Optimizing the Plasma Treatment Process Prior to Conformal Coating to Eliminate ESD-Induced Failures without Impact on Coating Performance

Trevor Zitek

NanoBio Systems

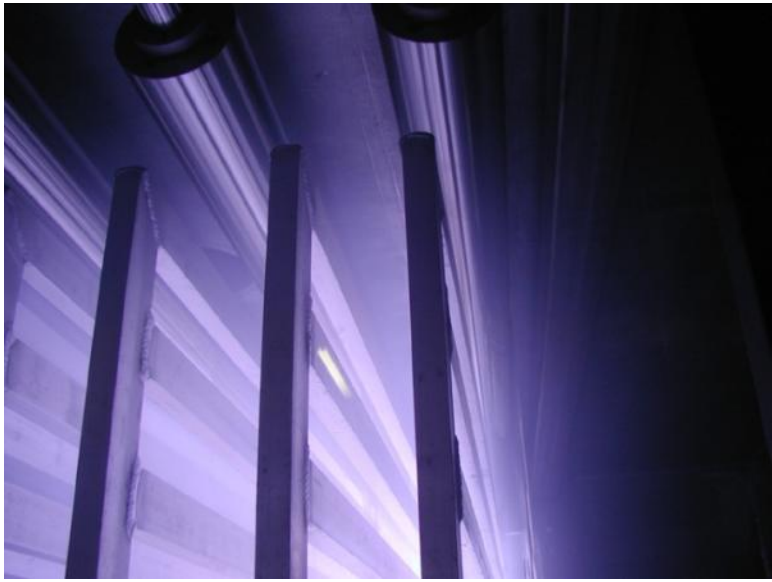
Collaborators

Nordson MARCH

SMART Microsystems

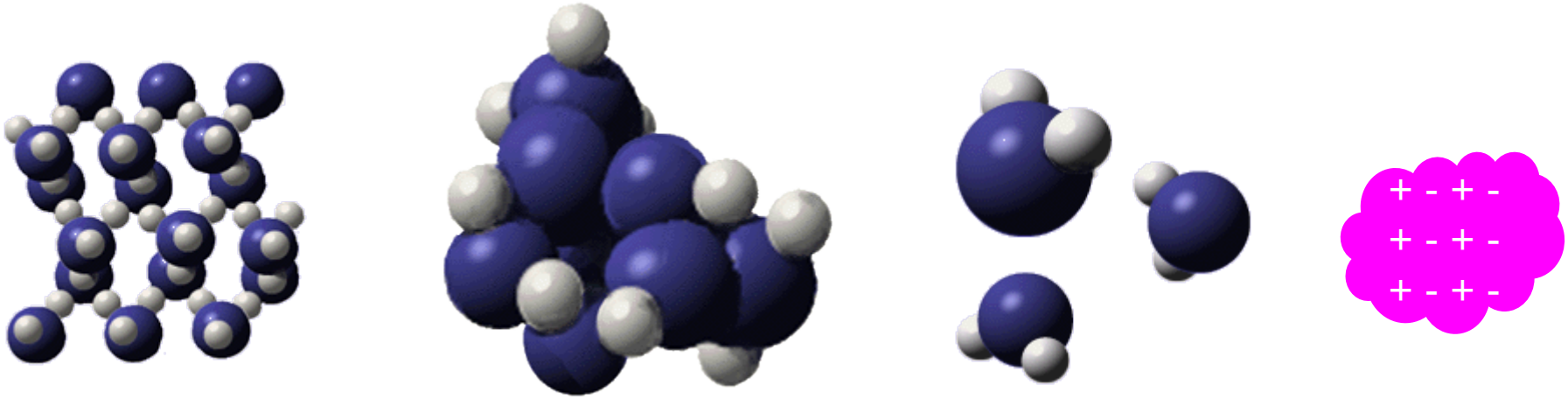
Lorain County Community College

Agenda



- Plasma Technology
- Applications for Plasma
- Adhesion Enhancement Using Plasma
- Addressing ESD Issues in Plasma Processes
- Conclusions

