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Semiconductor Wafer Test Workshop

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Controlling CRES

Clean the Wafer, Not the Probe Card!

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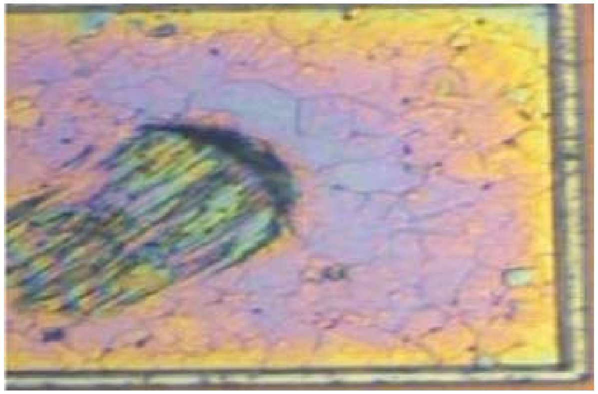
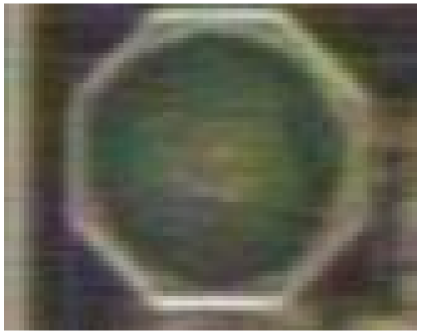
Why Clean the Wafer

- Root cause of high contact resistance (CRES) is corrosion and contamination, not the probe card. Goal should be to eliminate fluorine corrosion on bond pads
- A process that will strip the corrosion/oxidation but not attack the base metals is desired. Traditional methods include plasma and phosphoric (PAN or dilute phosphoric) acid derivatives for aluminum. Unfortunately phosphoric goes after good aluminum as well.
- Improve cost of ownership:
  - *Extend hardware life.*
  - *Improve assembly yield.*
  - *Reduce scrap die and wafers.*
- Reduce reliability risk and regain process control.
  - *Damaged pads lead to customer returns*

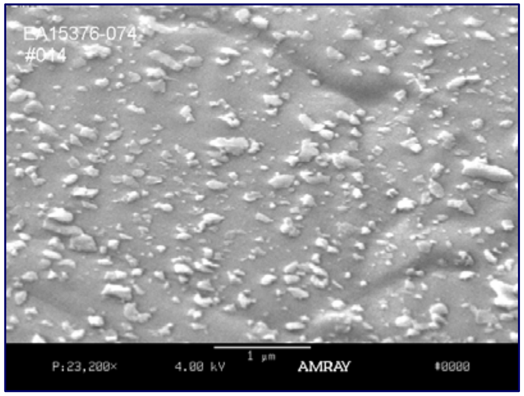
A Better Process Solution for Your Pads and Bumps

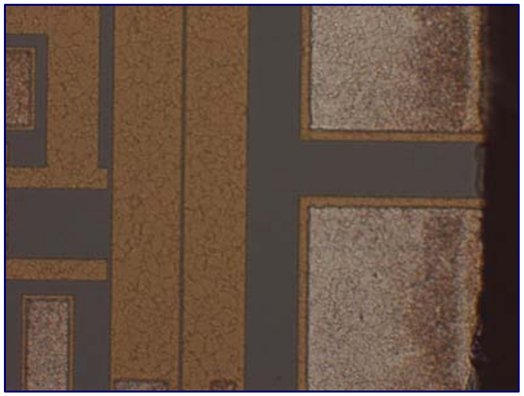
Fluorine induced corrosion

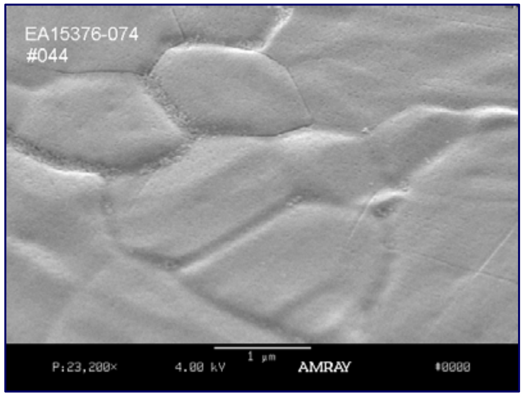




This is the desired pad condition for test, saw and assembly. Fluorine & oxide corrosion removed.



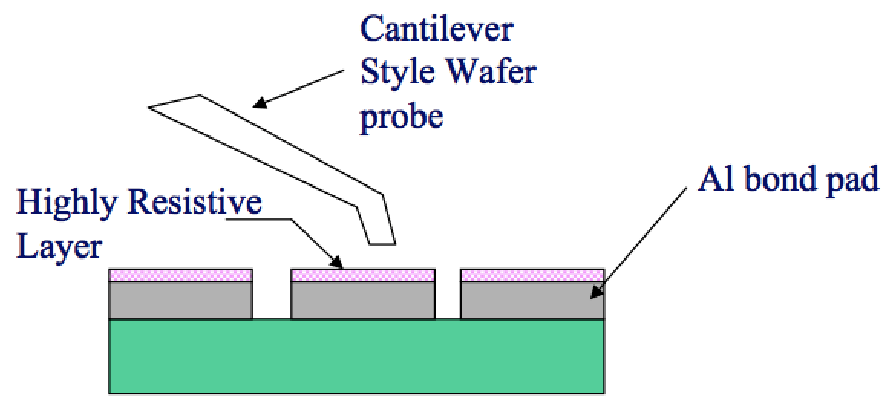




The Problem Statement - Probe

10kA-20KA thick Al layer;

Very thick corrosion layer



Visualization of a typical cantilever style probe on a bond pad

- Two items impact post fab yield:
  - Test hardware
  - **Bond pad conditions.**

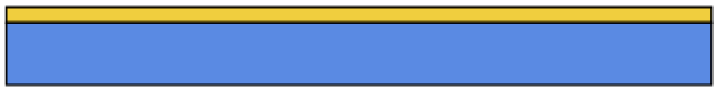
Removing the highly resistive layer can improve yield, extend probe card life, minimize reliability issues and help manage process control constraints

Goal: Remove the resistive layer without damaging the underlying metal layer.

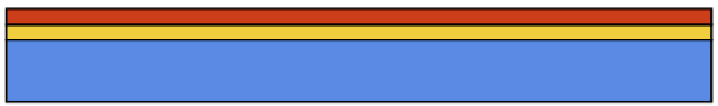
What process has the following capabilities:

- Low etch rate on metals
- Low etch rate on passivation layers and Si.
- Love oxide and corrosion.

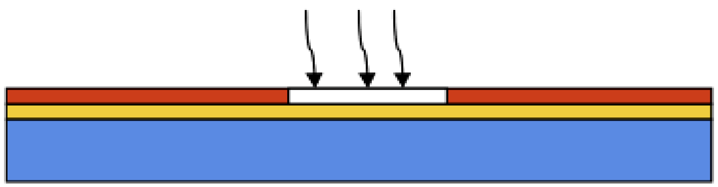
Bond Pad Fabrication Process



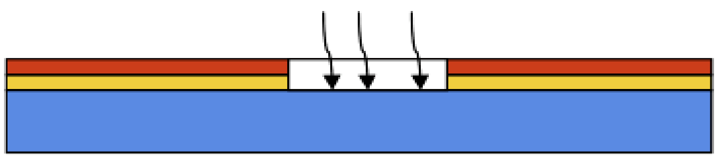
Si_3N_4 passivation applied to wafer to protect wafer surface



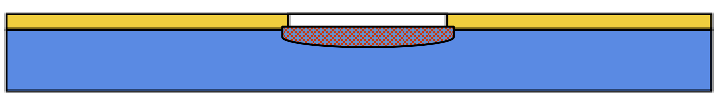
Photoresist layer applied to passivation to create openings for the bond pads, test structures and saw streets.



CF4/SF6 plasma used as an etch gas to open Si_3N_4 (or other inorganic passivation)



Goal is to remove all the Si_3N_4 else probe, wire-bonds, WLCSP processes are compromised



Si_3N_4 is completely removed from the Al pad but excess time on plasma converts some Al to AlF which is not volatized in the plasma. Some F penetrates grain boundaries and remain as free fluorine.

