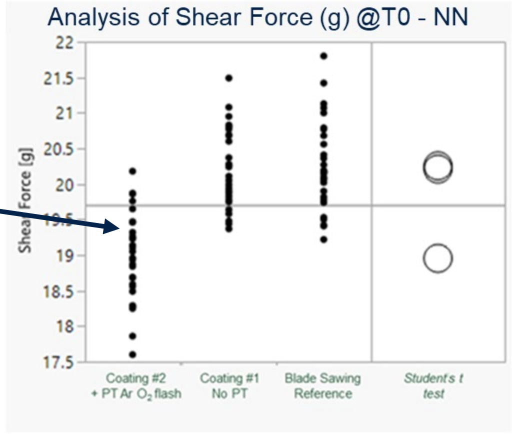
- By process split
- By wire bonding condition (leg)

Bond pull test

- No significant differences between process or WB leg
- Failure mode was 100% wire neck breakage, not bond related

Bond shear test

- More representative test of bond strength
- Typical variation between WB legs on all splits, including reference
- t-test used to determine statistically significant differences
- Example: NN leg showing that coating #2 with post-treatment exhibits lower shear force than coating #1 and the reference
- This statistical difference is confirmed for all WB legs



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High Temperature Stress Reliability @108hrs

Conditions: 175°C, dry bake

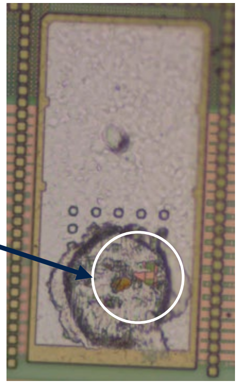
Bond pull test

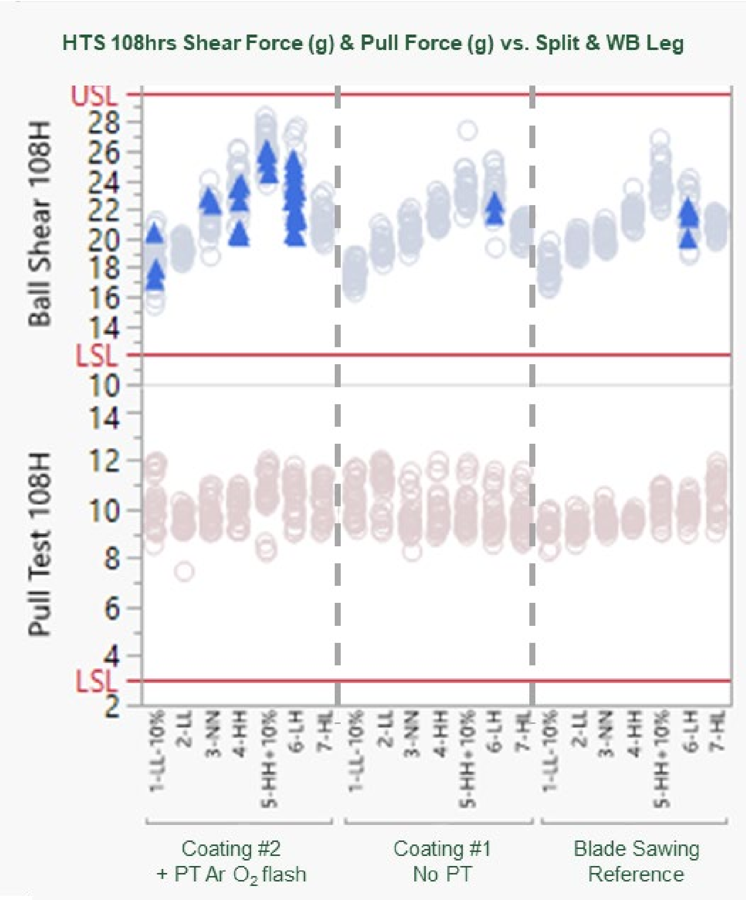
- No major differences observed after 1st stage HTS treatment
- Failure mode: Wire neck break on all samples

Bond shear test

- No large variations in mean force values
- No significant divergence of coating #1 split from reference samples
- Coating #2 with O2 flash process
  - Increase in dispersion of bond shear force values
  - Higher incidence of 'peeling' failure mode (shown by solid triangle in plot)

Example of peeling failure mode
Aluminum breaks from underlying layers





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High Temperature Stress Reliability @217hrs