What is Plasma



Solid → **Liquid** → **Gas** → **Plasma**

Energy **Energy** **Energy**

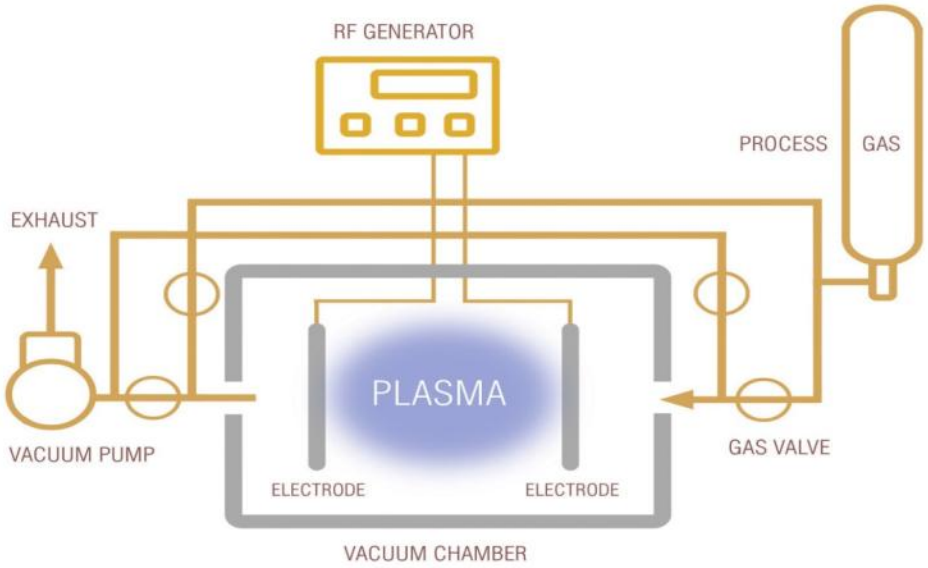
Plasma:

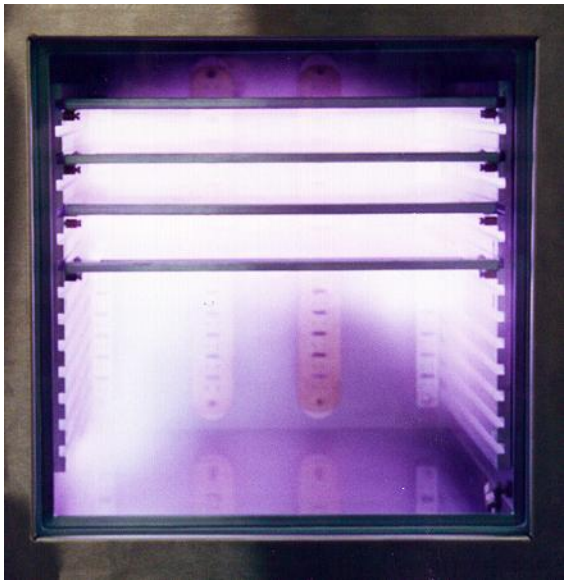
Sometimes referred to as the 4th state/phase of matter

Similar to gas phase, but capable of conducting electricity

Vacuum Plasma Technology

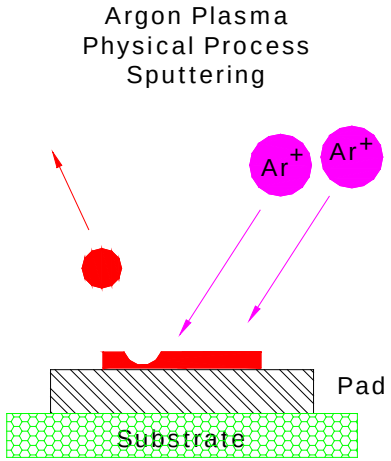
- Samples placed in reactor
- Evacuate air, input desired process gasses
- Apply RF energy across electrodes for surface treatment