Fluorine Induced Aluminum Corrosion and Contact Resistance (CRES)

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

Typical F and corrosion layers:

Al + F →AlF3

AlOF +H2O

AlO+H2O

AlOH+H2O

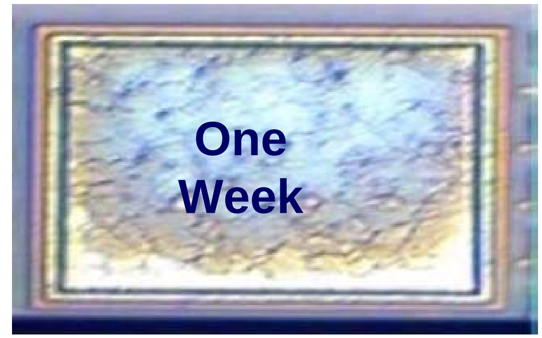
~~Al +CF4~~
~~(not good)~~

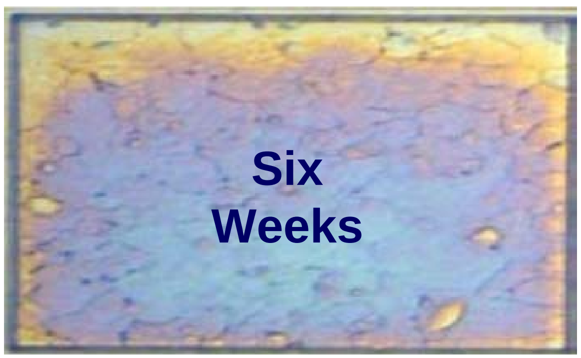
Aluminum oxide grows immediately to 20A then slows to 50A and then 100A over time. Passivation opening using fluorinated gasses initiate various corrosion layers and consumes aluminum metal.

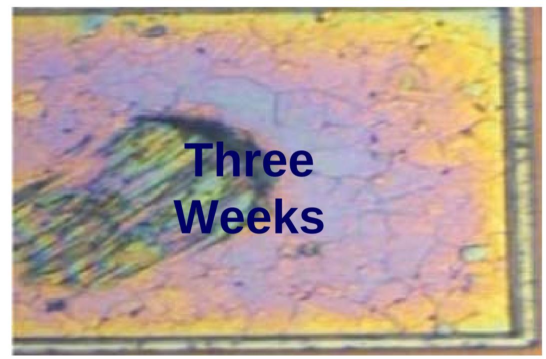
AlF3 is only slightly soluble in 25C water.

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 free fluorine. **AlF3 is slightly reactive in water and takes a much longer time to grow back a corrosion layer.**

Al Bond Pad Analysis Over Time



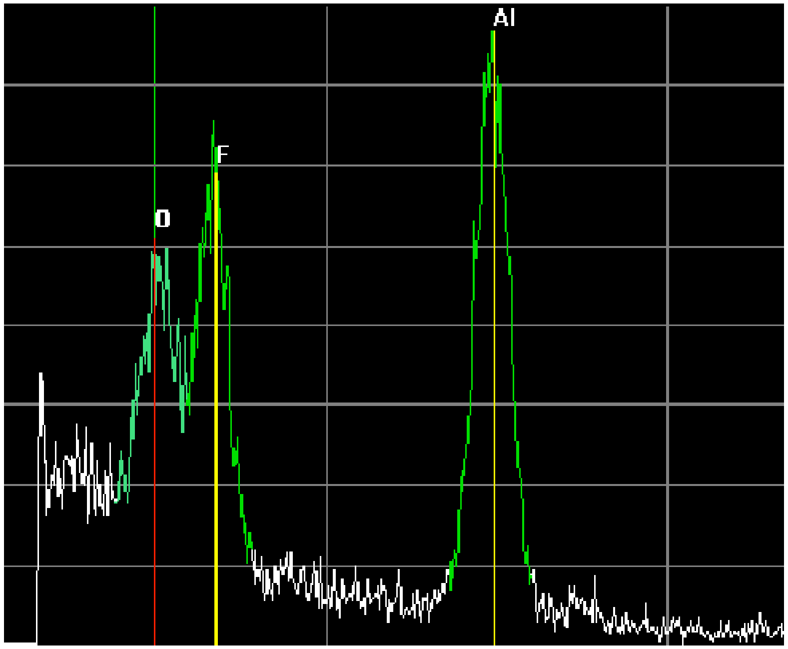




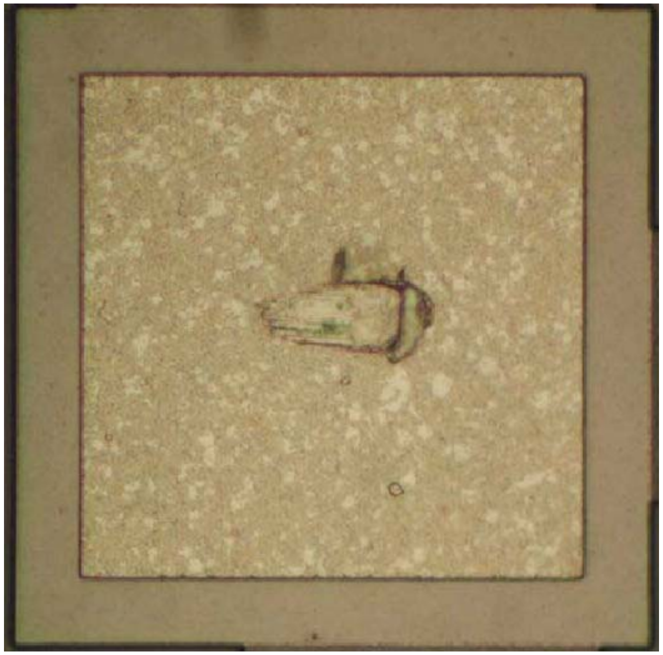
Dry Box Conditions - Fluorine contamination is apparent at time zero as received. As time continues the pads become more corroded. Conditions of these pads are typical and are the root of poor contact resistance. If the pads are not cleaned then poor yield is likely as well as die and hardware damage.

Post Probe Fluoride Corrosion

Downstream corrosion – fails wire bond



EDX results show OF covers more of the surface than Al



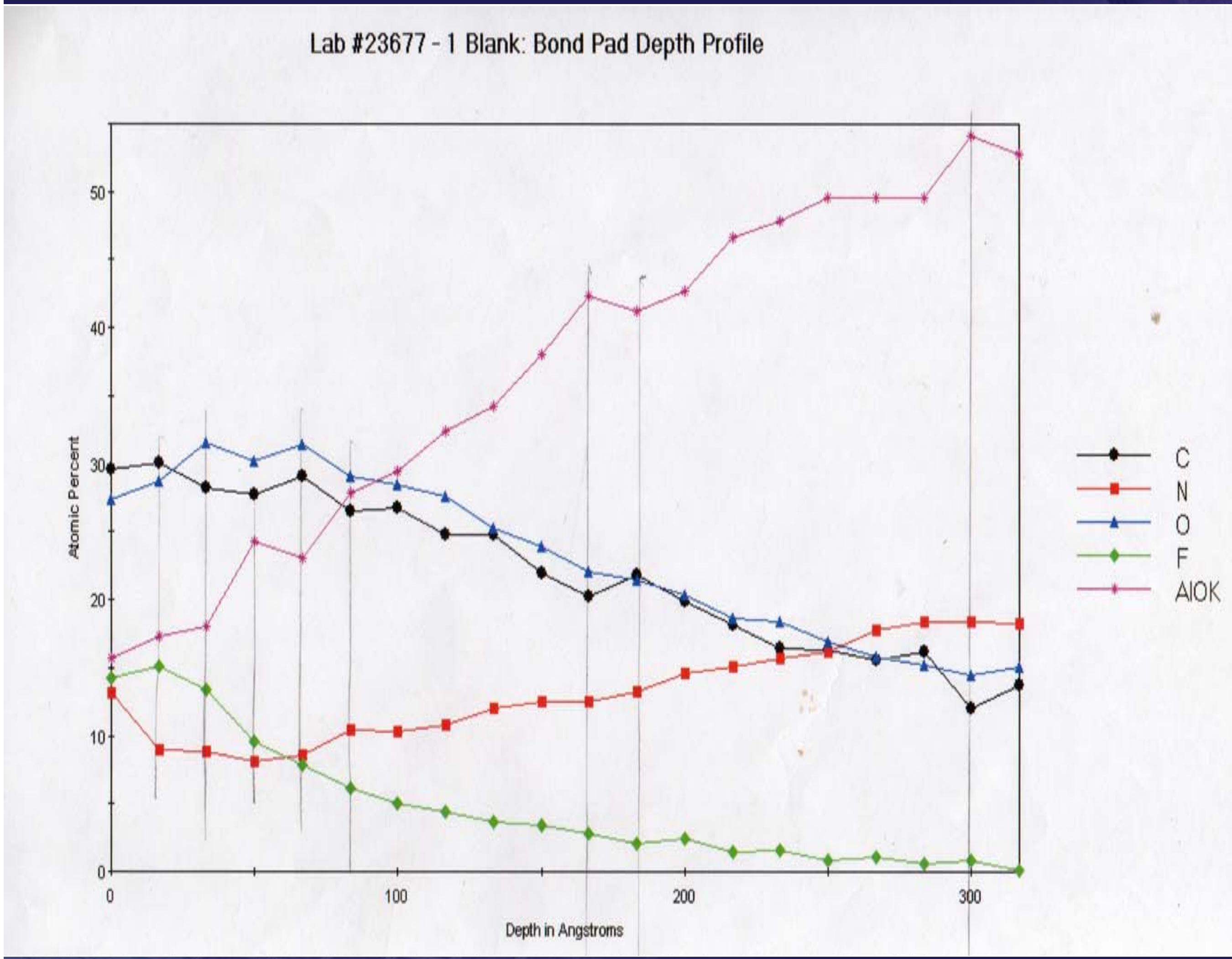
Optical image verifies that Al (white) is sparse. Fluorine corrosion regrowth in the probe mark.

