Al Corrosion-free Photoresist Stripping and Etch Residue Removal Process with Dilute Halide Solutions at Room Temperature

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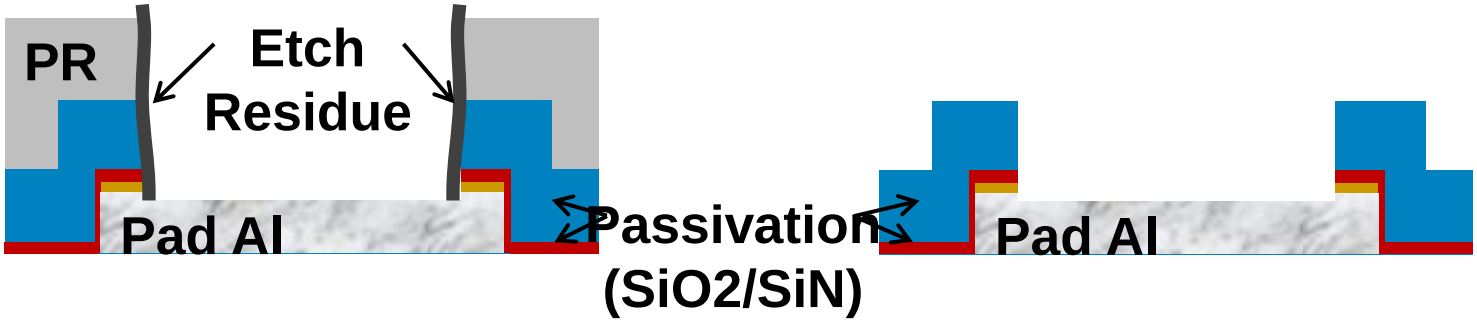
Objectives

- Demonstrate removal of photoresist (PR) and etch residue while maintaining high compatibility with Al/TiN/SiO2/SiN materials
  - Minimize corrosion defects post plasma etch process
  - Prevent galvanic corrosion during cleaning process