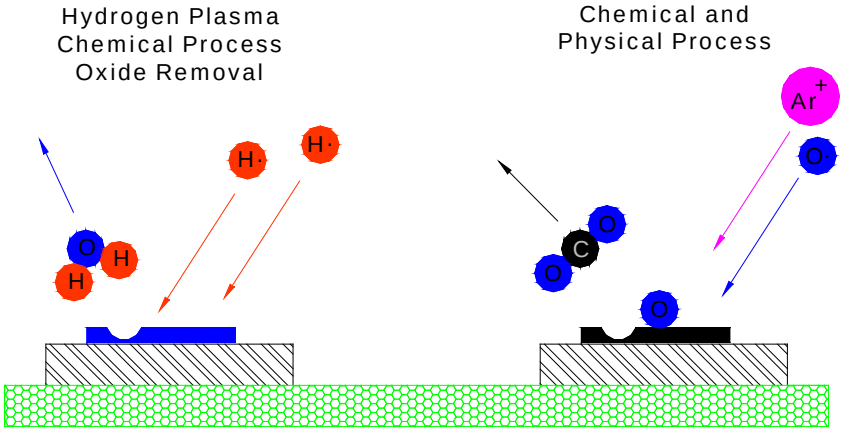




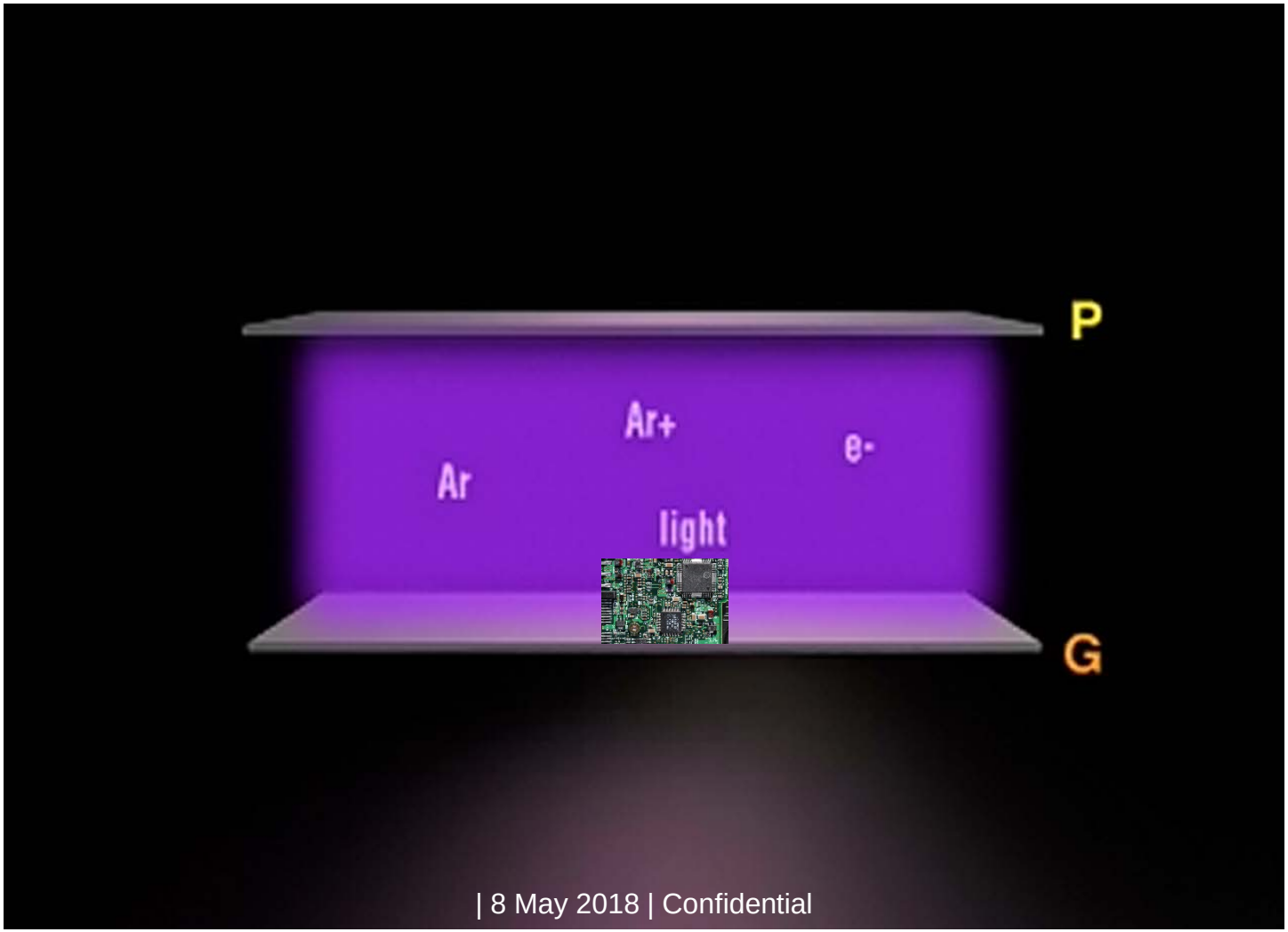
Plasma Considerations

- Oxygen cleans the surface of organic materials
- Argon increases surface tension by kinetic bombardment
- Combination of these two processes increases conformal coating wettability to microscale components
- Two processes for discussion are:



