Root Cause of Corrosion on Aluminum Bond Pads

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Abstract

During the process from wafer fabrication to completing the final plastic package there are a number of upstream processes that negatively impact subsequent operations. Problems at wirebond can be traced directly to both fab and saw operations. Analysis of bond pads from the fab reveal traces of flourine that can lead to the formation of HF which is highly corrosive to aluminum and some passivation materials. Most post fab processing operations such as test maintain high humidity levels to minimize ESD/EOS damage to the die. The same high moisture level conditions that are required to minimize ESD/EOS damage supply the necessary moisture to cause trace halogens to form HF causing further corrosion on the bond pads.

Provided with an infinite source of H2O, the flourine becomes a reactive ion that seeks aluminum to form aluminum fluorides. In this reaction the halogen ion is liberated and OH ions in the water reacts with Al to form Al (OH)x and then AlOF. Some of the AlOF becomes AlO and frees the F to become HF. The halogen can now react with a new aluminum atom to repeat the process forming layers up to hundreds of angstroms thick. To terminate the process the flourine has to be eliminated else wire bond ends up with a bond pad that is both difficult to process and can lead to long term reliability issues.

This paper discusses how to remove those halogens, eliminate saw corrosion and improve wirebonding without the use of legacy argon plasma solutions which only serve to redeposit both detectable carbon and halogen elsewhere on the wafer/die. This process also demonstrates a solution that is less than a “milli-penny” per die compared with the expensive and unreliable argon plasma. Results to date have shown that not only can corrosion be eliminated at saw but the die received at wirebond has a thinner oxide layer than material leaving the fab (~20A).

Introduction

One of the last operations in the processing of semiconductor die is to provide an electrical interface between the die and the outside world. This electrical contact is typically a metal layer of one to two microns of aluminum or aluminum alloy (adding silicon and or copper as alloying agents). As will be discussed later in this paper, the quality of the aluminum surface will be extremely critical on the ability to make reliable electrical connection but also simply testing the device can be jeopardized if the surface is not “clean”. A clean surface is free of carbon residues; etch residues and other fab processing contaminants.

The thickness of the native and non-native oxide can especially be critical. Too thick and the probe needle cannot penetrate effectively without damaging the die. Too thick also means the wire bond will not work. Too thick and the insulating properties of the oxide can negatively effect electrical performance. But one of the most damaging problems with the aluminum bond pad has nothing to do with the native properties of the aluminum itself. Fluorine contamination is perhaps the most damaging characteristic that can be introduced to the process.

The last operations in the processing of semiconductor die is to protect the die with a protective oxide (PO) or protective insulator (PI), typically silicon nitride (Si_3N_4) or silicon oxynitride (SiON). For the sake of this paper we are going to use silicon nitride (it’s also the most used in the IC industry). The PI can be as thin as 0.25 um or as thick as 5 um or more and is also deposited over the bond pad to seal the edge of the pad to die. Of course the pad needs to be reopened to provide a path for electrical connectivity,

As with all aluminum layers a thin self passivation layer of aluminum “oxide” is formed when a fresh layer of aluminum is exposed to ambient air. (The self passivation layer on aluminum quickly grows to 20 angstroms and can reach up to 50 angstroms over time.) The passivation oxide of aluminum provides a good adhesion surface for the Si_3N_4 operation. After completely covering the die surface (including bond pads) with Si_3N_4 the PI is selectively removed either with a wet or dry etch.

Using the standard dry etch process (the most common method), the nitride is removed from the bond pad layer by plasma etching, typically with carbon tetrafluoride, CF_4. CF_4 performs well removing the Si_3N_4 passivation layer as well as the thin aluminum oxide layer. The fluorine plasma does not react much with the base aluminum metal other than the formation of a nasty and insoluble aluminum flouride layer (AlF_3) that leads to both short and long term issues, some AlOF byproduct and an insidious fluorocarbon polymer. Each contaminant can lead to an associated failure mode/mechanism based on the level of contaminant and process stage. Of course once the fresh aluminum layer is exposed to ambient atmosphere, additional oxides of aluminum are formed resulting in a complicated stack of corroded metal layers.

Those last few processing steps are critical to everything that happens after the die including assembly, test and long term reliability. A thin layer of oxide on the aluminum is good and does a good job of protecting the base metal, easy to wirebond and presents little difficulty at probe. On the other hand thick oxidation of aluminum does lead to associated reliability and assembly issues. The addition of fluorine is a catalyst for disaster and is “detrimental” at every stage of the process.

Discussion

The fluorine corrosion process - Why eliminate flourine. Simply stated, fluorine is a very corrosive material. The presence of fluorine on the bond pad causes the native oxide layer to grow from 20 angstroms to a well over 250-300 angstrom corrosion layer upon exposure to ambient air. The critical parameter in ambient air is the moisture (even a desiccator will contain some moisture) which sets into motion a fluorine process with aluminum that goes back and forward with the formation of HF during the reactions. The destruction and reformation of HF is key in the destruction of the aluminum (see process below):

$AlF + H_20 \leftrightarrow AlOF$

$AlOF + H_2O \leftrightarrow AlO + HF$

$Al + HF \rightarrow AlF_3 + H$

Either of these, or all, can be at work continuing back and forth until all the aluminum is consumed leaving either a very corroded “pad” or just the exposed Si below the pad. An analysis of the bond pad shows layer one (typically a few angstroms) principally consisting of carbon with fluorine and oxygen levels as the primary contaminants. The carbon can come from ambient conditions, residual photoresist, etch gases, etc.

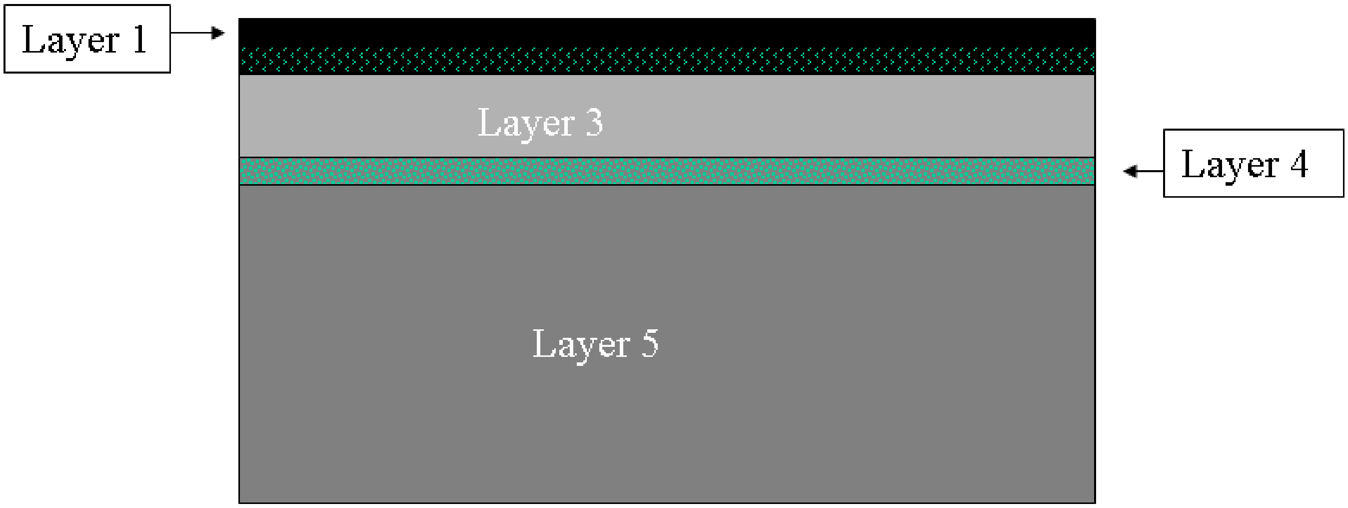


Figure 1. Bond Pad Stack with Corrosion and Contaminants by Layer (thickness of layers not to scale)

Layer two begins to show increased corrosion by products including high concentrations of fluorine and oxygen. AlOF and AlO are present with a higher percentage of fluorine containing materials. Layer three, typically a few hundred angstroms, shows higher oxygenated aluminum layers. Fluorine is present but is less. Layer four is primarily fluorine that has been driven into the aluminum during the plasma operation. Nitrogen is also present in this layer and some carbon can be detected. The levels of the C and N are low and pose no concerns. The fluorine can be detected at depths up to 400 angstroms before only aluminum metal is the only material found (ignoring N and C).

To prevent corrosion regrowth, all four layers have to be removed. If not the “thick” corrosion layer can grow back in less than a few days depending on storage or processing conditions. In operations where the humidity is high, basically everywhere except the dry box, an ample supply of moisture is present to prevent ESD/EOS problems. While high moisture is critical to minimize ESD/EOS problems, moisture quickly leads to scrap die.

Consider the steps prior to wirebond:

Test – The test floor can typically see moisture levels at 65% with product stored for weeks in die carriers. Many die, particularly small die on 300mm wafers (with a 24 piece wafer lot), can be exposed to high humidity for up to 48 hours during test. As such it no wonder that the last few wafers will typically yield not as good as the first wafers tested.
Storage – while dry boxes are maintained at low humidity, the die pads brings their own moisture trapped on the bond pad from exposure during test as well at prior operations where a DI rinse is required. A "crust" layer forms during the corrosion process trapping moisture as a hydrate. Going back and forth the corrosion slows a bit without new moisture but continues to grow.

Saw – unless laser saw is used an infinite amount of H_2O is supplied when one considers the bond pad is typically only 1-2 um of aluminum metal. Even if fluorine were not present DI water is very corrosive to aluminum. The self passivation layer of aluminum will protect the metal, albeit not like a layer of photoresist could accomplish to prevent moisture from contacting the pad but that layer is compromised with the fluorine. If the pad is an alloy the reaction can be worse as galvanic reactions are initiated.

Assembly – with minimum moisture levels of 40% once again an ambient supply of moisture is available. Layers of AlO and AlOF at thickness over 250 angstroms at wirebond lead to poor yield and increase cycle time. Even if wirebond is successful the fluorine contamination can lead to long term reliability issues as the fluorine plays the bad guy role speeding up galvanic reactions between the various metals in the wirebond and assembly process.