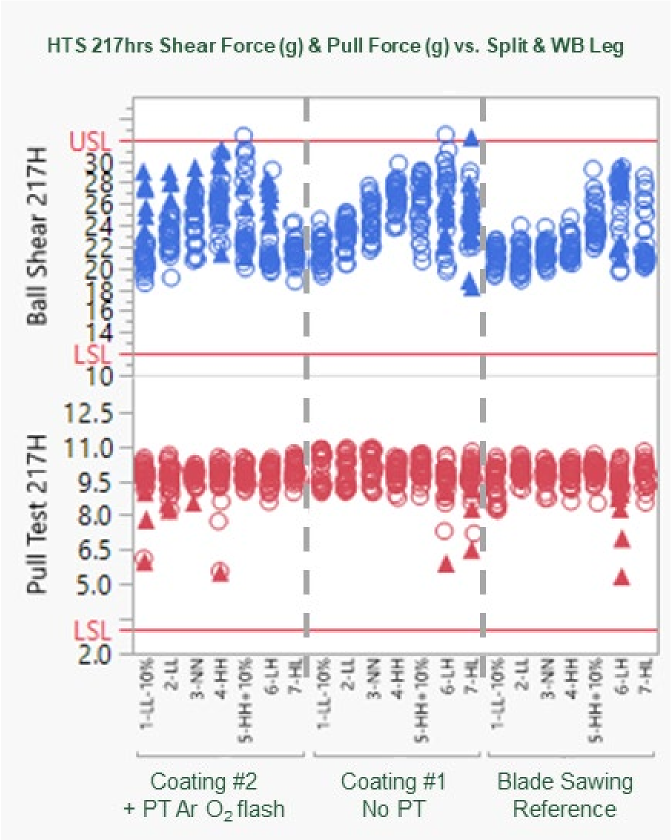
Conditions: 175°C, dry bake

Bond pull test

- Mean values aligned with reference for both splits
- Predominant failure mode: wire neck break
- Outliers mainly attributable to peeling failure mode after stress
  - 6/7 legs affected on coating #2 with O_2 flash sample
- All peeling observed to be small area, including reference samples

Bond shear test

- Overall higher mean values for all splits and reference
- Noticeable impact of stress on dispersion in bond shear force on all splits
  - Widest dispersion exhibited on samples of coating #2 with O_2 flash
- No failures observed for low bond shear force
- Significant increase in peeling failure mode for coating #2 with O_2 flash
  - Predominant failure mode on HH+10% and LH WB legs in this case

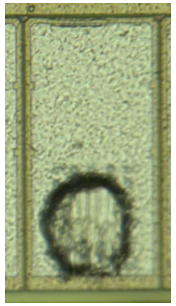


Temperature Humidity Bake Stress Reliability @24hrs

Conditions: 85°C, 85% R.H.

- Focus on bond shear force after humidity stress
- Data are summarized in the tables on the right
- Coating #1, no post-treatment
  - Bond performance close to reference across all WB legs
  - Both mean values and standard deviation are well aligned
  - Failure mode: 100% aluminum shear, no bonding issue
- Coating #2, O2 flash post-treatment
  - Overall lower mean values compared to reference
  - Slight increase in dispersion for HH+10% WB leg
  - Failure mode: 100% aluminum shear

Aluminum shear failure mode
No peeling visible



Blade Sawing Reference

WB settings	Requirement	LL-10%	LL	NN	HH	HH+10%	LH	HL
BS Mean	10.3g	17.08	18.73	19.36	20.43	22.23	19.33	20.22
BS SD		0.66	0.61	0.51	0.42	0.72	0.59	0.59
BS Min		15.62	17.86	18.41	19.62	20.24	18.04	19.27
BS Max		18.06	20.14	20.29	21.12	23.74	20.46	21.72
Failure mode	Al shear	100%	100%	100%	100%	100%	100%	100%
	Peeling	0%	0%	0%	0%	0%	0%	0%

Coating #1 no PT

WB settings	Requirement	LL-10%	LL	NN	HH	HH+10%	LH	HL
BS Mean	10.3g	17.02	19.02	19.80	21.00	22.33	19.36	20.74
BS SD		0.57	0.54	0.48	0.68	0.72	0.56	0.58
BS Min		16.02	18.05	19.20	19.48	20.77	18.00	19.72
BS Max		18.10	20.38	21.03	22.40	23.48	20.39	21.76
Failure mode	Al shear	100%	100%	100%	100%	100%	100%	100%
	Peeling	0%	0%	0%	0%	0%	0%	0%

Coating #2 Flash O_2 PT

WB settings	Requirement	LL-10%	LL	NN	HH	HH+10%	LH	HL
BS Mean	10.3g	16.40	18.22	19.14	19.81	21.55	19.17	19.39
BS SD		0.41	0.41	0.52	0.54	1.09	0.76	0.52
BS Min		15.61	17.51	17.97	19.07	19.70	17.90	18.46
BS Max		17.26	19.11	20.25	20.96	23.13	20.69	20.31
Failure mode	Al shear	100%	100%	100%	100%	100%	100%	100%
	Peeling	0%	0%	0%	0%	0%	0%	0%

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Conclusions

- The two process splits show all bond pull and shear test values within the standard specification used to evaluate wire bonding performance
- Statistical analysis reveals some differences in performance and reliability compared to reference samples diced with a standard blade sawing process
- Bond pull tests show mainly wire break failure mode, implying no major concern for the wire bond interface with this test
- From bond shear data, coating #1, without any additional post-etching plasma treatment, produces a wire bonding performance very close to the reference, both at T0 and after 217hrs, 175°C HTS
  - Very limited occurrence of peeling failure mode and similar levels to the reference
- From bond shear data, coating #2 with O2 flash post-treatment does exhibit differences from the reference
  - A lower bond shear force measured at T0 for all WB conditions applied
  - An increase in dispersion of values after 217hrs, 175°C
  - A significant increase in the observation of the peeling failure mode suggesting that the evolution of the structure of the intermetallic layer at the bond interface during thermal stress differs from the reference process
- To summarize: Preventive approach more effective than remedial method and simplifies plasma dicing flow