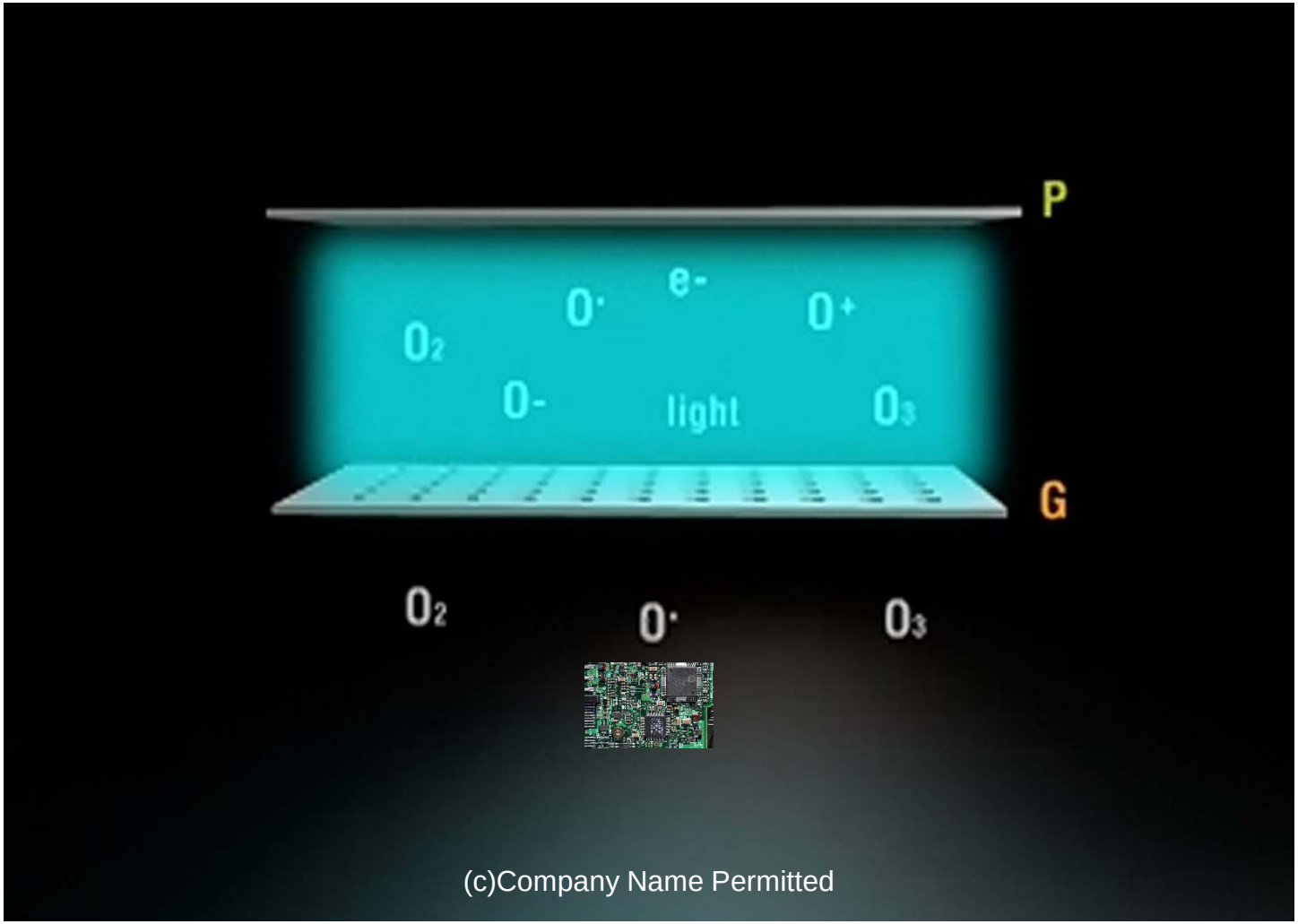


Direct Plasma

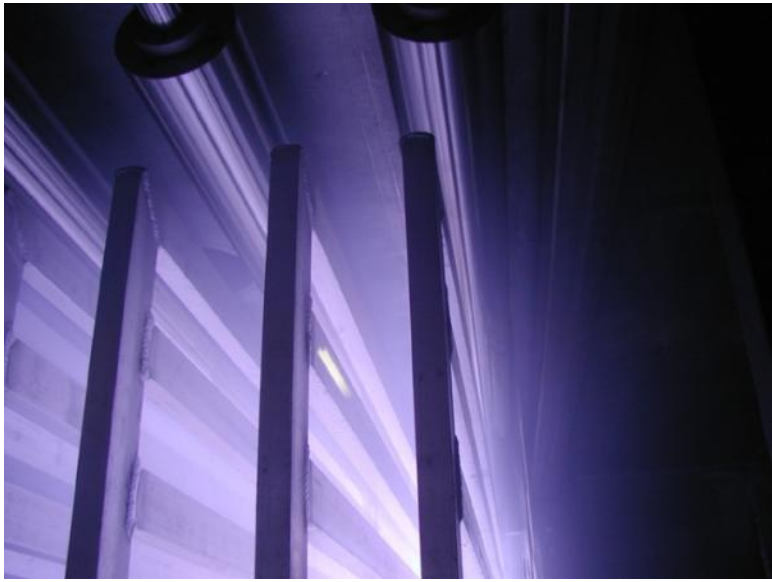


Downstream Ion-Free Plasma

(patented)



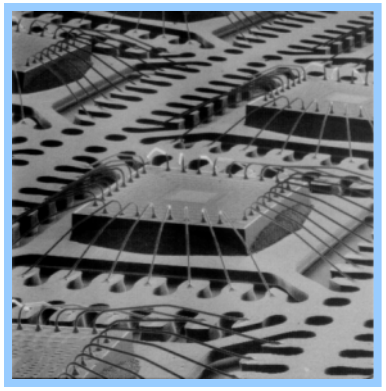
Agenda

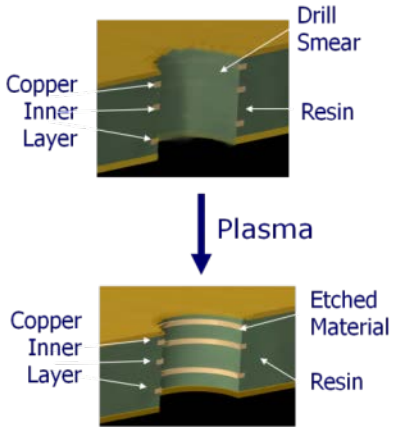


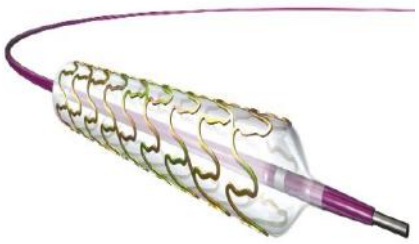
- Plasma Technology
- Applications for Plasma
- Adhesion Enhancement Using Plasma
- Addressing ESD Issues in Plasma Processes