Before Treatment **After Treatment**

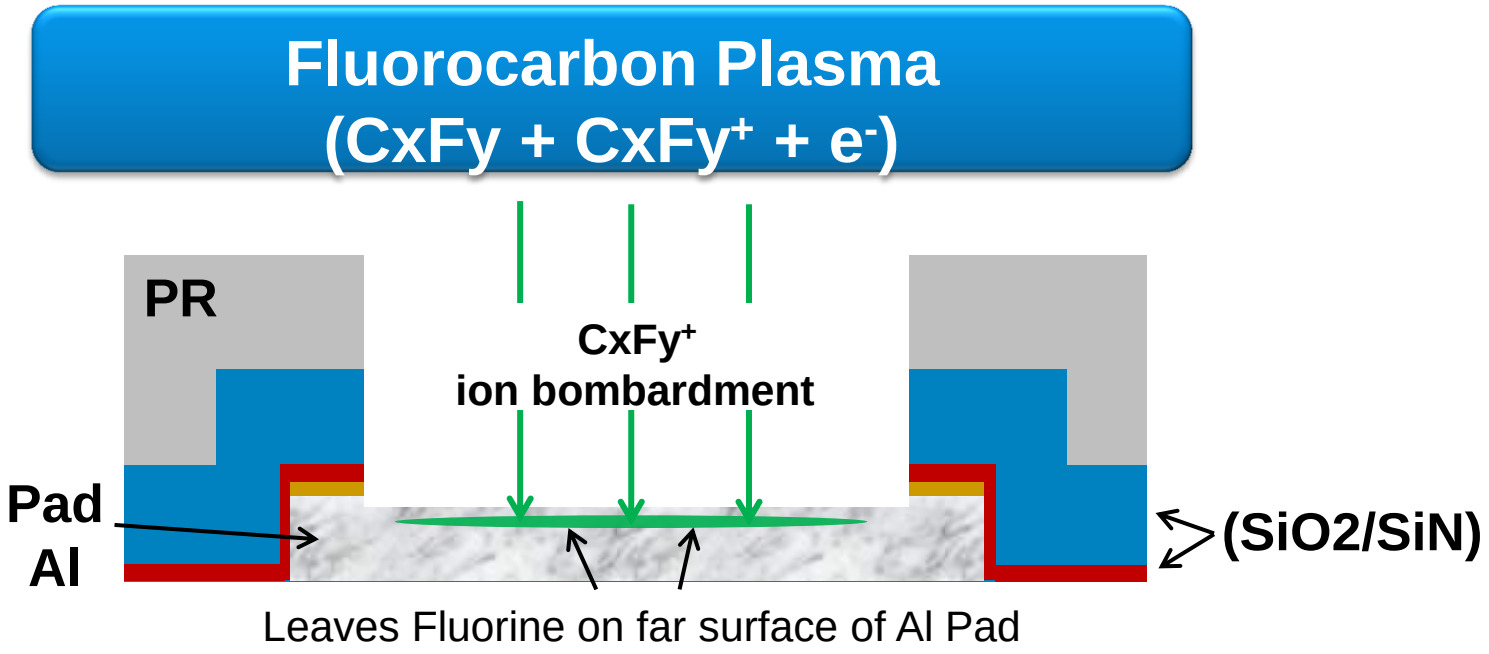


Challenges

- Removal of PR and PERR on Al surfaces using halide-containing materials which typically cause corrosion of the Al bond pads

Challenges

Al Corrosion by Fluorocarbon Pathway



Leaves Fluorine on far surface of Al Pad

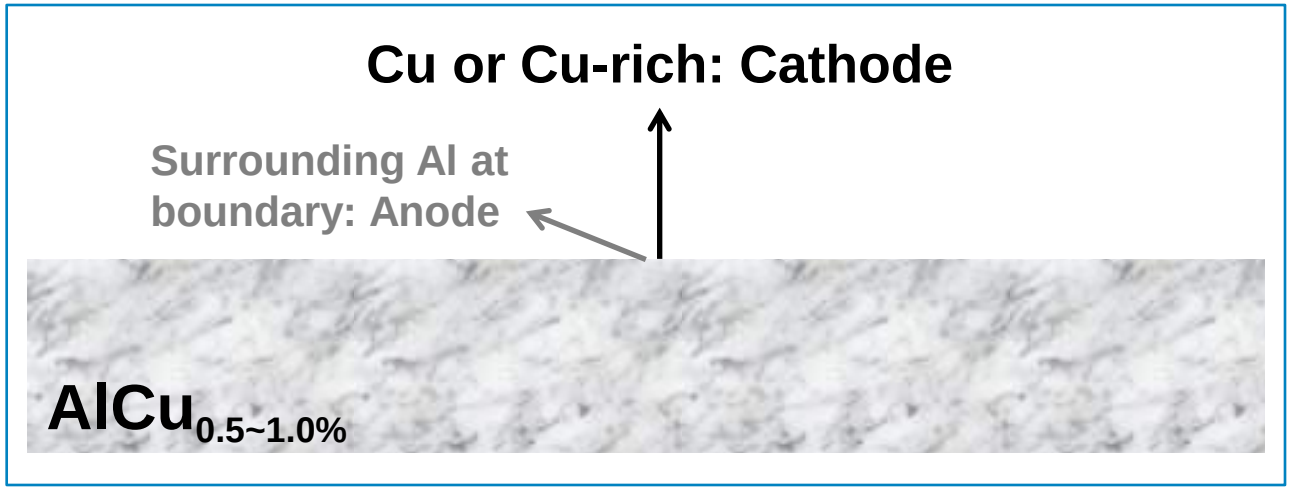
Pad Al Corrosion by AlFx and AlxOyFz Formation

$[AlF_x]^{(x-3)-} + 3e- \Leftrightarrow Al + 6F-$ (X=3 or 6)

$[AlF_x]^{(x-3)-} + Al_2O_3 \rightarrow Al_xO_yF_z$

Challenges

Al Corrosion by Formation of Galvanic Cell



Anode: $Al \Leftrightarrow Al^{3+} + 3e : -1.662\ V$

Cathode: $Cu^{2+} + 2e \Leftrightarrow Cu : +0.337\ V$

$O_2 + 2H_2O + 4e \Leftrightarrow 4\ OH^-$

$4Al + 3O_2 + 6H_2O \Leftrightarrow 4Al^{3+} + 12OH^- \Leftrightarrow 4Al(OH)_3$

Testing Plan

Goals:

- Demonstrate that halide-containing product (XM-426) does not remain on the surface following cleaning
  - XM-426 removes photo resist from the wafer surface
  - XM-426 cleans post-etch residue

Method:

- Expose blanket and pattern wafers to CxFy etch processing
- Perform cleaning by XM-426

Analysis:

- **Time of Flight SIMS (TOF-SIMS):** Depth profile analysis for halide contamination remaining on Al bond pad
- **Auger Electron Spectroscopy (AES):** Grazing angle analysis for halide remaining on the Al surface
- **SEM Image Analysis** for corrosion analysis and cleaning performance
- **Optical Imaging Analysis** for corrosion analysis

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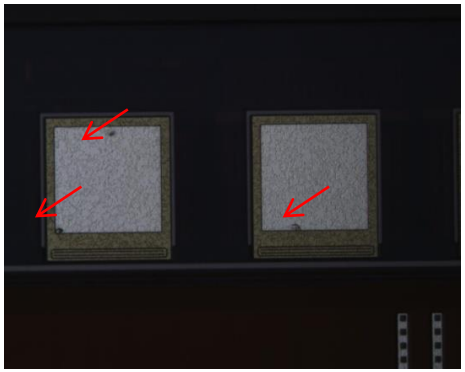
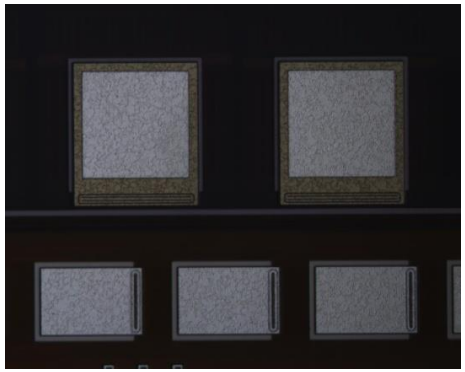
Test Parameters

Sample ID	Test Condition	Optical Analysis	SEM Analysis	TOF-SIMS	AES	Purpose
S1	Before chemical treatment	X	X	X	X	Measure residual fluoride before cleaning
S2	Chemical treatment without DI rinsing (air dried)	X	X	X	X	Reference for DI rinsing effect
S3	Normal chemical treatment with DI rinsing	X	X	X	X	DI rinsing effect
S4	Chemical treatment with multiple concentration (3x) of halide component	X	X	X	X	Examine corrosion by increased halide concentration

Results – Corrosion Prevention of Al Pad after Cleaning

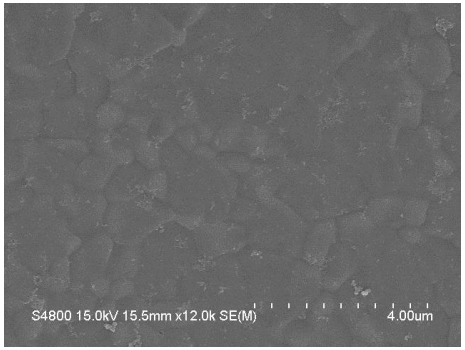
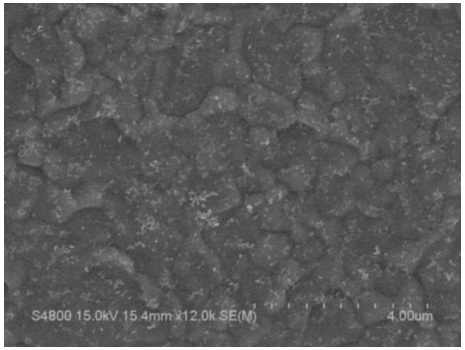
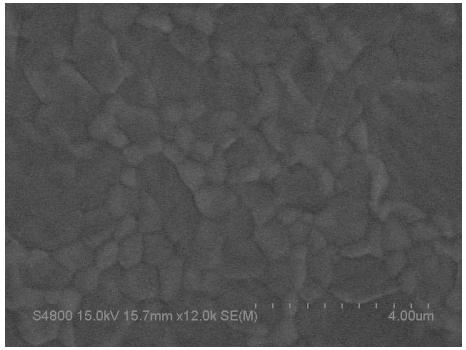
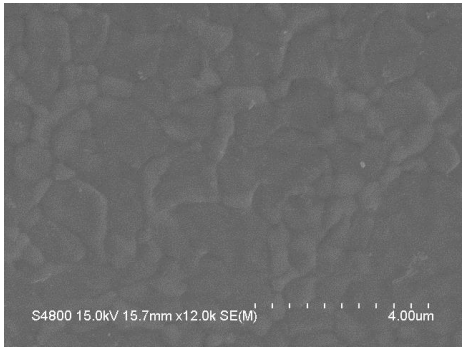
Optical Microscope Inspection of Al Bond Pads