In agreement with the reference, the author found that pads which exhibit poor wirebondability, either no sticking or weak wire shear (failure at the ball to pad interface), we found that strong wirebonds had little to no fluorine present whereas poor wire joints result in various amounts of flourine (typically a minimum or 6 weight percent as determined by Auger). Oxygen and carbon had little impact as long as the thickness was less than 50-75 angstroms. Our test results also show agreement with the reference: parts allowed to sit over time regrew a thick corrosion layer that inhibits good wirebond results. Although lower fluorine levels improve time zero results long term reliability results demonstrate that zero fluorine is the desired result.

How does one eliminate the fluorine problem? The answer is: Quickly, economically and with minimum impact on yield. The Texas Instruments reference suggests an initial water clean and oxygen plasma to be ineffective at removing the fluorine. The reference does suggest a four minute argon sputter was able to remove the fluorine and other contaminants. Unfortunately that four minute etch also caused electrical damage on the die. For an optical die thirty seconds would even be detrimental and similarly for MEMS and MOEMS devices. In short it suggests there is no economically feasible method to clean the bond pads without damaging the die.

Results

How to remove fluorine? There are a few methods including chemical etching, plasma, and an improved process the author has determined to be quite effective. It should be pointed out right off that chemically etching bond pads is not a good idea. Most techniques require removal of substantial amount of an already thin layer of aluminum. Coupled with the amount of aluminum consumed by the initial corrosion process the metal could be thinner than a one micron. Wet etches of phosphoric, acetic and nitric (PAN) are effective at "cleaning" the aluminum but "PAN" etches can also consume aluminum in very short process windows. Other etches include caustic solutions containing OH which will etch aluminum readily. Unfortunately the corrosion that remains can be worse than the fluorine corrosion. The surface is left very rough and pitted which can trap solution. The author has found that if the OH is not completely removed with a "very long" rinse the aluminum pad can completely disappear in less than 20 minutes.

Obviously the chemical etch process using PAN acid etch or OH basic solutions are not adequate. Argon is a process that is widely accepted in the industry for "improvement" at wirebond. A number of suppliers sell argon plasma tools and promote them as effective at cleaning bond pads, somewhat. A second reference from March Plasma is summarized in table 1. The data in this report points out the process is not 100% effective at cleaning the surface and does leave some corrosion. The report also does not specify if the carbon is a fluorocarbon or ambient carbon. March uses XPS to measure but unfortunately XPS is effective in the range of 50 to 70 angstroms. With contamination layers in the range of a few tens of angstroms this author would question the results as the layer can be lost in the background. It's also important to note that the plasma does etch the surface so if the detector is not turned on immediately information can be lost.

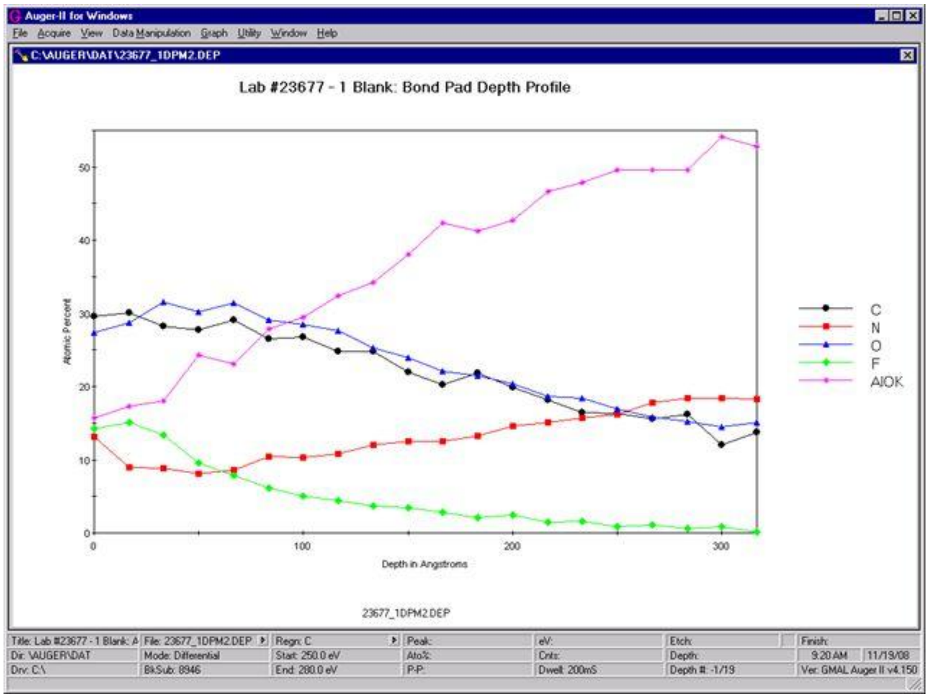
It is also important to note that a fresh sample will show fluorine levels at the surface much lower than one that has been out of the clean room for months. Auger results of a fresh die just out of CF_4 plasma shows fluorine levels at 4.0 to 5.0 percent. The data in table one suggest a relatively fresh die. The data also conflicts with observations by the author and results generated by Texas Instruments in reference number one. It is assumed the detector might not be sensitive enough to detect the lower fluorine levels compared to the other components if the sample depth is too high.

For such an analysis auger is the preferred method as it can capture information from a smaller layer slice. XPS at 50 to 70 angstroms is not preferred when compared to auger which looks at a 20 angstrom thin or less layer. The chart below does agree with the results in the Texas Instrument reference that the carbon and oxygen level does not seem to impact the wire bond results at time zero though detectable fluorine does lead to longer term reliability concerns. More importantly the data does not provide a depth profile for the surface. A quick review of figure 2 demonstrated that it is important to test the immediate surface but to also mill the top surface away, retest and map the true concentration by layer.

Table 1 Bond Pad Analysis Results Using March Plasma Argon Etching

Criteria	**Results**	**Discussion**
Fluorine % Pre Clean	4. 9	This is unusually low for fluorine
Fluorine % Post Clean	Not detected	Fluorine it typically 200 to 300 A deep
Carbon % Pre Clean	48. 7	
Carbon % Post Clean	35. 2	Is this fluorocarbon or ambient carbon
Oxygen % Pre Clean	16. 3	
Oxygen % Post Clean	11. 7	Is this oxygen or oxyflouride
Results from March Plasma, Ref 2.		

The data presented in figure two shows concentrations of carbon, nitrogen, oxygen, fluorine and aluminum by depth. The nitrogen is a non critical item that gets trapped in the grain boundaries and verified on both good and bad die to exist. Fluorinated carbon was found to be more a surface item contaminant whereas the additional carbon was ambient carbon. Oxygen is found in different forms at various levels. AlO, AlOF and OF are all corrosion products. Even with successful removal of OF corrosion AlO layers present problems. If the aluminum oxide layer is too thick then wire bonding is not successful. In cases where wirebond is successful one has to address the insulative nature of the bond on electrical performance. The results of an auger mill and profile demonstrate the necessity of to assure if an adoptive fluorine removal regiment might demonstrate improvement. These die were part of a wafer allowed to sit on an engineer's desk for over 12 months suggesting fluorine does not go to background levels until beyond 300 angstroms for this particular customer process. These samples were used to test the DOE process and process splits developed to look at reducing fluorine levels to zero.



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Drv: C:\
BkSub: 8946
End: 280.0 eV
P-P:
Dwell: 200mS
Depth #: -1/19
Ver: GMAL Auger II v4.150

Figure 2. Depth profile of CF_4 etched Al pad with no fluorine cleanup

In the development of the process it was determined that the oxygen content had to temporarily increase to reduce the fluorine content. This requires a two step process involving the fluorine remove (aluminum oxidation) followed by the thick oxide removal. Key to the overall process is to assure no more than the aluminum oxide and AlF_3 layer are removed (300 angstroms). As discussed earlier, it's unfortunate that increasing the oxide can result in other problems.

Luckily we were able to find a couple off the shelf product by our business partner, Air Products, which will remove the oxide without attacking the base metal. We selected BPS100, referred to as "B" in the following sections, to eliminate the oxide layer. This material proved exceptional for the task since it remove the oxide in less than a few minutes and has a very low etch rate on the aluminum (less than 1 angstrom/min). This product also proved very safe such that when left in contact overnight we verified that we still had over 9000 angstroms of a 10K angstrom starting pad. This was quite a contrast to PAN and OH which consumed the aluminum entirely in less than 30 seconds.

So step one to remove the fluorine sources followed by a etch seemed to work well as noted below. When normalized, the as received wafer shows fluorine over 18% on the surface. Milling 30 angstroms into the pad and retesting dropped the fluorine levels to just under 16 angstroms. Interestingly enough the oxygen levels 30 angstroms into the sample is over 20% (excluding aluminum oxide) whereas on the surface total oxygen amounts to 16.18%. Since the milling is completed in-situ in a high vacuum the oxygen is not regrowth but more likely the result of destruction of AlOF (which is a higher percentage on the surface) followed by slightly high proportion of AlO deeper into the sample.