- Conclusions

Plasma Applications

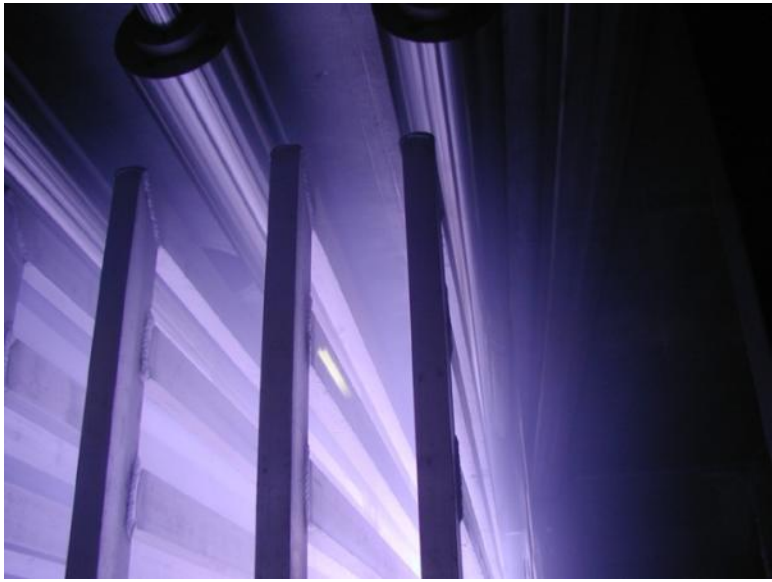
- Semiconductor/MEMS
  - Pre Die Attach
  - Pre wire bond
  - Pre mold
  - Pre Underfill
  - Wafer level packaging
- Printed Circuit Board
  - De-smear
  - Surface activation
  - Pre conformal coating
- Medical Device
  - Pre adhesive bonding
  - Pre device coating
  - Wettability enhancement