CRES After Treatment

- **Root Cause of High Contact Resistance**
  - Fluorine from passivation opening on pads lead to Al corrosion
  - Thickness of corrosive layers will be much thicker than the natural oxide and can exceed 250A in many cases
  - Probing on F can imbed the halogen deep into the pad
  - At high temp probing the corrosive effects will be accelerated.

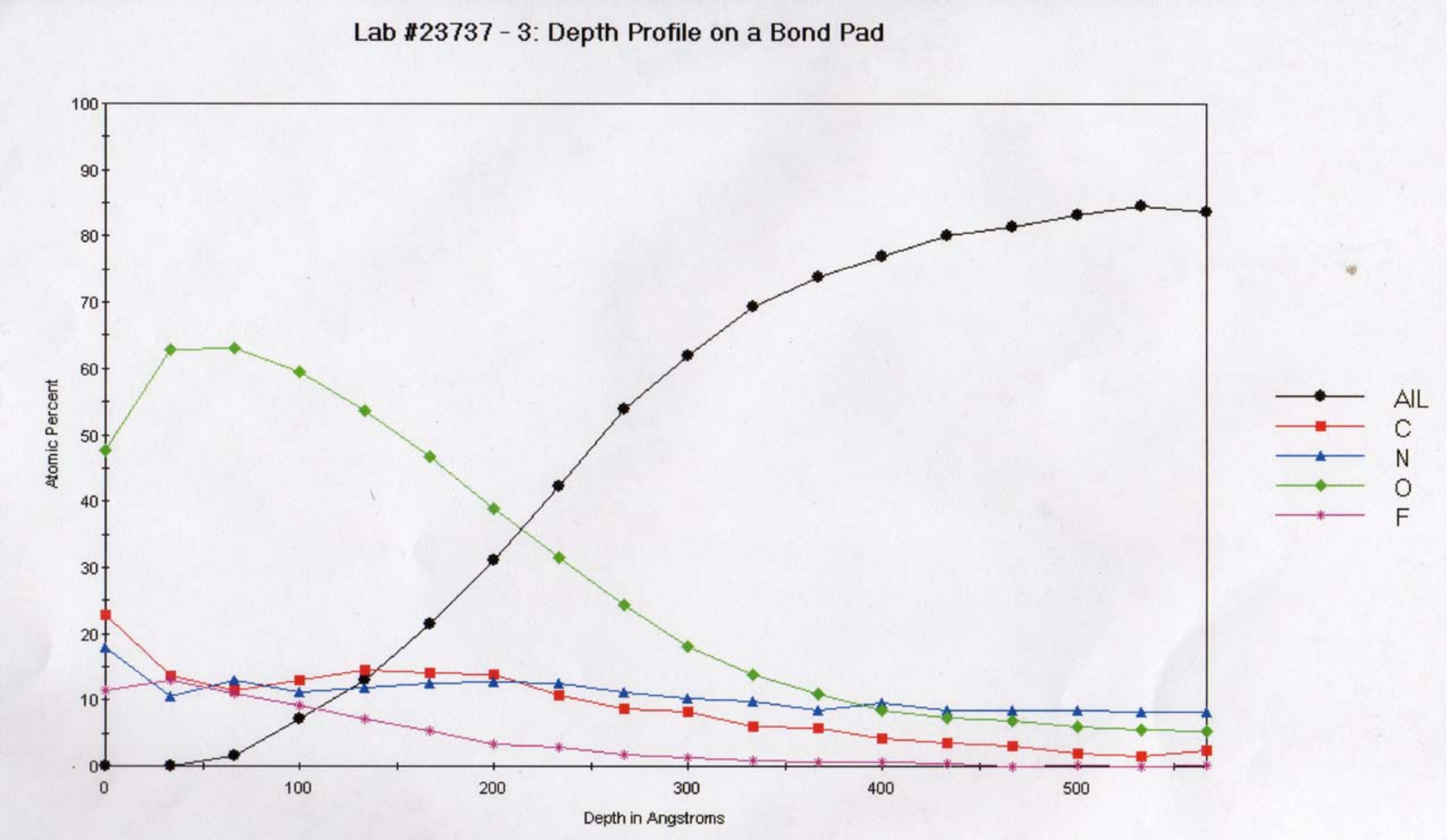
- **Process Improvement (BPS100/101)**
  - Remove the AlOF/AlO+OH and corrosion stops at the natural oxide thickness ranging from 20A (hours) and terminating at 50A after a few months
  - Improved test results as contaminants removed, demonstrated that cleaned versus non-cleaned wafer is improved.
  - Removing F ions eliminates corrosion at saw (excess H2O)

As Received Wafer

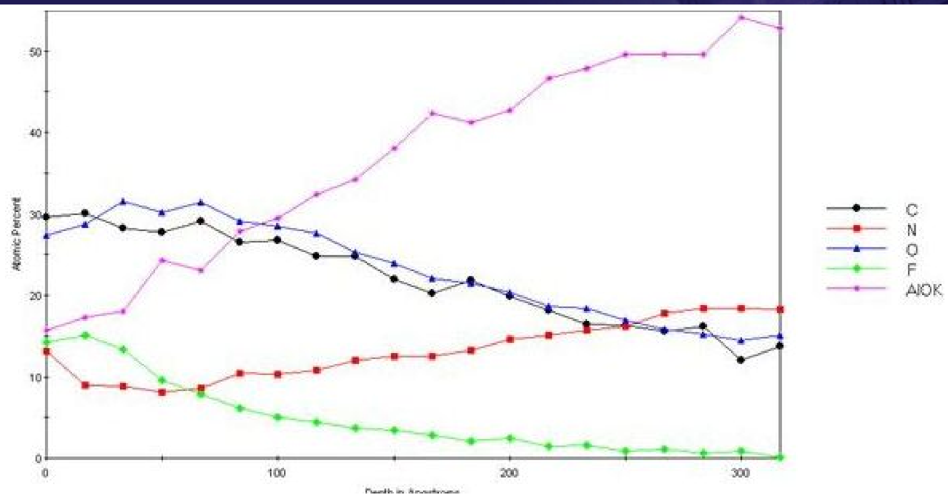


- High initial F
- F detected at +300A
- AlO increasing
- AlO does not sputter at same rate as others
- Fluorinated C molecules detected