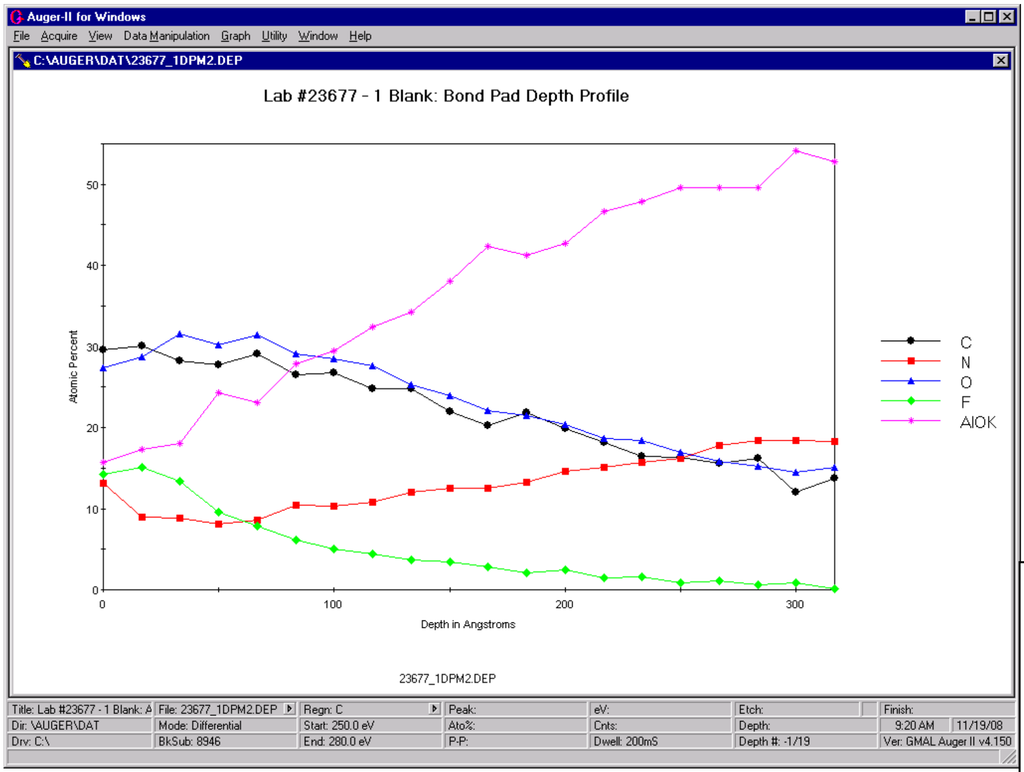
Element, Atomic %	**1) Blank, As-Received**	**1) Blank, 30A Ion Etch**	**2) Test 1, As Received**	**2) Test 1 30A Ion etch**
Carbon	44. 51	37. 45	24. 66	13. 73
Nitrogen	3. 23	5. 96	5. 48	7. 70
Oxygen	16. 18	20. 12	39. 42	45. 28
Fluorine	18. 33	15. 90	5. 87	4. 33
Aluminum Oxide	17. 75	20. 57	24. 57	28. 96
Element, Atomic %	**3) Test 2, B As-Received**	**3) Test 2, B 30A Ion Etch**	**4) Test 3, B2 As Received**	**4) Test 3 B2 30A Ion etch**
Carbon	33. 04	19. 35	34.38	23.90
Nitrogen	5. 87	7. 54	3. 14	7.78
Oxygen	31. 63	40. 04	36. 10	40.47
Fluorine	9. 83	9. 19	7.86	5.84
Aluminum Oxide	19. 63	23. 89	18. 51	22. 01

Table 2. DOE splits showing elemental analysis at time zero

DOE splits show that final fluorine levels in the die can be reduced in the correct combination of processing. The initial goal of the experiment was to eliminate the fluorine, reduced the oxide thickness and to do this economically. Economically in assembly and test typically means fast (under five minutes) and cheap. The first run on the DOE demonstrates that the fluorine can be reduced from 15.9% to 4.33%. The data suggest that the fluorine level is at the AlF_3 level of the pad. There is delta between the surface and 30 angstroms into the sample which also strongly backs the need for depth profile by sputter etch. The data also points out the first step to remove the fluorine are critical else the process recipe fails. A comparison of Test 1 and Test 2 in table 2 suggests that we need to increase our time in the B cleaning process. Shortening the time increased the fluorine content which suggests we were not at the AlF_3 level.

One should also note that oxygen and aluminum oxide levels should increase dramatically as fresh aluminum will instantly grow a 20 angstrom layer of aluminum oxide or hydrates. Any test run on the angstrom level that does not show high oxygen should be rerun and checked for validity. The issue with oxygen is that both wire bond and probe has to break through this high level of oxygen to be successful. The process successfully reduced the oxygen surface content as well as decreased fluorine as noted from the images.

We then ran the process B1 and a control with argon etch. The argon sample was run in an ICP argon plasma chamber (not a March tool) with Ar at 30 SCCM, power at 300W, pressure at 20mT and 120 seconds as not to damage the die electrically. Both units were held in a dry box for 14 days to allow the corrosion layer to regrow. For example test two reversed the process where application of B was the first step but the fluorine removal was not complete for the time.



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Depth:
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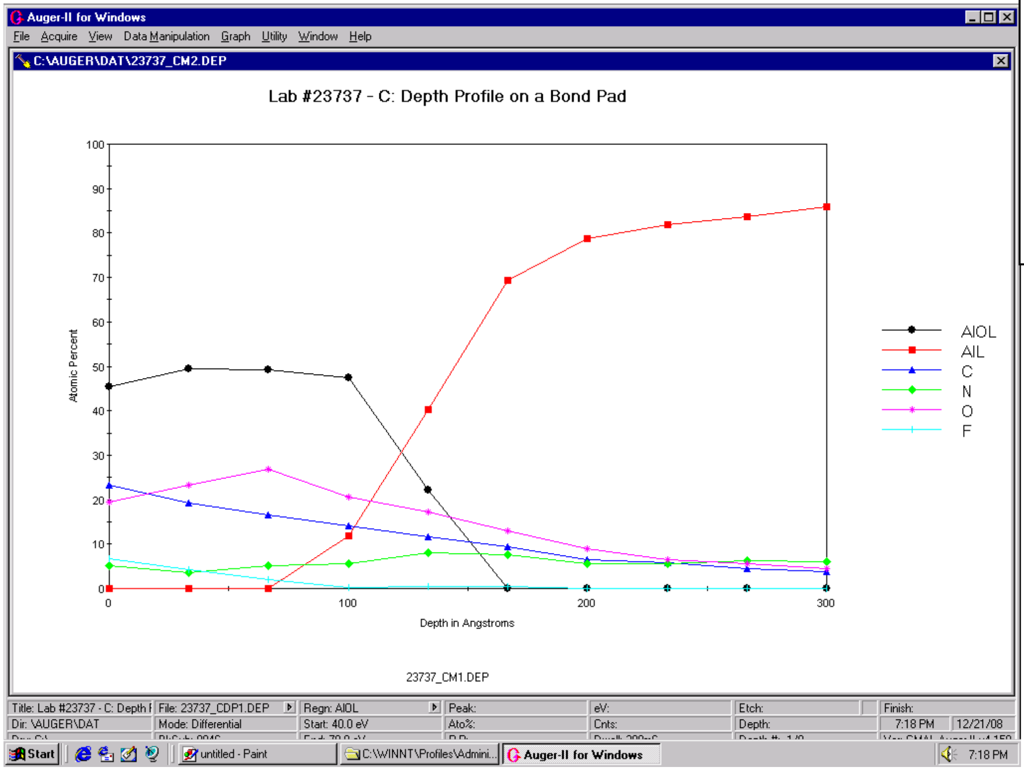
Drv: C:\
BkSub: 8946
End: 280.0 eV
P-P:
Dwell: 200mS
Depth #: -1/19
Ver: GMAL Auger II v4.150

Figure 3. Ar etch bond pad after two weeks in dry box

Please note that the colors for the lines were not kept constant. The F line in the upper image is green and light blue in the lower image.

The overall amount of Al is also higher in the lower image.



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Mode: Differential
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Depth:
7:18 PM 12/21/08

Figure 4. Etch bond pad after two weeks in dry box

Conclusion

A quick review of figure 3 and figure 4 show that cleaning has better long term results than argon cleaning. The process also has a low etch rate on the aluminum which means the parts can sit for hours in a bath with no damage to the die compared to 6 minutes in Ar and 30 seconds in PAN or OH etchants. Since the process is not energetic and focused on oxygenated compounds there is nil damage to the Si_3N_4, Si, BCB or other metals and organic packages.

The figures also show that oxygen and oxygenated aluminum is high on the process and begins to drop off in the region where the fluorine goes to zero. The results suggest a possible AlOF layer which is possible after two weeks due to the fluorine corrosion process. Additional experiments will be run to optimize the process. It should also be noted that these wafers are an extreme case in which the material sat on a desk for over 1 year. Most material should be processed long before that to eliminate the fluorine early in the process. Early processing would reduce the oxide and oxyflouride growth resulting in a more streamlined and robust process.

The data also defines that surface analysis is not adequate to accurately determine surface conditions. A minimum of a surface scan plus milling to 30 angstroms and rescan is required. For accurate results and auger is also the preferred analytical too. Experimental data confirms that oxide levels increase (as expected) when the process is used. Since the cleaning removes the initial oxide levels and exposes fresh metal the subsequent rinse and dry causes regrowth in oxides. Those oxides are not detrimental to the wire bonding or probe process when kept to a minimum. (We are also investigating a new product as a rinse instead of DI water as it has been found to reduce oxidation in our experiments as well.) A current experiment running as this paper was being completed demonstrates that the fluorine levels can be reduced to the background noise (of the auger) by increasing the time of the die in the cleaning solution.

“Working around the fluorine factor in wire bond reliability,” Jeanne Pavio, Robert Jung, Craig Doering, Randal Roebuck and Mario Franzone. Texas Instruments, pages 428-430.

Using Argon Plasma to Remove Fluorine, Organic and Metal Oxide Contaminantion for Improved Wire Bonding Performance, March Plasma Systems, Scott Szymanski, 15July2008.