Agenda

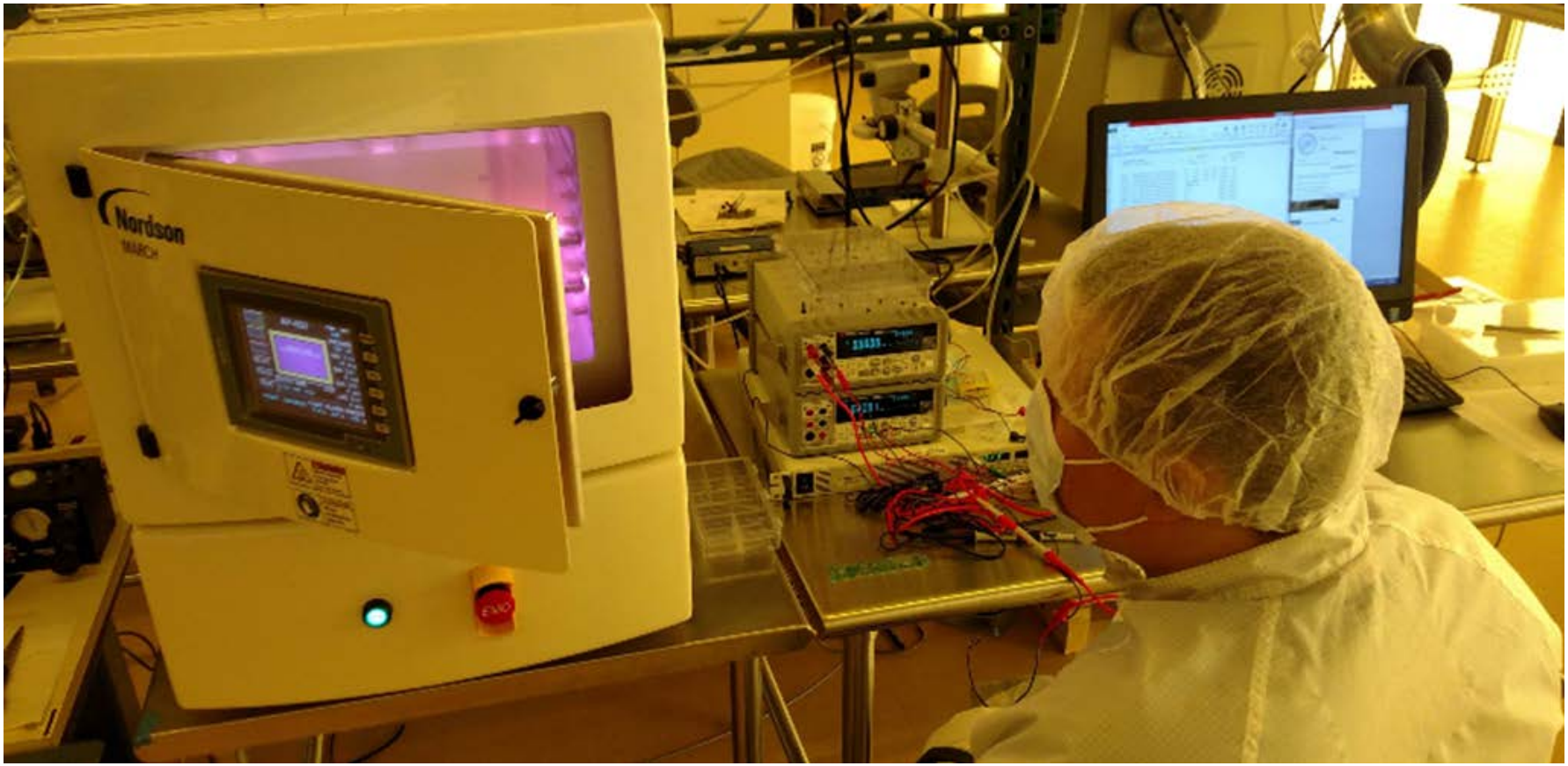


- Plasma Technology
- Applications for Plasma
- Adhesion Enhancement Using Plasma
- Addressing ESD Issues in Plasma Processes
- Conclusions

Pre-Conformal Coat Plasma Evaluation

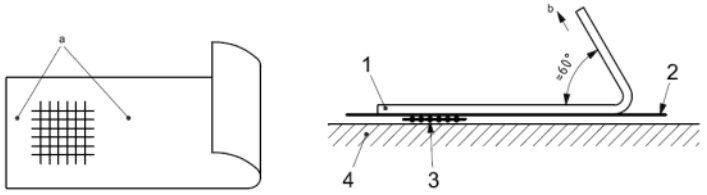
- Determine plasma process conditions that enhance conformal coating adhesion
- Plasma treat solder mask coated boards, apply coating and cure
- Nordson MARCH AP-600 Plasma Processing System
- Nordson ASYMTEK SelectCoat® SL-940 Dispenser
- Humiseal® 1B31 Acrylic Conformal Coating
- Evaluate process parameter sensitivities on adhesion
  - Gas type
  - RF Power
  - Time
  - Process pressure