Fresh from the CF4 Plasma



Pad Analysis

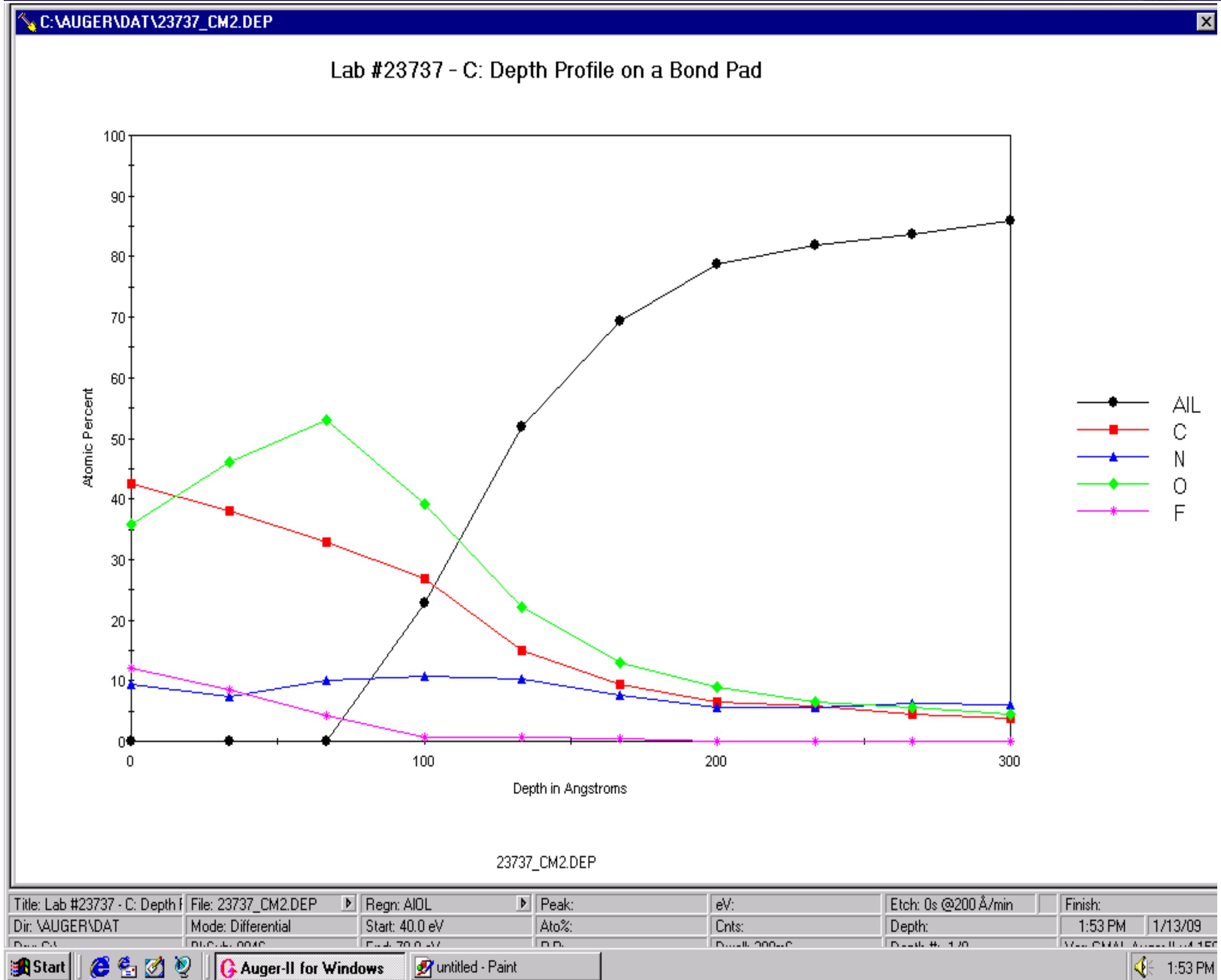


Preclean pads show a high amount of fluorine compounds. At 300 angstroms no “pure” aluminum metal is found. The auger detects AlO but is not capable of differentiating various AlO materials (AlOH versus AlOF). The F is likely a combination of AlF3, AlOF and CxFy.

Auger ion milling with initial reading at the surface. Carbon is likely fluorinated organic resulting from CF4 plasma. The goal is to remove as much of the free fluorine as possible. If the free fluorine is not completely removed the AlO and AlOF will regrow.

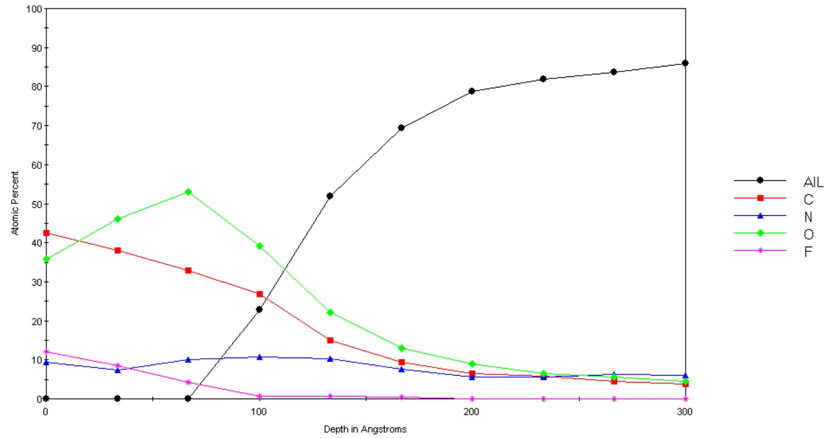
Using CF4 as an etch gas, the peak fluorine level is at 15% prior to reaching 5% at 100A and beyond. AlF3 is 3% to 4.5% as a layer.

Post BPS100 Clean



- **Al detected prior to 300A**
- **F drops to zero at 100A**
- **C drops to under 10%**
- **O drops to below 10%**
- **Al0 species removed**

Post Clean Analysis

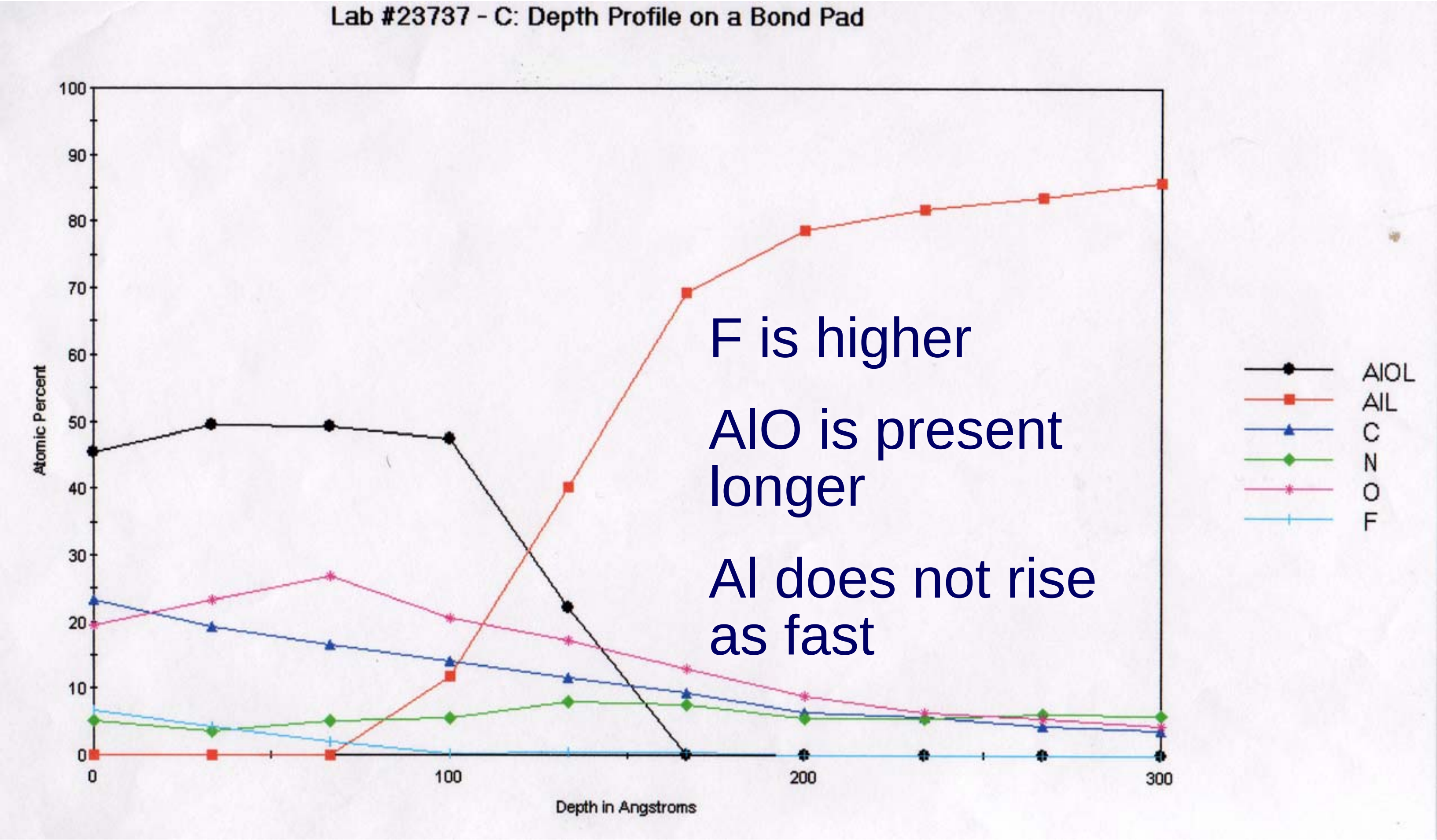


Post clean analysis shows “pure” aluminum metal at 75 angstroms. The auger analysis was run 3 weeks after clean to determine how long the surface would be viable.