Root Cause of Corrosion on Aluminum Bond Pads

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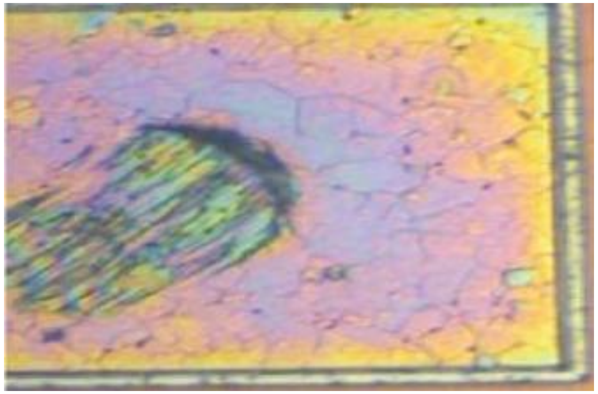
Post Fab Processing – Assembly/Test

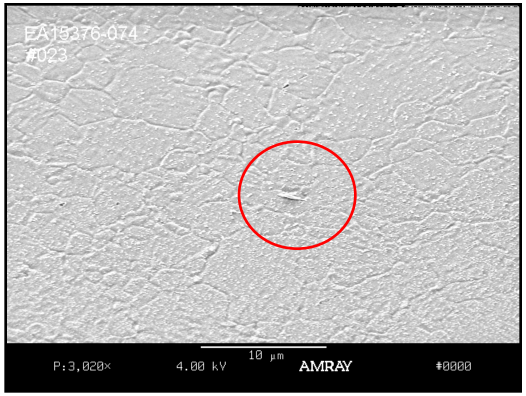
- Test
  - Bond pads
  - Flip chip bumps
  - Organic contamination
  - Burned flux
- Saw
  - Oxidation
  - Corrosion
- Wirebond
  - Corrosion
  - Organic contamination
  - Oxidation

The Better Process Solution
Pads and Bumps

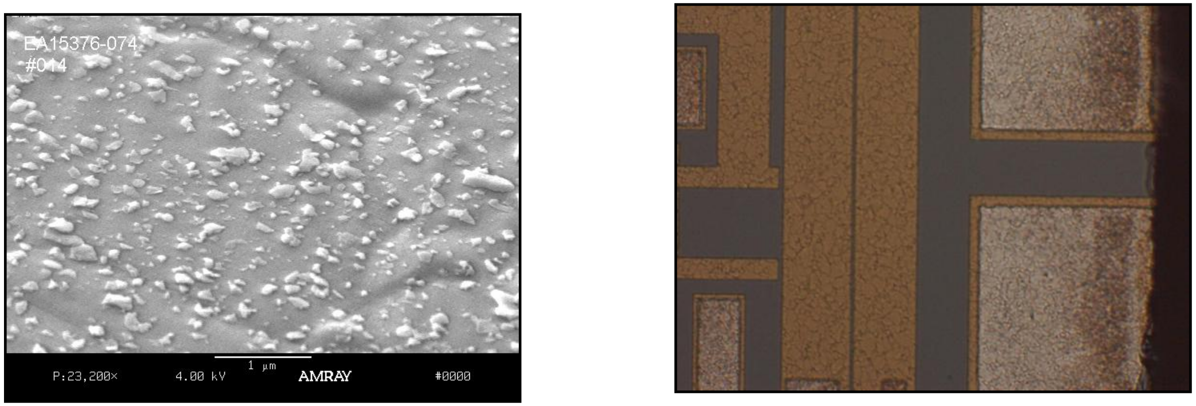
Fluorine induced corrosion



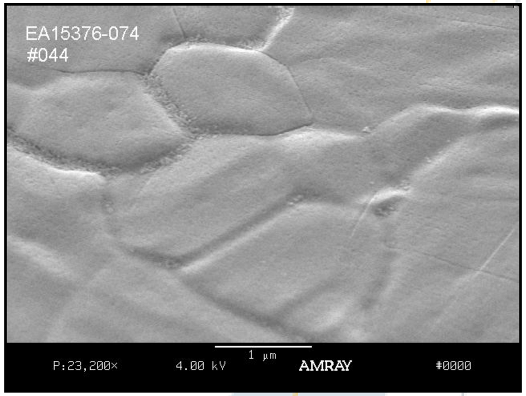
Corrosion initiation site



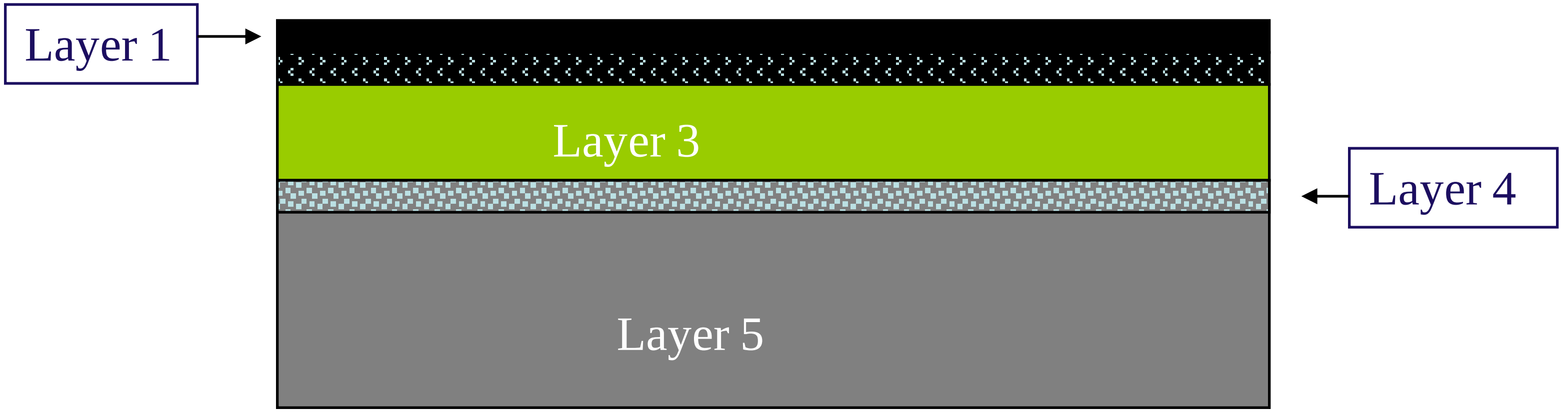
Highly oxidized bond pads post saw.



BPS brings the pad back to prime condition for test, saw and assembly. Fluorine and oxidation removed.



Cross Section of A Plasma Ashed Pad



Layer 1

Layer 3

Layer 4

Layer 5

Layer 1 – AlOF

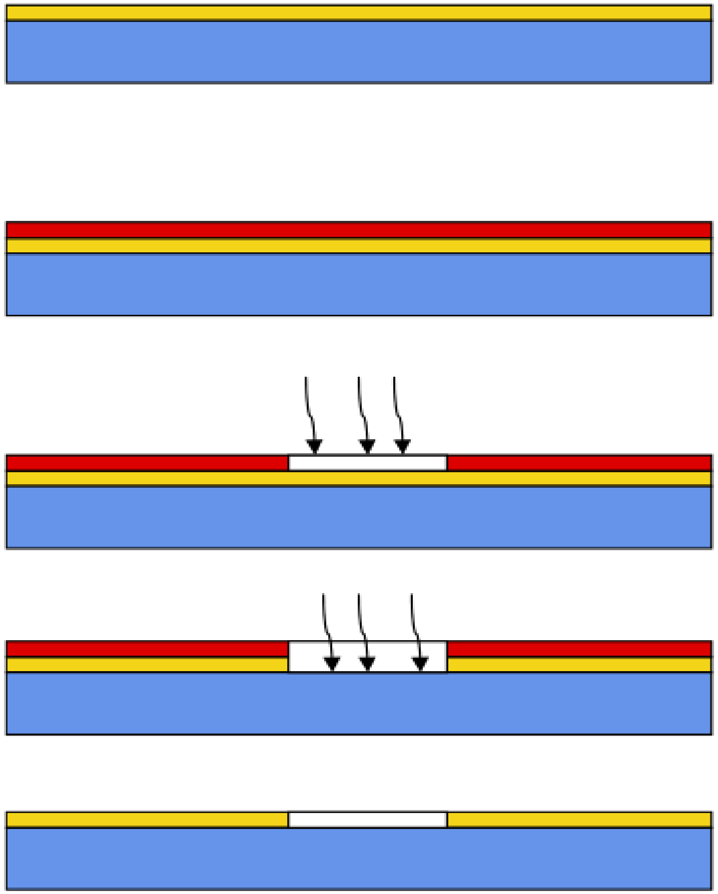
Layer 2 – AlOF + AlO

Layer 3 – AlO

Layer 4 – AlF3

Layer 5 - Al

Bond Pad Fabrication Process



Si3N4 passivation applied to wafer to protect wafer surface

Photoresist layer applied to passivation to create openings for the bond pads, test structures and saw streets.

CF4 plasma used as an etch gas to open Si3N4

Goal is to remove all the Si3N4 else probe, wire-bonds, WLCSP processes are compromised

Si3N4 is completely removed from the Al pad but excess time on plasma converts some Al to AlF which is not volatized in the plasma

Fluorine Induced Aluminum Corrosion and Contact Resistance (CRES)

$\mathrm{Al + F \rightarrow AlF3}$

$\mathrm{AlF3 + H20 \rightarrow AlF3 + H\text{-}OH}$

$\mathrm{AlOF \leftrightarrow AlO + HF}$

$\mathrm{Al + HF \rightarrow AlF3}$

$\mathrm{AlF3 + H2O \rightarrow AlOF}$

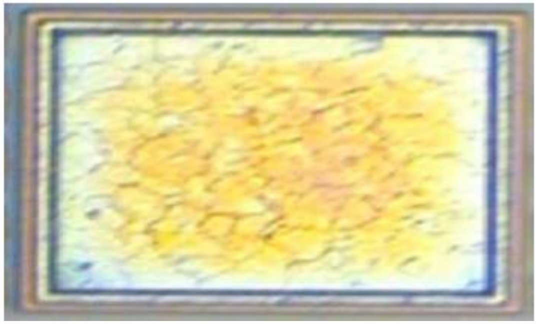
Aluminum oxide grows immediately to 20A then terminates at 50A over time. Passivation opening results in an aluminum oxyfluoride layer that will continue to grow until all the aluminum were consumed

This process repeats until corrosion layer is thick enough to impact probing, saw and assembly (wirebond)

Even in a dry box the corrosion layer grows in H2O levels as low as a few percentage points. The only way to terminate the process is to eliminate the fluorine to less than background levels

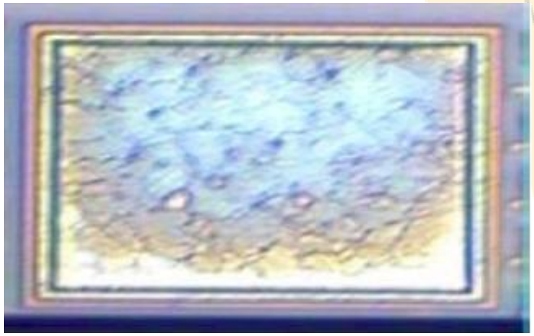
Residual fluorine on the bond pad leads to corrosion in the presence of moisture. Eliminate the F or corrosion will consume the entire bond pad.