(S1) Before Cleaning	(S2) Cleaning w/o DI Rinsing	(S3) Cleaning w/ DI Rinsing	(S4) Cleaning with 3X of Halide
			

- Sample S2 shows corrosion on Al pad after chemical treatment without DI rinsing
- Samples (S1, S3, S4) show no corrosion following processing

Results – Corrosion Prevention of Al Pad after Cleaning

SEM Inspection of Al Bond Pad

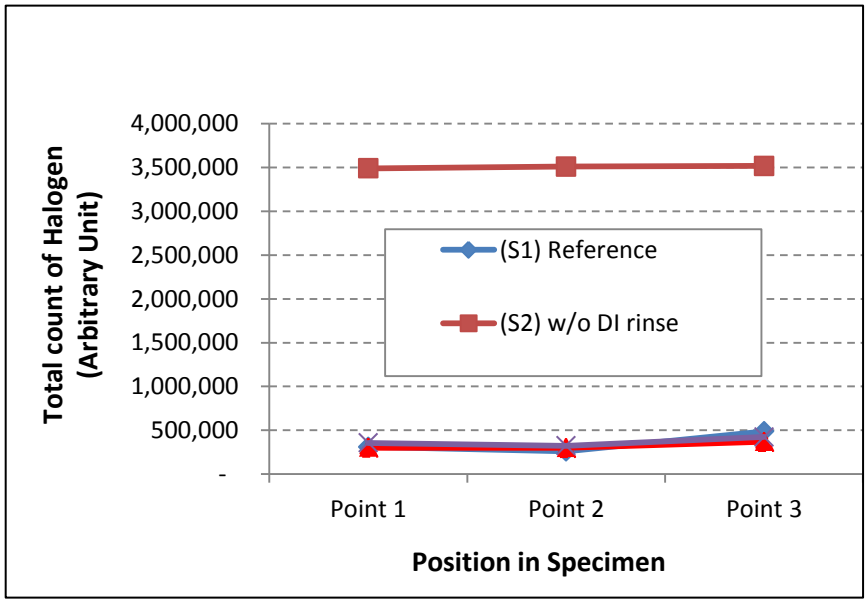
(S1) Before Cleaning	(S2) Cleaning w/o DI Rinsing	(S3) Cleaning w/ DI Rinsing	(S4) Cleaning with 3X of Halide
			

- Samples S1 and S2 shows residue on Al Pad
- Samples S3 and S4 show a clean surface free of corrosion