When a pure aluminum surface is cleaved it will immediately grow 20A of oxide. That oxide will reach 50A to 75A as detected by this graph. The presence of small amounts of fluorine can speed the growth but the BPS100 solution demonstrates a drastic improvement over the original surface.

Fluorine counts, going to zero at just over 100%, is much lower than the original fluorine amount. AlO is not detected as the surface on aluminum is likely an Al-HOH layer.

Clean Rate Changes

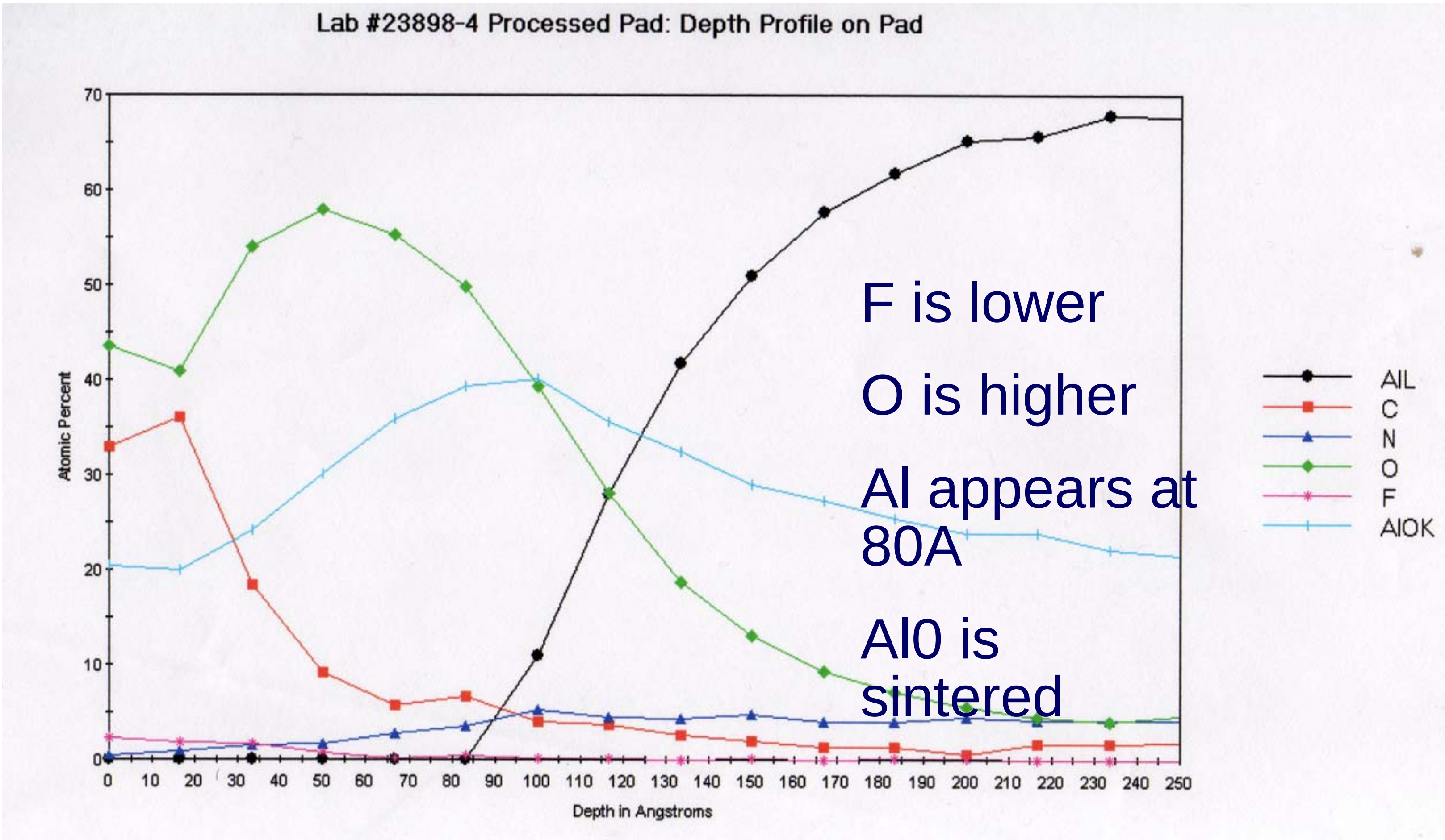


F is higher

AlO is present longer

Al does not rise as fast

Clean Rate Change II



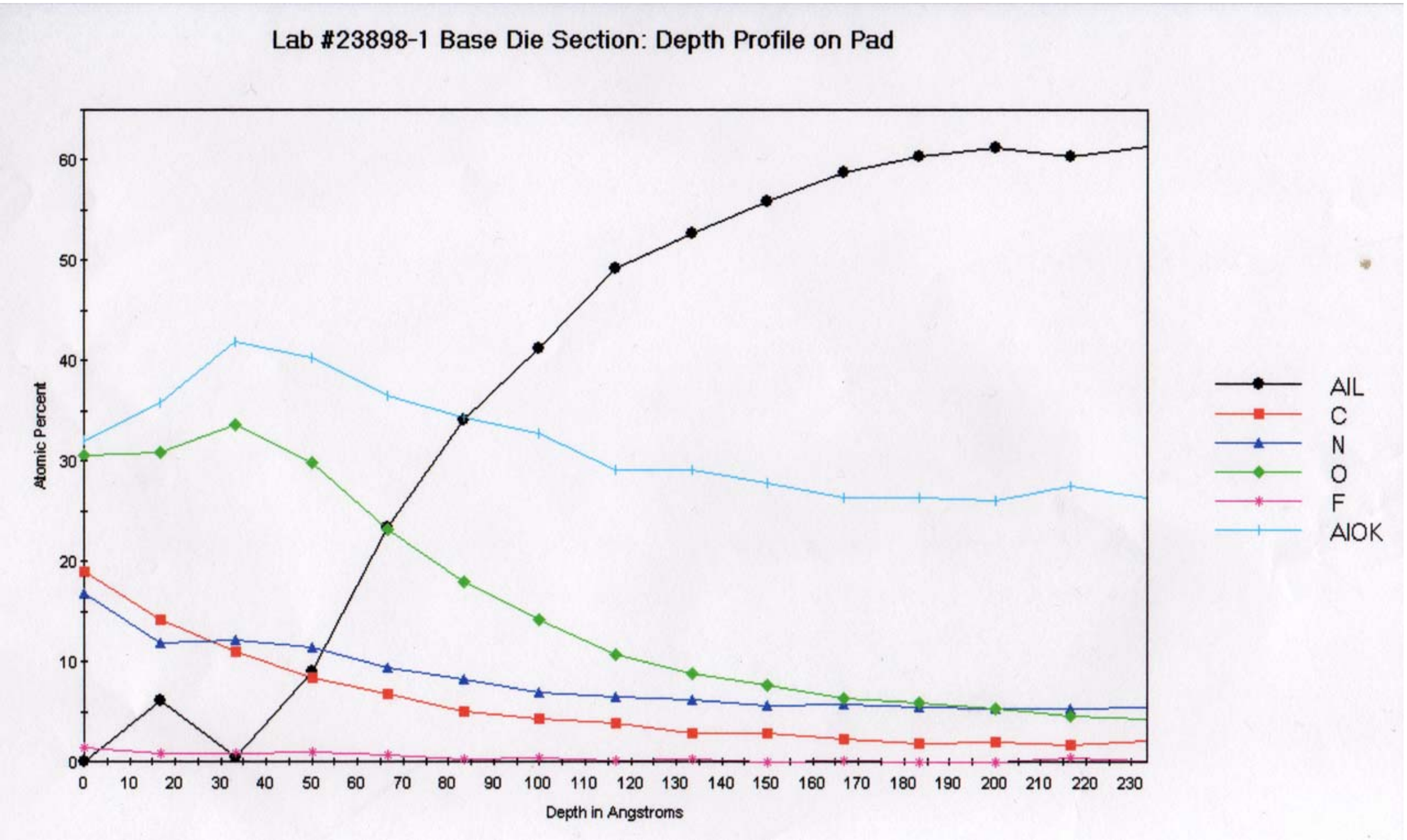
F is lower

O is higher

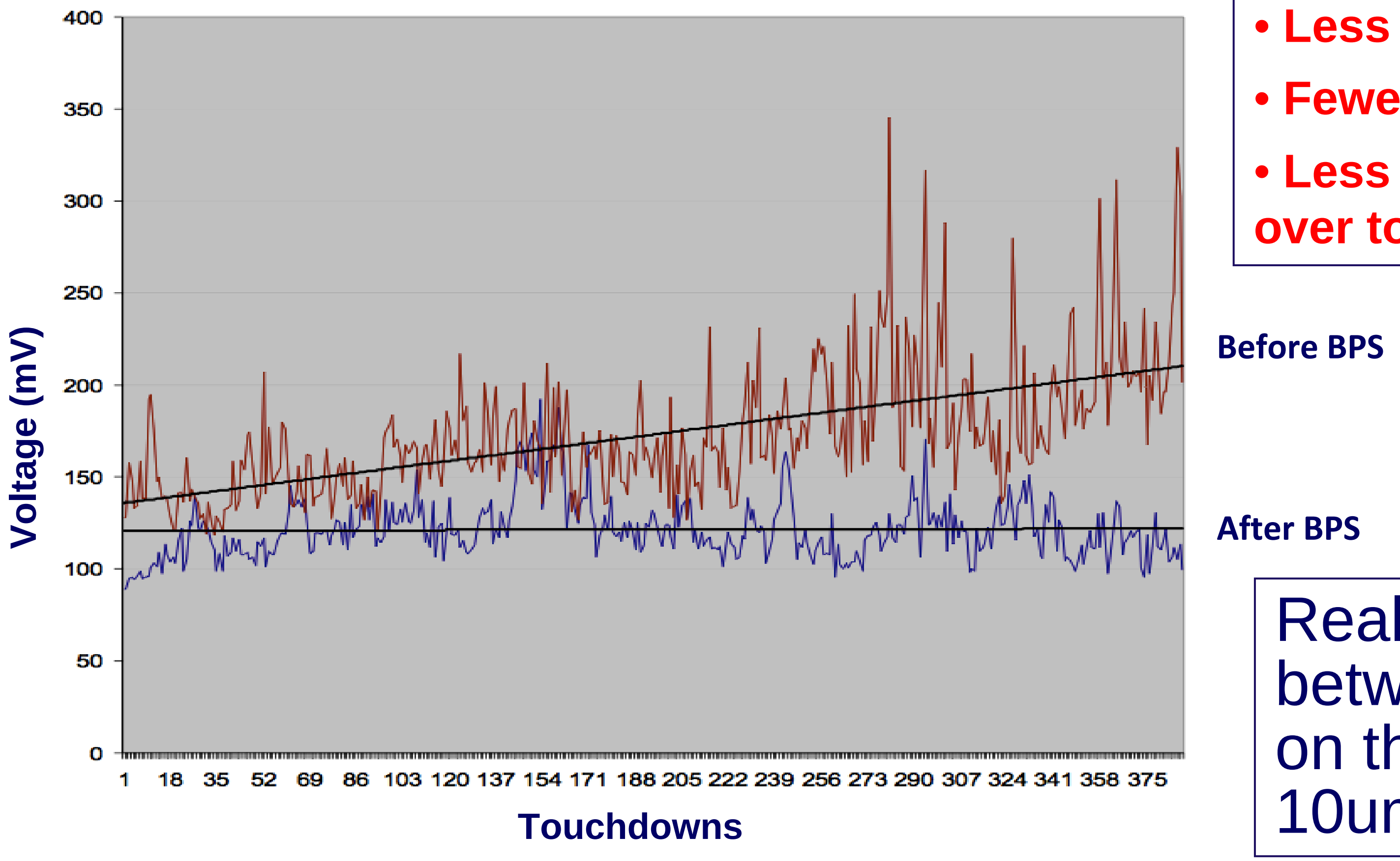
Al appears at 80A

Al0 is sintered

Clean Rate Change IIA



Dramatic Results After BPS on Al



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

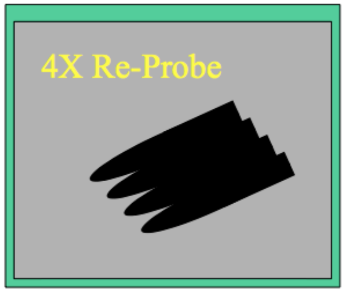
Real resistance between two pins on the pad at 10um overtravel

Auger/EDX Analysis - Discussion

- **Oxygen and fluorine peaks on EDS spectra are smaller on processed Al bond pads**
    - Oxygen and fluorine peaks on processed pads are almost down to background noise level
    - Processed Al bond pads have lower amounts of oxygen and fluorine on their surface than unprocessed pads