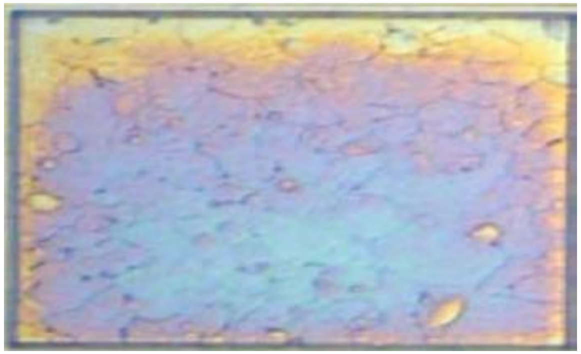
Al Bond Pad Analysis At Various Times



Zero Time

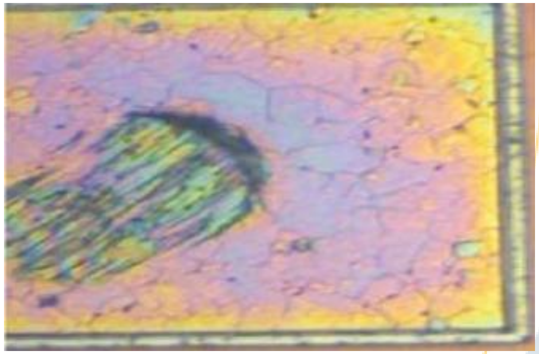
One Week





Three Weeks

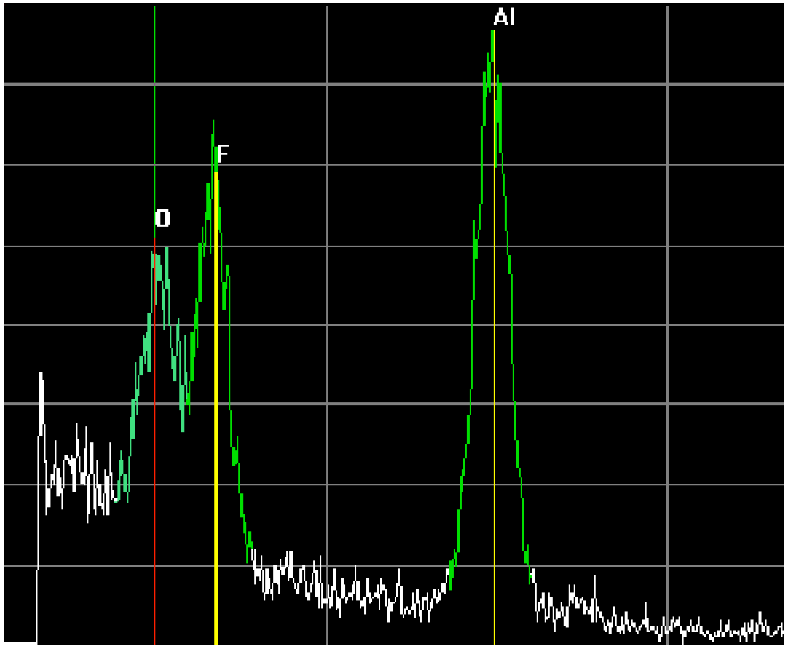
Six Weeks



Fluorine contamination is apparent at time zero from the fab. As time continues the pads become more corroded. Conditions of these pads are typical and are the root of poor contact resistance and bondability. If the pads are not cleaned then poor yield is likely as well as die and hardware damage.

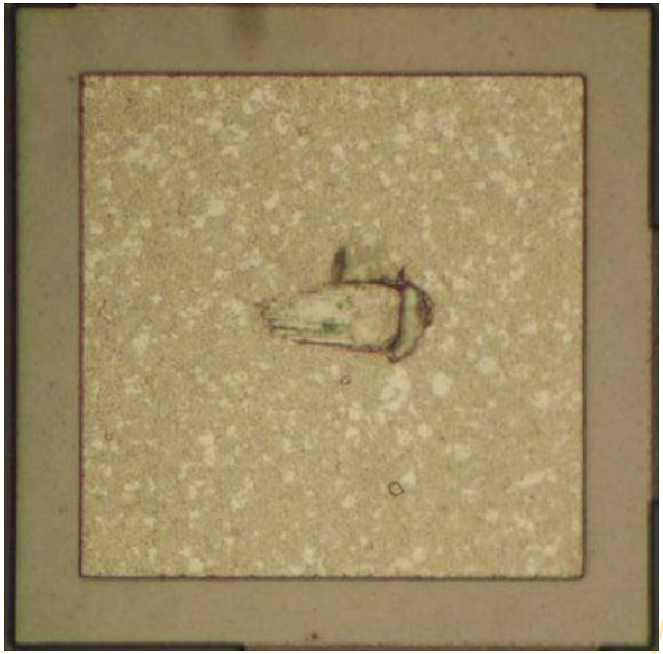
Wirebond - Oxyfluoride Corrosion

Post saw corrosion – fails wire bond



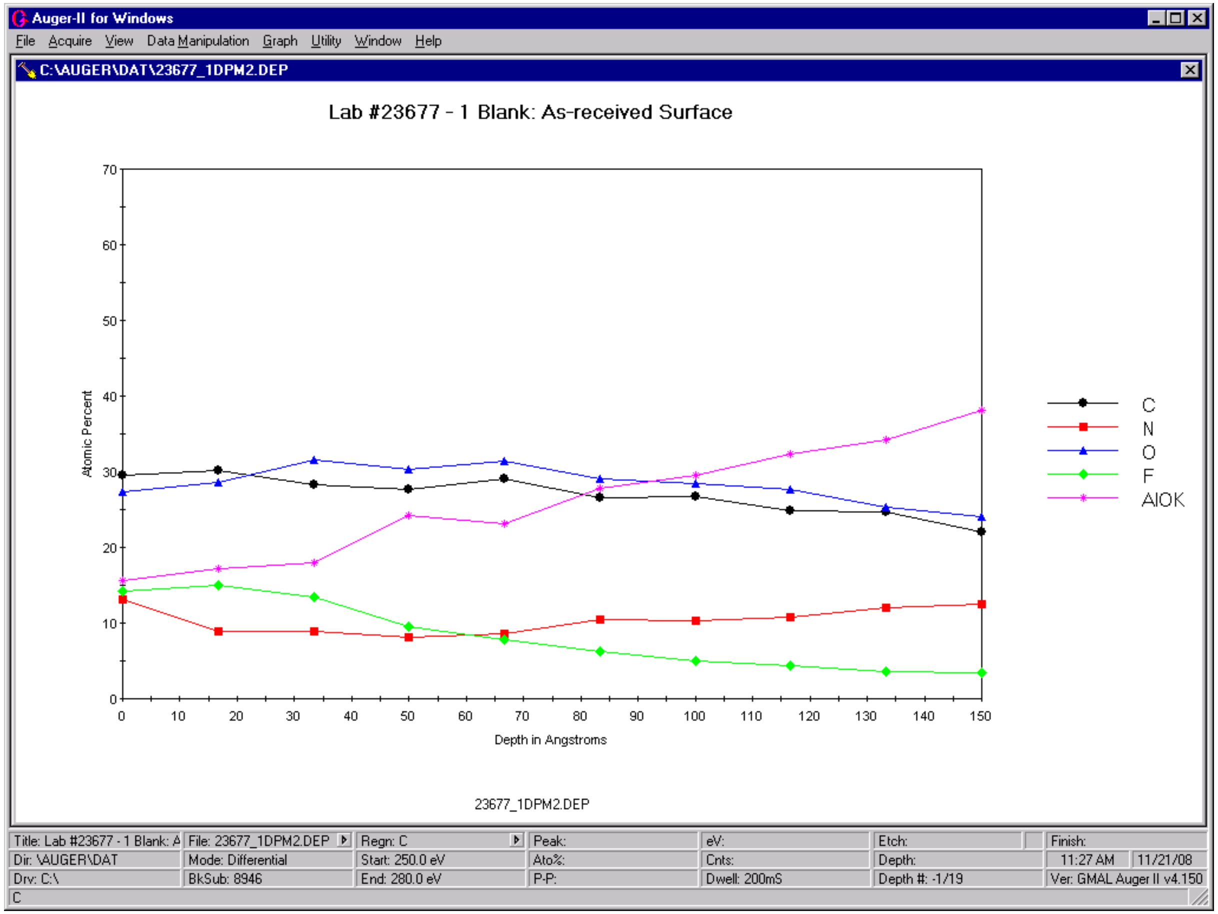
EDX results show OF covers more of the surface than Al.

EDX is not as sensitive as Auger or XPS.



Optical image verifies that Al (white) is sparse. Fluorine corrosion regrowth in the probe mark.

Auger Layer Comparison
As-Received Die



Title: Lab #23677 - 1 Blank: A	File: 23677_1DPM2.DEP	Regn: C	Peak:	eV:	Etch:	Finish:
Dir: \AUGER\DAT	Mode: Differential	Start: 250.0 eV	Ato%:	Cnts:	Depth:	11:27 AM 11/21/08
Drv: C:\	BkSub: 8946	End: 280.0 eV	P-P:	Dwell: 200mS	Depth #: -1/19	Ver: GMAL Auger II v4.150

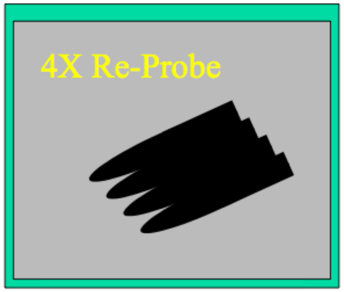
C

No pure aluminum detected in the first 150A

Contact Resistance – Probing and Bonding

- **Root Cause of High Contact Resistance**
  - Fluorine from passivation opening on pads lead to Al corrosion
  - Confirmed high CRES ranging from a few ohms to kohms
  - Thickness of corrosive layers will be much thicker than the natural oxide and can exceed 300A in many cases
  - Probing/Bonding on F can imbed the halogen deep into the pad
- **Process Improvement (BPS100/101)**
  - Remove the AlOF and corrosion stops at the natural oxide thickness ranging from 20A (hours) and terminating at 50A after a few months
  - Improved test/bond results as contaminants removed, demonstrated that cleaned versus non-cleaned wafer is improved.
  - Removing F ions eliminates corrosion at saw (excess H2O)
  - Removing the F ion will eliminate the need to clean prior to wirebond and improve long term reliability.