Results – Corrosion Prevention of Al Pad after Cleaning

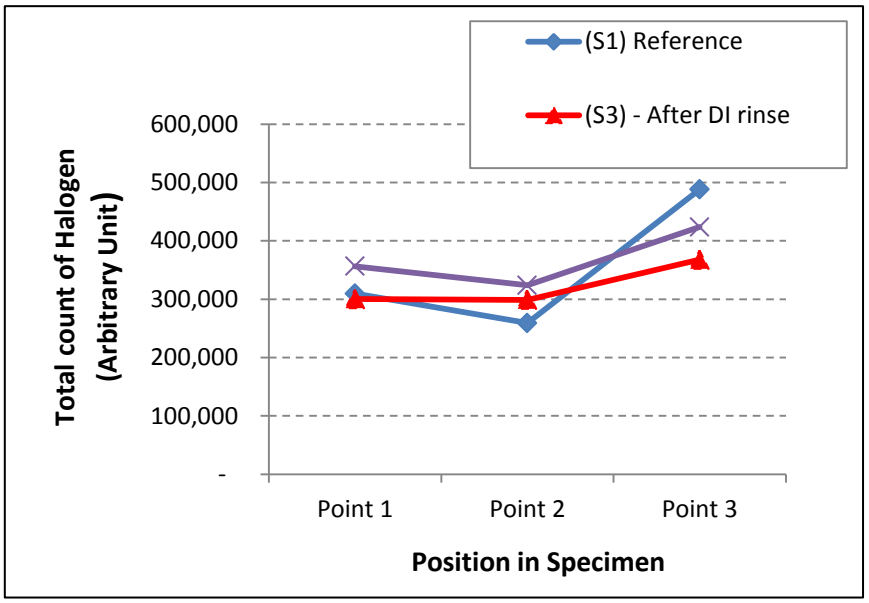
TOF-SIMS Analysis

Total Count of Halogen: Without DI Rinse



- Dominant existence of halide component was observed in S2

Total Count of Halogen: After DI Rinse



- Following the clean and rinse process, the halide concentration is within range of the control sample

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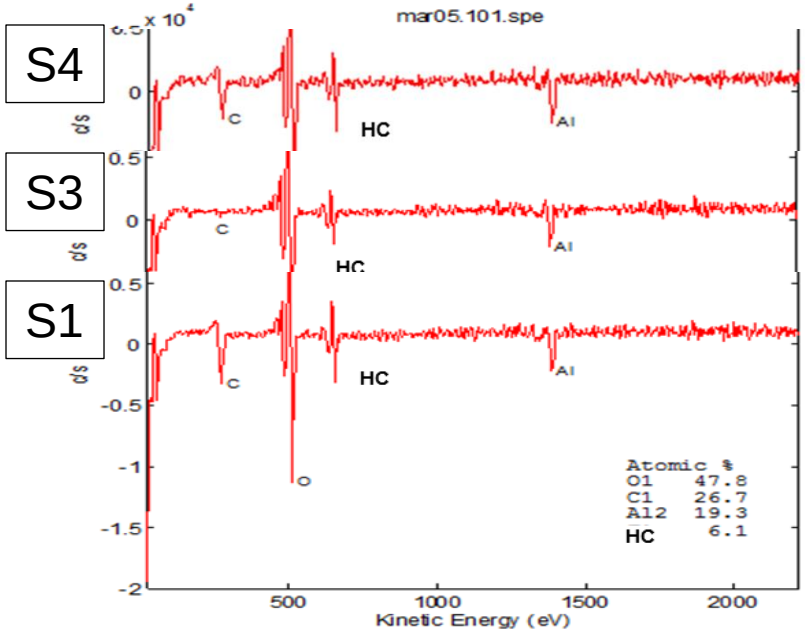
Results – Corrosion Prevention of Al Pad after Cleaning

AES Analysis: Spectra of S1, S3 and S4



Sample	Al	C	O	HC
S1	19.3	26.7	47.8	6.1
S2	8.0	82.6	6.7	2.5
S3	23.6	N/A	67.8	4.1
S4	22.3	20.7	51.7	5.4

- S1 and S4 show similar HC peak/Al peak ratio
- S3 peak ratio shows HC reduced compared to S1 and S4
- S2 appears to be masked by residue

Results – Corrosion Prevention of Al Pad after Cleaning

Summary of Analysis

Variable	Optical Analysis	SEM Analysis	TOF-SIMS	AES
(S1) Before chemical treatment	No corrosion	Residue visible	Minimum halide signature	Baseline
(S2) Chemical treatment without DI rinsing (air dried)	Residue/ corrosion visible	Residue visible	Halide signature	Halide masked by residue
(S3) Normal chemical treatment with DI rinsing	No corrosion	No residue/ corrosion	Minimum halide signature	Halide signature reduced
(S4) Chemical treatment with multiple concentration (3X) of halide component	No corrosion	No residue/ corrosion	Minimum halide signature	Halide signature similar to S1

Results – Cleaning and Stripping Performance

Photoresist Cleaning and Material Compatibility

60 seconds @ 23 ˚C	Positive Photoresist	Al	TiN	TEOS	SiN
Target ER (Å/min)	> 4,000	< 50	< 50	< 50	< 50
XM-426 etch rate (Å/min)	> 20,000	1.2	0	2.8	0.3
Non-halide containing Al PERR	> 10,000	3.0	< 0.1	< 0.5	N/A
Non-halide/NMP containing Al PERR	> 10,000	1.8	< 0.1	0.1	0.3

- XM-426 demonstrates similar performance to industry-accepted products but contains halides