- **BPS-101 removed most of the oxygen and fluorine on the Al bond pads**
    - This should results in lower CRES
    - Process time needs to be optimized for this wafer condition

Downstream Problems Caused by Probe Yield



Depiction of Reprobe

• Compounding initial poor bond pad surface conditions, damaged pads introduce additional variability and yield loss further downstream (saw and **wire bond).**

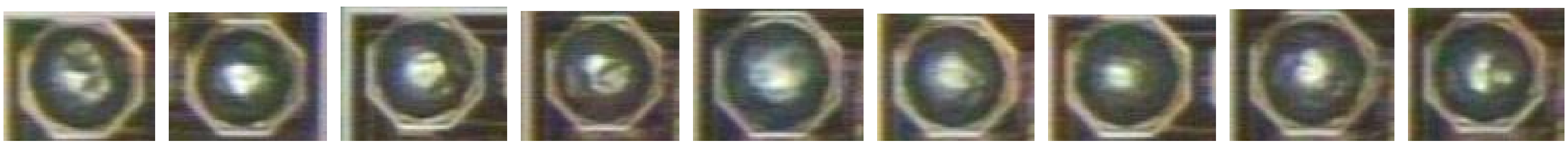
• Saw – Infinite amount of H2O to accelerate the HF/DI/Galvanic corrosion problem. Agressviely probed pads might also demonstrate corrosion down to barrier and adhesion level metals

•Wire bond requires a clean contact surface free of debris, probe voids, contamination, particles and expecially corrosion. Some fluorine is not detrimental but excessive fluorine and corrosion by-products can lead to time zero and longer term reliability issues.

Bump Evaluation on CSP Wafer

Before Chemical Clean (temp cycled wafer)

After Chemical Clean



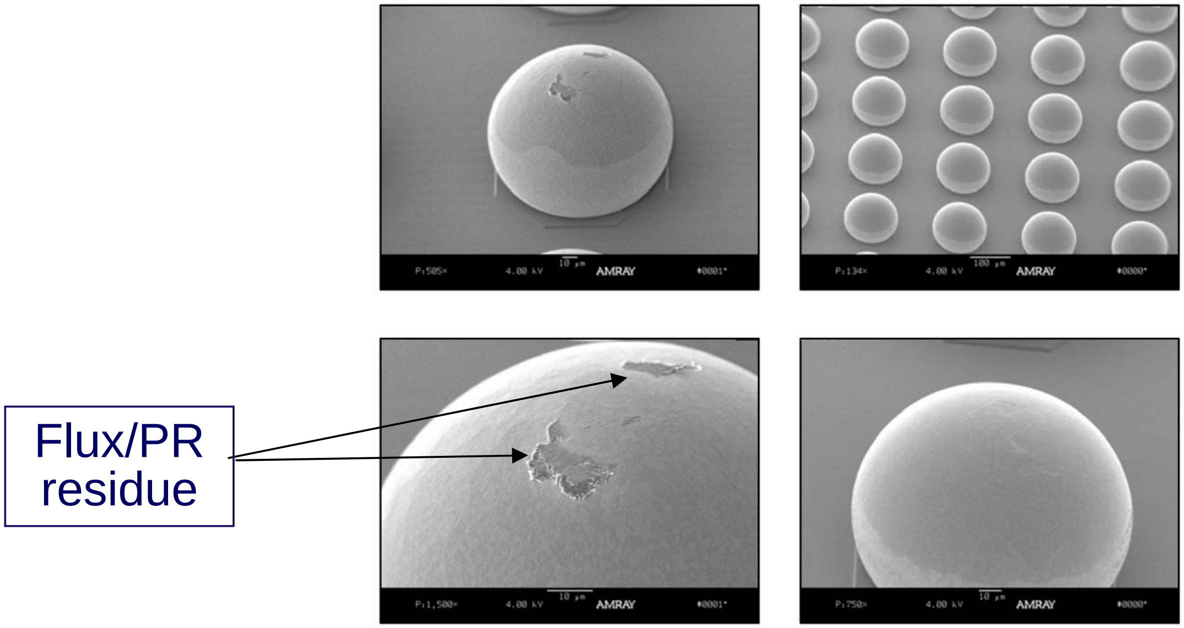
Soak wafer in Cleaner

40 °C for 5 to 6 mins

Rinse with DI water for 1 to 2 mins

Dual Benefit of removing both oxide and burned organic materials in one process!