The Problem Statement - Wirebond

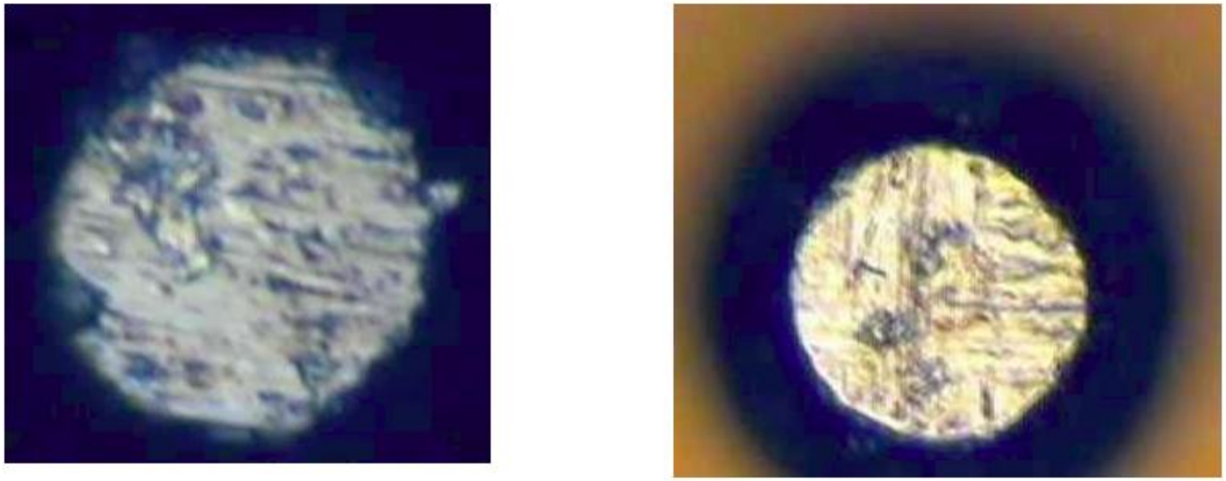


Depiction of Reprobe

- Compounding initial poor bond pad surface conditions, damaged pads introduce additional variability and yield loss at operations such as **wire bond.**

- Wire bond requires a clean contact surface free of debris, probe voids, contamination and particles.
- **Goal: Remove the resistive layer without damaging the underlying metal layer.**
- BPS series of products remove oxide and corrosion minimal attack of films.
- Less than 4A/min etch rate on metals
- Less than <1A/min on passivation layers and Si.

Residue Deposited on Probe Tips



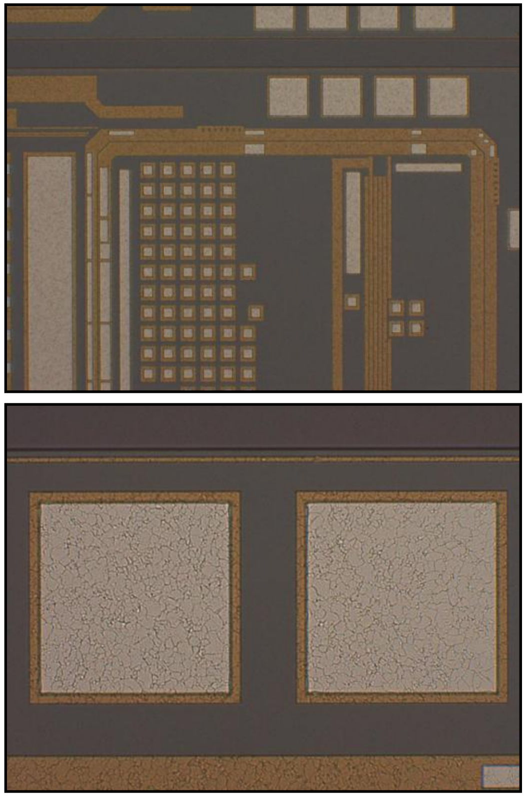
Cantilever Probe Tip

Vertical Probed Bumps

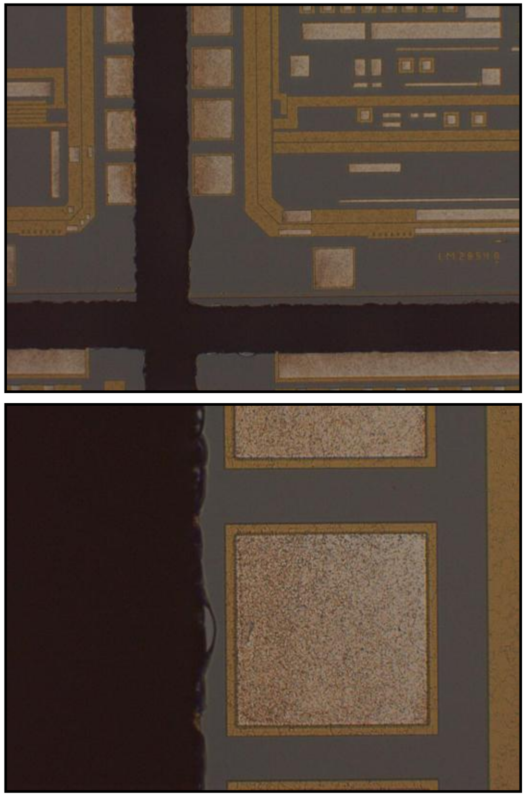
Images of probe tips after 75 touchdowns on the die.

Probes pickup the residues and debris present on the pads/bumps. The material can be “embedded” into the pad as well as contribute to shorts elsewhere (probe card or wafer). Analysis of the probe tips confirm fluorinated hydrocarbons, oxygenated aluminum, aluminum and fluorinated aluminum.

Influence of F on Al Pads at Saw



Before Strip



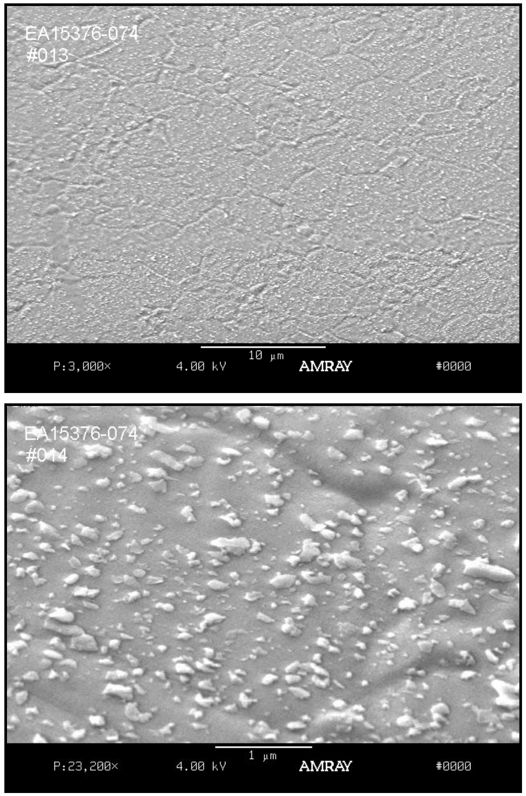
No Pre-Treatment; DI Water

No Pre-Treatment; BPS-729

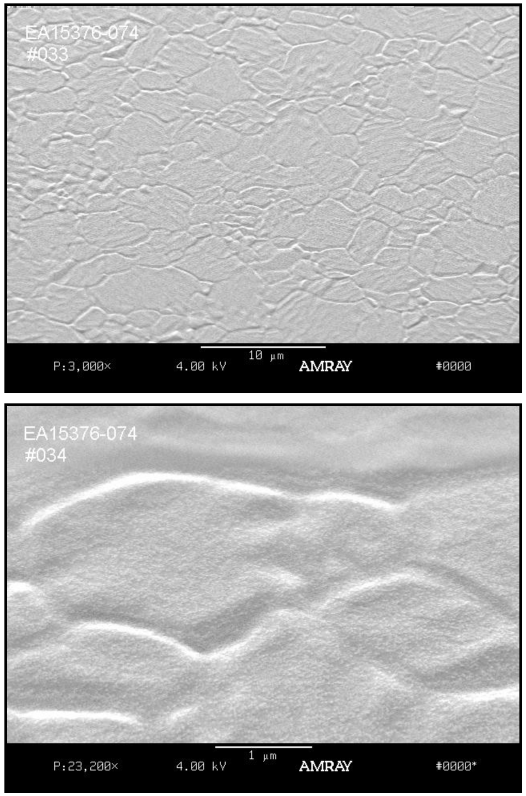
Initial corrosion layer helps protect pads

Al Tests Results

Little to no silicon slurry from the saw contaminates or corrodes the bond pads making wire bonding less difficult.