Nordson MARCH AP-600



Adhesion Testing

- ASTM Method D3359 or ISO 2409
- Scotch Tape Test
- Cross score the coating, apply tape and peel
- Compare the number of squares removed



a) Position of adhesive tape with respect to grid

b) Position immediately prior to removal from grid

Table 1 — Classification of test results

Classification	Description	Appearance of surface of cross-cut area from which flaking has occurred (Example for six parallel cuts)
0	The edges of the cuts are completely smooth; none of the squares of the lattice is detached.	—
1	Detachment of small flakes of the coating at the intersections of the cuts. A cross-cut area not greater than 5 % is affected.	
2	The coating has flaked along the edges and/or at the intersections of the cuts. A cross-cut area greater than 5 %, but not greater than 15 %, is affected.	
3	The coating has flaked along the edges of the cuts partly or wholly in large ribbons, and/or it has flaked partly or wholly on different parts of the squares. A cross-cut area greater than 15 %, but not greater than 35 %, is affected.	
4	The coating has flaked along the edges of the cuts in large ribbons and/or some squares have detached partly or wholly. A cross-cut area greater than 35 %, but not greater than 65 %, is affected.	
5	Any degree of flaking that cannot even be classified by classification 4.	—

Evaluation on Solder Mask Substrates

Power Watts	Pressure mTorr	Gas	Time Sec
100	100	O_2	30
200	200	Ar	60
300	300	O_2:Ar	90

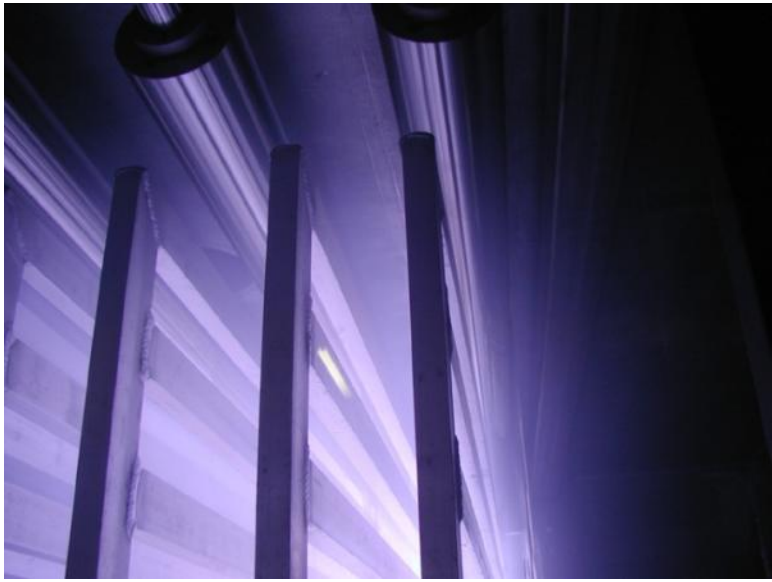
- 31 process tests performed
- All improved adhesion!
- Lower power and less time required if we want to see adhesion sensitivity

Problem Statement

Plasma improves adhesion; however, packaged devices can have ESD related issues with direct plasma.

Specifically, MEMS devices have high possibility of electronic failure when using direct plasma.

Agenda



- Plasma Technology
- Applications for Plasma
- Adhesion Enhancement Using Plasma
- Addressing ESD Issues in Plasma Processes
- Conclusions

Goal Statement

- Test the newly patented downstream ion free plasma process and compare to direct plasma process
  - Is adhesion of Humiseal® 1B31 Acrylic still enhanced after downstream IFP process?
  - Are discrete IC's and MEMS devices electronically functional after downstream IFP process?