Oxide/Organic Residues on Bumps

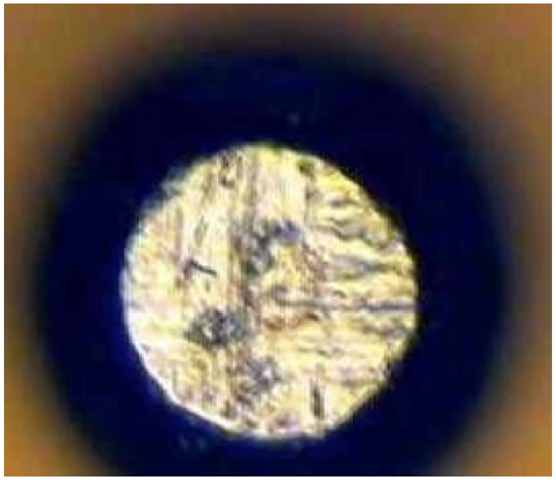


Before Strip **BPS-125, 25°C, 2 min**

- Bumps do not arrive clean. In addition to oxidation, organic contaminate the surface of the bump and lead to poor probe results.
- Images show bumps with photoresist residue as received from the bump house.
- Wafer was cleaned with BPS125 for 5 minutes then BPS170 to remove oxide.

Residue Deposited on Probe Tips

Cantilever Probe Tip

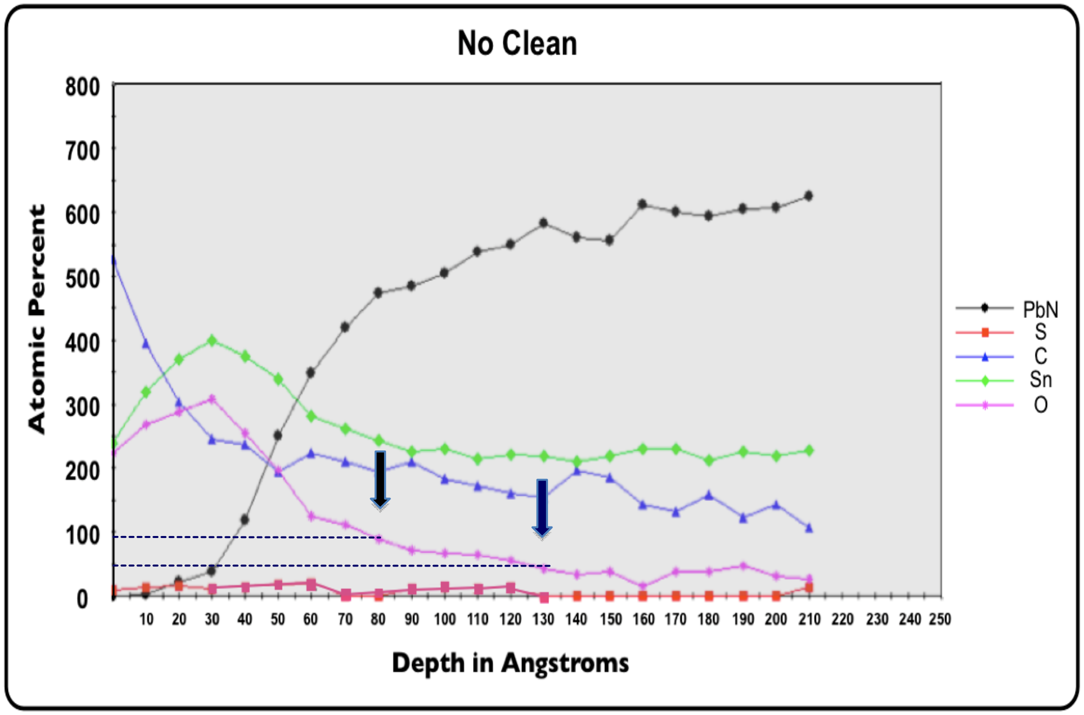


Vertical Probed Bumps

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).

Highly Oxidized SnPb Bumps



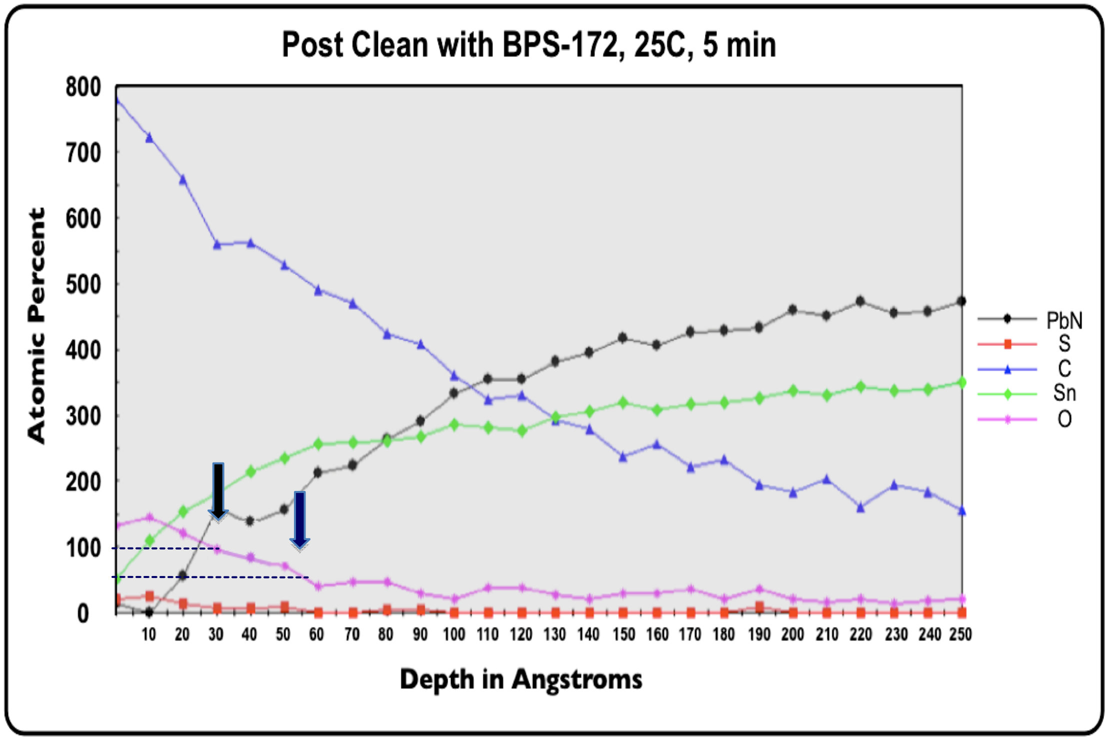
Before Clean:

Recently processed wafers with 10% level reached at 80 Å and 5% level at 130 Å Area under oxygen curve is high

Highly oxidized bumps require 2nd reflow, scrap or aggressive flux..

Oxide levels determined by Auger milling to 250 Å depth

BPS 170/172 for SnPb Bumps



<u>Wafers cleaned</u> with BPS-172:

10% level reached at 30 Å and
5% level around 55 Å
Oxygen levels lowered by 70%!