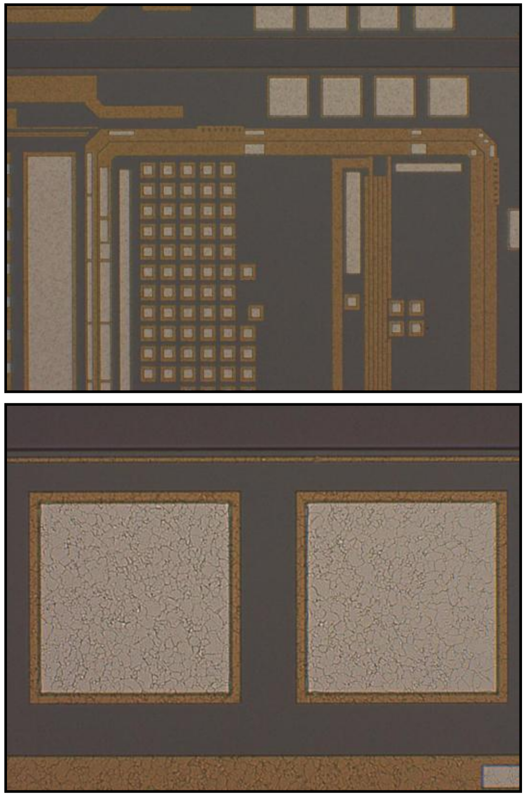
No Pre-Treatment; DI Water



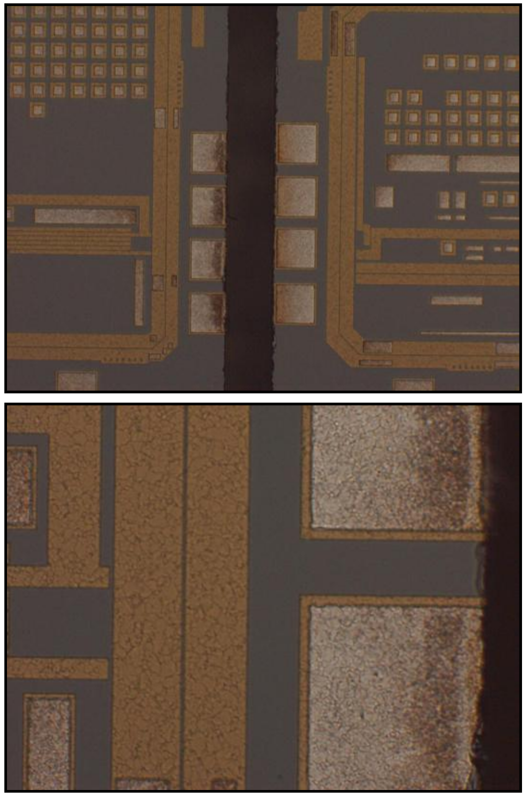
No Pre-Treatment; 50:1 BPS-729

Al Tests with Pre -Treatment

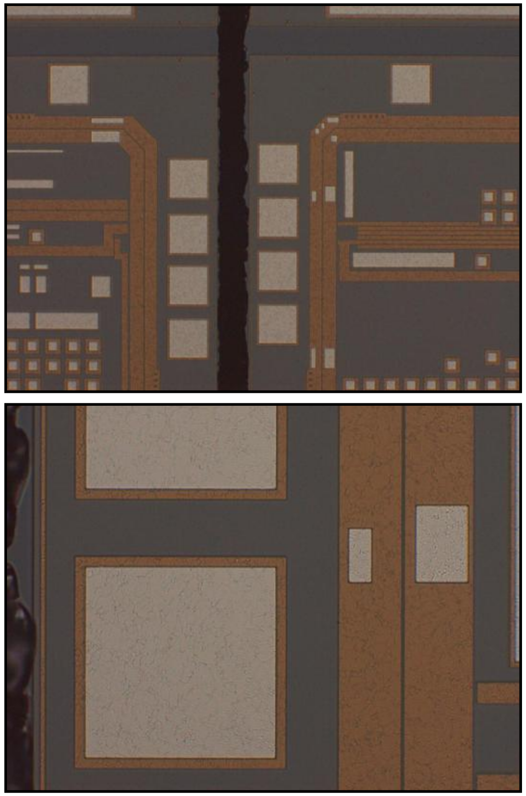
Before Strip



BPS-100 Pre-Treatment; DI Water



BPS-100 Pre-Treatment; BPS-729

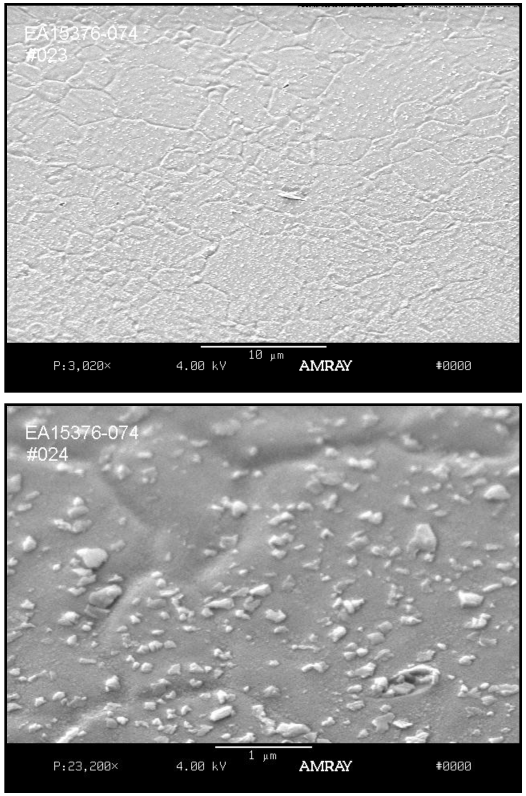


With corrosion layer stripped some protection is needed at saw.

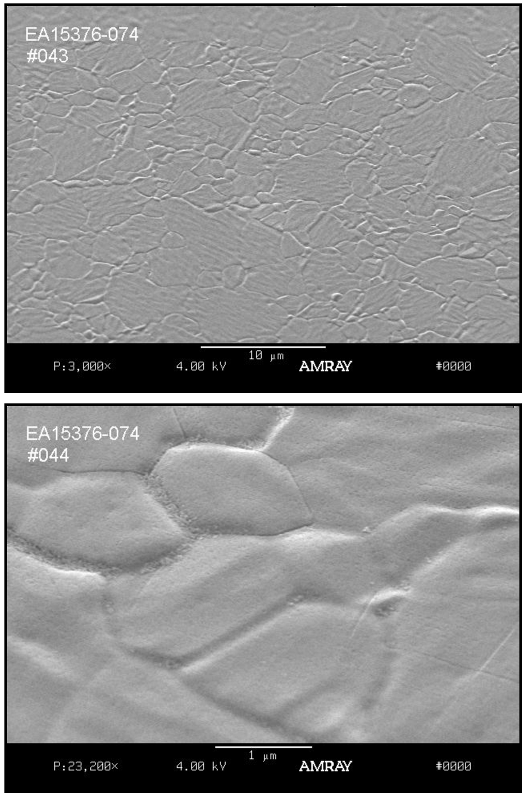
Al Tests Results W/BPS100 To Saw

Stripping the fluorine corrosion can bring the bond pads back to time zero (after metal dep) conditions.

BPS-100 Pre-Treatment; DI Water



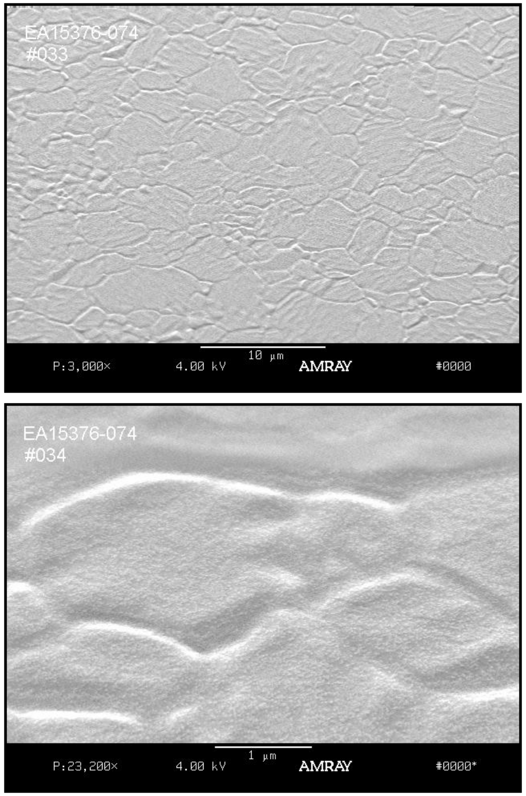
BPS-100 Pre-Treatment; 50:1 BPS-729



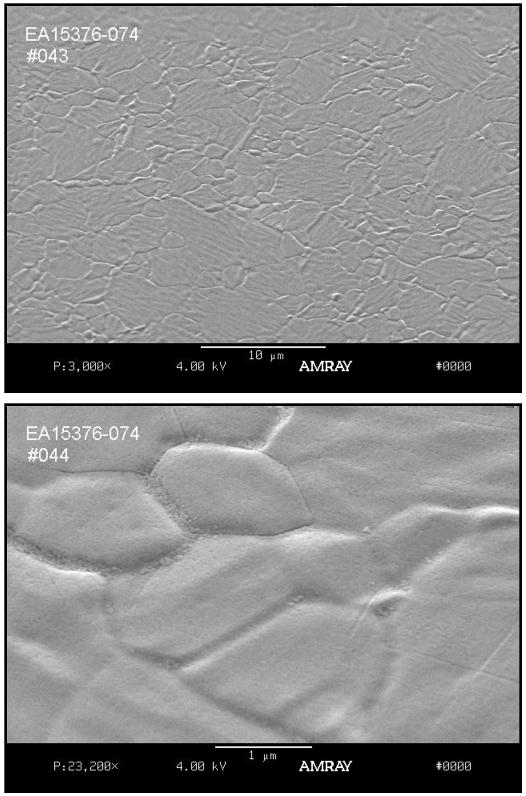
Fluorine Removal Comparison

By providing an additive to saw bond pads can be improved. But most important is the conditions of the pad by removing the initial corrosion layers. Even after saw the grain boundaries are very visible; testament to the conditions of the pads.

No Pre-Treatment; 50:1 BPS-729



BPS-100 Pre-Treatment; 50:1 BPS-729



Typical Plasma Results

Argon plasma is typically used to “sputter” debris onto the wafer/die

Criteria (plasma)	Results (plasma)
Fluorine %, Pre-Cleaning	**4.9%**
Fluorine %, Post-Cleaning	Not detected
Carbon %, Pre-Cleaning	**48.7%**
Carbon %, Post-Cleaning	35.2%
Oxygen %, Pre-Cleaning	**16.3%**
Oxygen %, Post-Cleaning	11.7%

Is this real! Materials ENG 101.