ESD Damage Evaluation

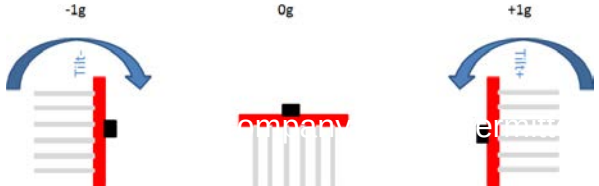
- AP-600 system for evaluation
  - Direct plasma on power electrode
  - Direct plasma on ground electrode
  - Ion-free plasma configuration
- Five discreet devices chosen for evaluation
- Functional testing pre/post plasma to determine plasma induced damage
- Most sensitive device chosen for further evaluation

Components Tested For ESD Damage

- Components purchased from Digi-Key

Components used in Testing		Technical Data Sheet	
Component 1	NPN Bipolar Junction Transistor	P/N:	2N3904
Component 2	N-Channel MOSFET	P/N:	2N7000
Component 3	555 Timer – Integrated BJT Chip:	P/N:	TLC555C
Component 4	555 Timer – Integrated CMOS	P/N:	LMC555
Component 5	MEMS Accelerometer	P/N:	ADXL337

- MEMS accelerometer found to be most sensitive to ESD damage
  - Nominal orientation outputs out of spec following some direct plasma conditions
  - Damage to demodulator circuitry



Results: Experimental Matrix on MEMS Device

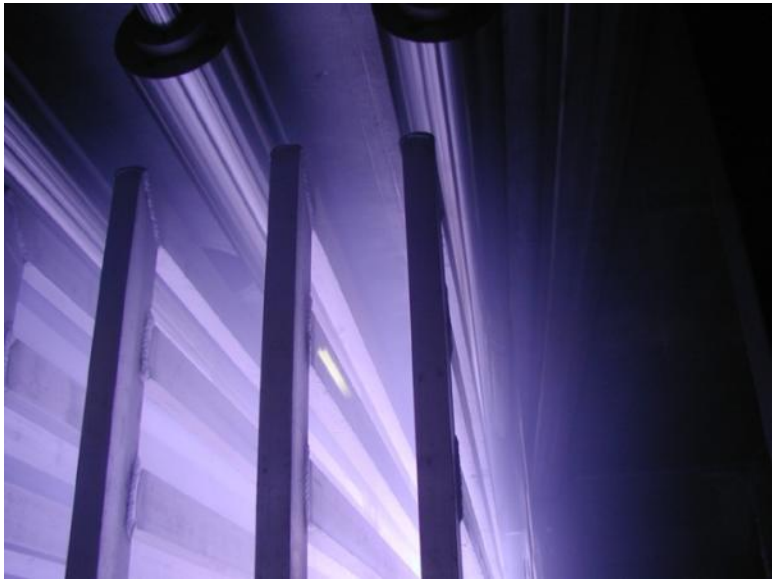
Number Of Failed Components 5 min plasma on time with 1" gap between plates and 3 samples per run			Plasma Power		
			100 W	300 W	500 W
Power	Ar	50 mT	0	0	0
		200 mT	0	1	1
		300 mT	0	1	0
	O2	50 mT	0	0	0
		200 mT	0	0	3
		300 mT	0	0	2
Ground	Ar	50 mT	0	0	0
		200 mT	0	0	1
		300 mT	0	0	1
	O2	50 mT	0	1	1
		200 mT	0	0	0
		300 mT	0	0	0
IFP	80% N2 / 20% O2	50mT	0	0	0
		200mT	0	0	0
		300mT	0	0	0

- Downstream Ion-free plasma (IFP) results in no damage regardless of pressure or power settings

ESD Summary

- The vast majority of PCB's and their components are not sensitive to plasma induced ESD damage
- Proper selection of hardware configuration and process parameters can mitigate ESD damage
- Ion-Free Plasma will eliminate ESD induced damage

Agenda



- Plasma Technology
- Applications for Plasma
- Adhesion Enhancement Using Plasma
- Plasma Cleaning of Contaminants
- Addressing ESD Issues in Plasma Processes
- Conclusions

Conclusions

- Plasma treatment improves adhesion of conformal coatings applied to PCB’s
- Plasma treatment has been demonstrated to remove residues from PCB’s
- Proper chemistries and plasma configurations are required to optimize the adhesion properties
- Plasma induced ESD damage can be eliminated with proper selection of hardware configuration and process conditions
- Ion-free plasma is the safest method for plasma treatment if ESD is a concern

Acknowledgement

- I would like to thank Johnny Vanderford The Center for Microelectronic Sensor Fabrication and Hybrid Board Assembly at Lorain County Community College, Elyria, Ohio, USA for creating and implementing this test plan.
- I would also like to thank Dave Selestak and David Foote of Nordson MARCH for coordinating this effort with the LCCC.
- I would also like to thank Ann Paxton of SMART Microsystems for performing the initial evaluation of conformal coating adhesion enhancement by plasma processing

Thank You!

To learn more about innovations in plasma technology, visit:

www.nordsonmarch.com