5 minutes in BPS170/172 reduces oxide and can eliminate the need for flux during assembly

Oxide levels determined by Auger milling to 250 Å depth

BPS Costs versus Benefits

COSTS

- Material & Application
- Tool Type
  - Single wafer spray tool
  - Batch tools
  - Wet Bench (Bath)
- Process Times
- Recirculation/One-Time-Use

BENEFITS

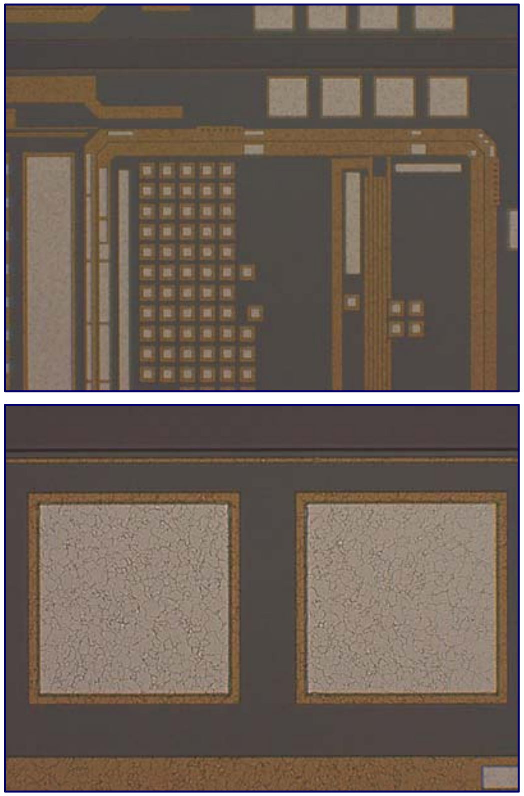
(Recovering costs of poor probe)

- Probe card cost & repair costs
- % yield lost
- Probe time
- Technician overhead
- Probe card cleaning media
- Assembly yield cost
- Short and long term reliability concerns

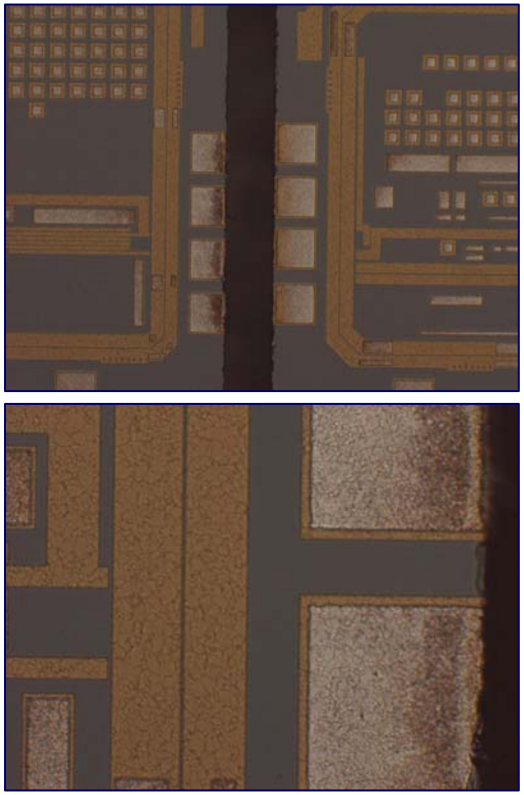
BPS benefits far outweigh the costs ➔ overall cost of ownership is greatly reduced

Al Tests with Fluorine Removal

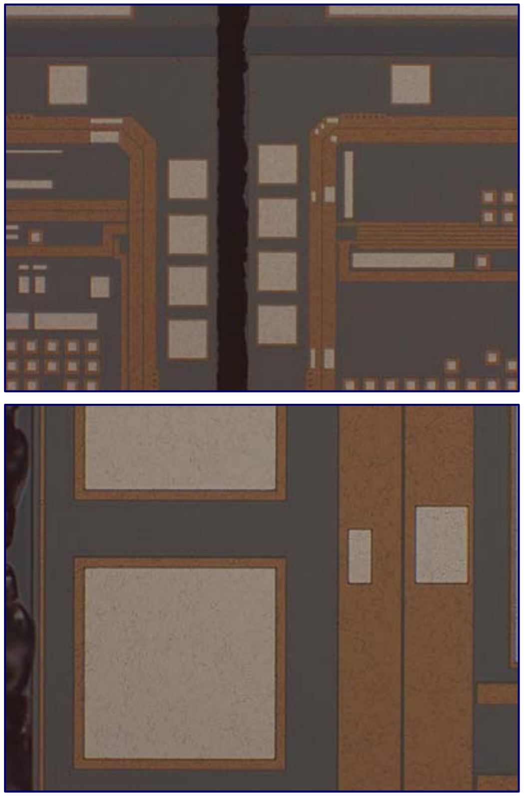
Before Strip



BPS-100 Pre-Treatment; DI Water



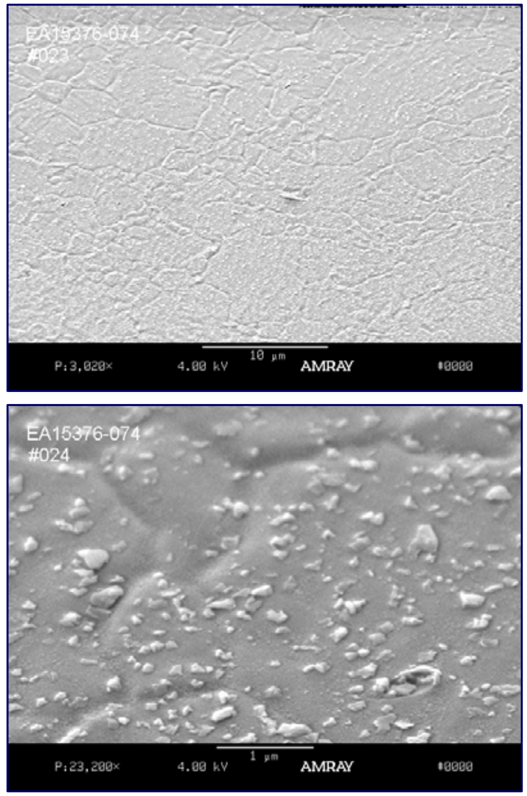
BPS-100 Pre-Treatment; BPS-729



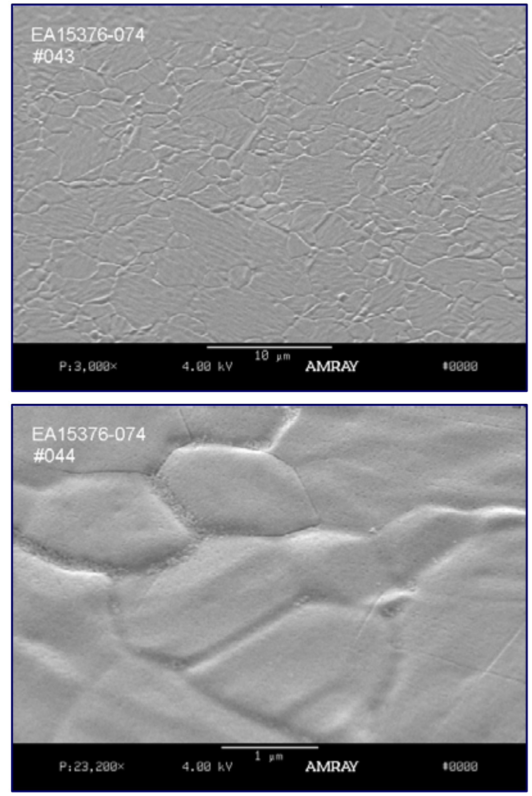
Al Tests Results W/BPS100 To Saw

Preclean to remove the oxide carries over to the BPS729 saw. Not only is the Si slurry missing but the initial oxide has been removed and not grown back as evident in the clarity of the grain boundaries

BPS-100 Pre-Treatment; DI Water



BPS-100 Pre-Treatment; 500:1 BPS-729



BPS 100/101 - Al Bond Pads

- 5 minute process + 30 second DIW rinse
- High selectivity of oxide to base metal (<4A/min etch on Al)
- Oxides, carbon and corrosion (fluorine induced) removed
- CRES virtually eliminated
- Extended probe card life
- Real time processing
- Long bath life

Al Bond Pad Treatment	Atomic % by Element				
	C	O	Cu	Al	Si
Without	16.17	8.97	3.64	61.46	9.76
After	0	0	4.19	93.45	2.36

BPS -vs- Plasma Results

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

Criteria (plasma)	**Results (plasma)**		**Criteria (BPS)**	**Results (BPS)**
Fluorine %, **Pre-Cleaning**	4.9%		Fluorine %, **Pre-Cleaning**	14.7
Fluorine %, **Post-Cleaning**	**Not detected**		Fluorine %, **Post-Cleaning**	**<3%**
Carbon %, **Pre-Cleaning**	48.7%		Carbon %, **Pre-Cleaning**	30%
Carbon %, **Post-Cleaning**	**35.2%**		Carbon %, **Post-Cleaning**	**<5%**
Oxygen %, **Pre-Cleaning**	16.3%		Oxygen %, **Pre-Cleaning**	27.9%
Oxygen %, **Post-Cleaning**	**11.7%**		Oxygen %, **Post-Cleaning**	**15.6%**

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

BPS Summary

Clean the wafer, not the probes!
Root Cause of the problem are dirty bumps and pads!

- Five minutes in BPS will remove the oxides on metals
- Five minutes to remove fluorine corrosion byproducts.
- Reduces bottlenecks.
- Reduces hardware costs.
- Improves yield.
- Improves cycle time.
- Decreases reliability risks.
- Decreases test costs.

BPS eliminates both oxidation and corrosion

“CLEAN THE WAFER, NOT THE PROBE CARD!”

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