When a fresh aluminum surface is exposed to air it immediately grows ~20A or oxide of some sort.

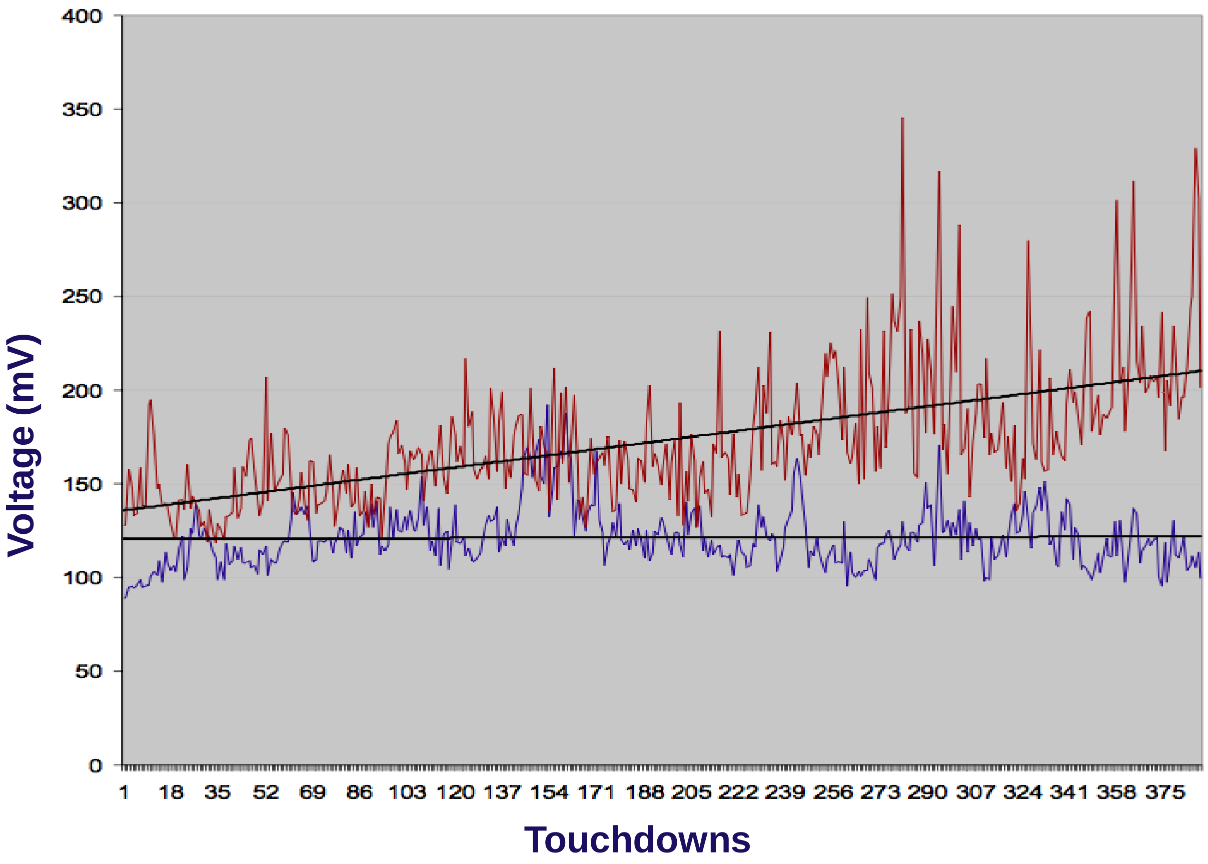
In addition fluorine is detectable up to 300A deep into a sample as AlF3

Plasma data taken from March Plasma 2008 Semicon Wirebond Symposia – EDX used for evaluation; Auger would be more precise

BPS Evaluations for Fluoride Removal

Element, Atomic %	**1) Blank, As-Received**	**1) Blank, 30A Ion Etch**	**2) Test 1, As Received**	**2) Test 1 30A Ion etch**
Carbon	44. 51	37. 45	24. 66	13. 73
Nitrogen	3. 23	5. 96	5. 48	7. 70
Oxygen	16. 18	20. 12	39. 42	45. 28
Fluorine	18. 33	15. 90	5. 87	4. 33
Aluminum Oxide	17. 75	20. 57	24. 57	28. 96
Element, Atomic %	**3) Test 2, BPS As-Received**	**3) Test 2, BPS 30A Ion Etch**	**4) Test 3, BPSII As Received**	**4) Test 3 BPSII 30A Ion etch**
Carbon	33. 04	19. 35	34.38	23.90
Nitrogen	5. 87	7. 54	3. 14	7.78
Oxygen	31. 63	40. 04	36. 10	40.47
Fluorine	9. 83	9. 19	7.86	5.84
Aluminum Oxide	19. 63	23. 89	18. 51	22. 01

Time Zero Contact Resistance Run



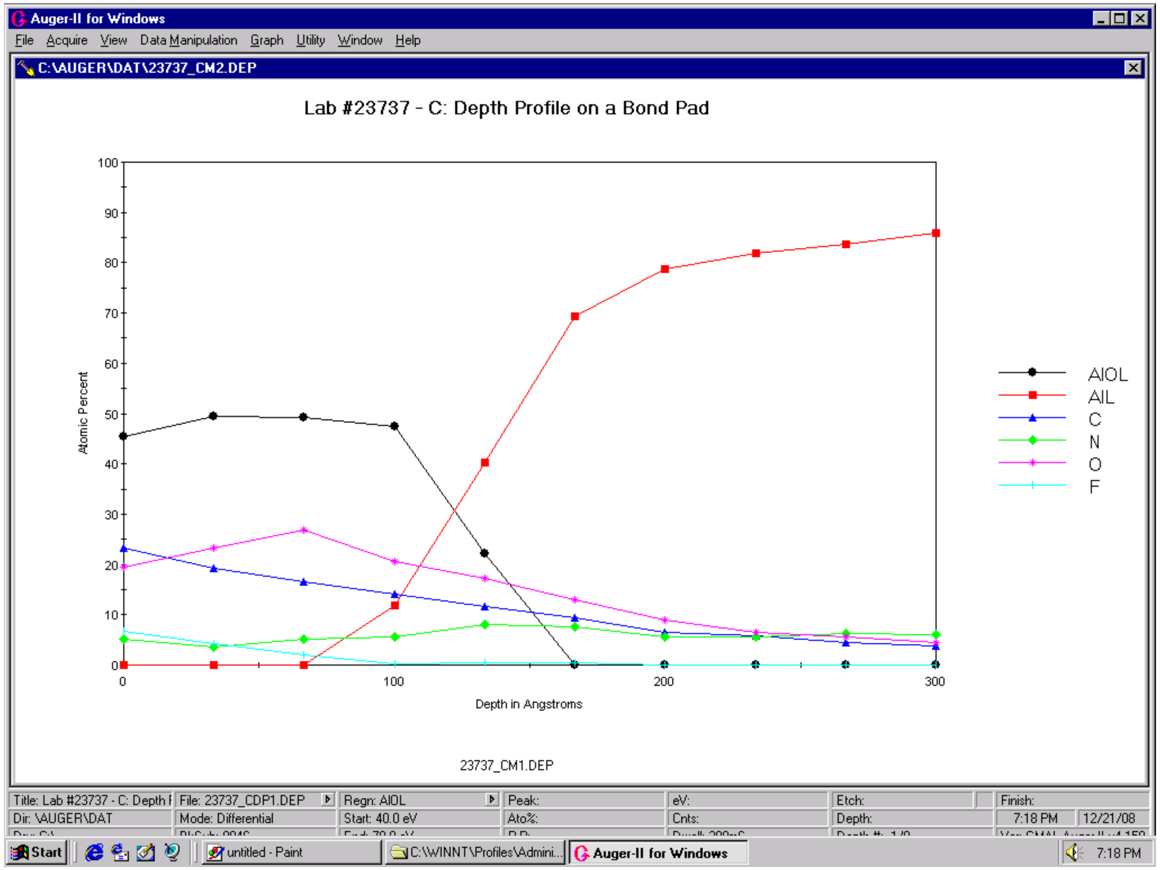
- Lower CRES
- Less Noise
- Fewer false fails
- Less CRES increase over touchdowns

Before BPS

After BPS

Real resistance between two pins on the pad

First Run After Two Weeks.



Title: Lab #23737 - C: Depth P
File: 23737_CDP1.DEP
Regn: AlOL
Peak:
eV:
Etch:
Finish:
Dir: \AUGER\DAT
Mode: Differential
Start: 40.0 eV
Ato%:
Cnts:
Depth:
7:18 PM 12/21/08

Fluorine was only 15A deep into the sample, initially. Aluminum detected at 60A.

Cost of Ownership

	BPS	Plasma	Discussion
Equipment	Wet bench, SRD, SST	Plasma Equipment	Plasma unit cost between $75k to $650k for backend
Consumables	BPS $55/$70 per gallon	Gas (Ar/O2)	BPS has extended bath life.
Cycle time	5 minutes	5-10 minutes	Process cycle time only
Units Per Hour	+250WPH	Up to 60WPH	Depends on equipment
Short Term Reliability Risk	None – BPS does not attack metal	Ar plasma is not a selective etch	Radiation damage on die
Long Term Rel Risk	None – does not attack Si or Si3N4	Inadequate cleanup of F and OH	Argon can damage structures and layers particularly MEMS
Reworkable	Repeat cleans ok	One time use	Component damage on repeat exposure

Conclusion

- Fluorine contamination was found deeper than 300A into sample
- Unless fluorine is completely removed the corrosion will regrow
- BPS products can be used to effectively remove fluorine without die damage
- Process can be completed in less than 5 minutes and has less than 1A/min on aluminum, PI and PO.

Thank You

CVInc appreciates you listening to our presentation and the acceptance by IPC. Any questions can be directed to TQCollier@covinc.com