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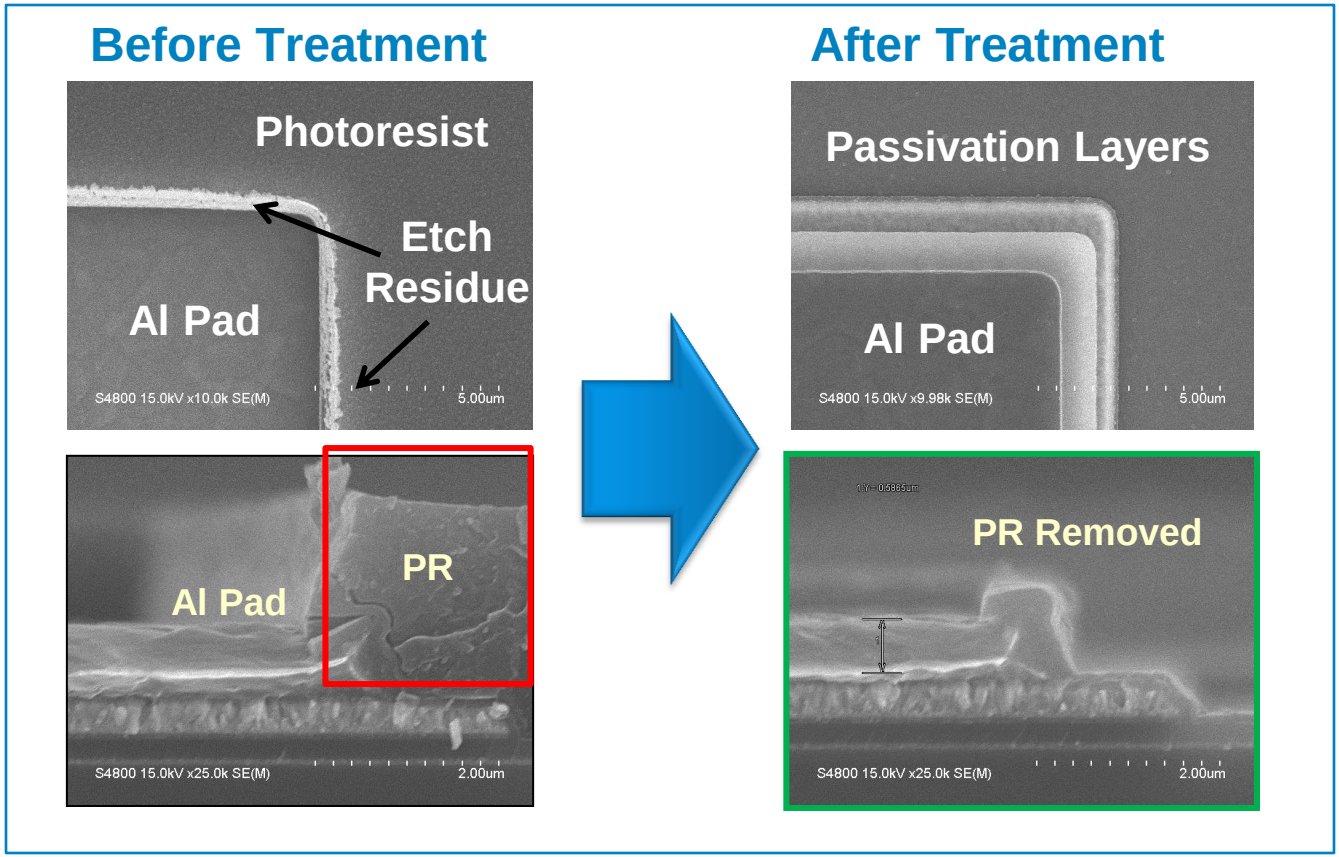
Results – Cleaning and Stripping Performance

Performance of XM-426



- XM-426 demonstrates ability to remove photoresist and clean post-etch residue without damaging the Al bond pad

Conclusion

- Al pad corrosion can occur when fluorocarbon gas is used during the plasma etch process for opening of passivation layers
- Avantor's study tested a J.T.Baker® corrosion-free photoresist stripping and etch residue removal cleaning solution
- Results were confirmed by AES and SIMS which showed complete removal of the photoresist and post-etch residue without corrosion to the Al bond pad