Cleanroom Considerations for ESD Control

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IBM
2007 SEMI NA ESD Workshop
Agenda

- Cleanroom/Environment Static Charge Challenges
- Control Strategies
- Case Studies
- Summary and Acknowledgements
Static Charge Problems: Contamination and ESD

Contamination
- Pellicles
- Wafers
- Equipment Surfaces

ESD Damage
- Integrated Circuits
- Reticles

Process Interruptions
- Equipment

Yield Throughput
Clean Environments and Static Charge

- Clearly many industries require “Clean Manufacturing”
- But with Clean Manufacturing also comes:
  - Lowered Humidity Levels
  - Process-Required Insulators
  - Ultra-Clean Surfaces
  - Processes which involve product movement
  - Lack of naturally occurring ions
- All of which can be contributors to elevated static charge levels in and around product
Static Charge and Humidity

Electrostatic Voltage Levels Generated by Production Personnel

Voltage Level

Source: IEST-RP-CC022.2 Electrostatic Charge in Cleanrooms and Other Controlled Environments
Humidity

- Cleanroom humidity level specs intentionally kept at low levels
  - Typically between 30 and 45% RH
  - Driven by tooling, product requirements

- Humidity can affect levels of generated static charge
  - However provides ineffective method of static control once it exists
Process Required Insulators

- Many insulators in clean environments
- Example items and maximum charge levels
  - Oxide Coated Wafers: 5-10KV/in
  - Carriers: 20KV/in
  - Enclosure Materials: >20KV/in
  - Plastic Films/Tape: >10KV/in
  - Teflon: >10KV/in
  - Ceramic: 10KV/in
- Cannot ground an insulator!
Ultra-Clean Surfaces

- Cleanroom protocol typically calls for frequent cleaning of surfaces, Result:
  - Minimize conductive film of contamination that helps dissipative charge
  - Act of cleaning/wiping surfaces can itself can result in tribo-charging of insulators
Product Movement and Other Sources of Tribo-Charging

- Product handling/movement
  - Tweezers
  - Robots
  - Pliers
  - Rollers
- Wet and Cryogenic Processes
  - Cleaning
  - Etch
- Wipe Down
- Environmental
  - Low humidity
  - High temperature

- Personnel
  - In chairs
  - On floor
  - Against walls
- Product Storage
  - In/Out of carriers
  - Moving across work surfaces
- Packing/Unpacking
  - Packing material
  - Sheet protectors
Static Charge is a Contamination Issue

• Charged surfaces attract contamination
• Very difficult to remove!
Deposition Velocity vs. Particle Size

- Deposition velocities shown for:
  - Gravitational
  - Diffusion
  - Electrostatic
    (at 200 volts/cm and 2000 volts/cm)
  - Combined for 200 V/cm

Electric Fields Drive Discharges

Static charge on plates and adjacent objects (i.e. rollers) drive discharges!
ESD Discharge Currents are Large

\[ q = CV \]
with \( V = 5000 \text{ V} \),
\( q = 100 \text{ nC} \)

\[ i = 50 \text{ Amps} \] !!!

This causes large EMI Transients
Exact Timing to Effect a µP

ESD Events

µP Clock
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Key Elements of Electrostatic Charge Control

- Ground All Conductors
  - Establish plan to assure that tool components are grounded
- Ground Personnel
  - Static control garments, ESD shoes, Wrist straps as required
- Implement static dissipative materials when possible
- Use room or tool ionization to reduce static charge values to tolerable levels on required insulators
Problem: How To Dissipate Static Charge on an Insulator?

Solution: Make the Air Conductive

Air Ions neutralize surface charge by contact.
Types of Commercially Available Ionizers

- **Radioactive** - ionizing alpha particles
  - Po\(^{210}\) alpha particles which collide with air molecules and ionize them.
- **AC Corona Discharge**
  - Applies 50/60 Hz AC HV to a grid of emitter points.
- **DC Corona Discharge**
  - DC of both polarities is fed to discrete emitters for each polarity
- **Soft X-ray**
  - 5-10 keV photons use the photoelectric effect.
  - Generate ions in a volume not a point
ANSI ESD S20.20 ESD Control Program

Overview

Based on three fundamental principles

The “Plan” defines program:

Administrative Requirements

Technical Requirements

Ground/Bond all conductors

Control Charges on Nonconductors

Use protective packaging for transit and storage

• Documented Plan
• Training Plan
• Compliance Verification Plan

• Grounding/Bonding
• Personnel Grounding
• Protected Area Requirements
• Packaging Requirements
IEST RP CC002.2 (2004)

- “Recommended Practices: Electrostatic Charge in Cleanrooms and other Controlled Environments”

- Purpose:
  - Provide guidance in specifying components of overall static control system for clean rooms
IEST RP CC002.2 Basic Methods

- Electrostatic Charge Control (ESCC)/Electrostatic Discharge Control (ESDC) Basic Methods
  - Ground all tool/facilities components
  - Reasonable and appropriate use of conductive/static dissipative materials
    - Includes personnel garmenting
  - Use of local and/or room ionization to control charge on insulators
  - Implementation of personnel training in area of ESD control
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Case Study # 1

- International SEMATECH (ISMT) and ION Systems study of static control on particle adders in semiconductor photolithographic process

ISMT Litho Bay Study

- Focus on ISMT litho bay consisting of:
  - 193nm DUV Stepper
  - Photo Resist Coat/Develop Track for 193nm support
  - 248 DUV Scanner
  - 248 DUV Photo Resist Coat/Develop Track
  - In-Line CD SEM
  - In-Line Tilt SEM

- Ionizers installed as follows:
  - Room ionization on 8’ centers throughout 80m² bay
  - Ionizer bars in all tools
ISMT Litho Bay Study Experiment

- 25 test monitor wafers pre-scanned for defects
  - 6000A oxide insulator coating on each wafer
  - Pre-Scanned on KLA-Tencor 6420 SurfScan

- Wafers cycled 23.5 hours in 193nm Track
  - Ionization turned on and allowed to equilibrate
  - 1050 number of wafer passes
  - Rescanned on KLA-Tencor 6420

- Wafers cycled 10.5 hours in 193nm Track
  - Ionization turned off and allowed to equilibrate
  - 562 wafer passes
  - Rescanned on KLA-Tencor 6420
Ionizer Installation

In the Room
As well as in Tool
Distribution of Initial Particle Counts

Initial Particle Count

Net: Relatively clean incoming wafers
Distribution of PWP Values

- PWP: Particles per Wafer Pass
- \[ PWP = \frac{\text{particles}_{\text{before}} - \text{particles}_{\text{after}}}{\text{number of passes}} \]
Summary of Results

<table>
<thead>
<tr>
<th>State</th>
<th>PWP Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ionization On</td>
<td>0.117</td>
</tr>
<tr>
<td>Ionization Off</td>
<td>0.31</td>
</tr>
</tbody>
</table>

- PWP Delta = 0.193 +/- 0.044
- T-Test T Value of 2.35
- 2.3% chance that difference driven by statistical fluctuation at 98% confidence level
Discussion of Results

- Assume we have a .13um technology process
  - Critical defect size – 0.065um
- Scaling ESA induced PWP value to critical size
  - $0.193 \text{ PWP @ 0.2um} \Rightarrow 1.83 \text{ PWP @ 0.065}$
- Assume 30 lithography steps in process
- ESA-related yield loss for varying kill ratios (200 die/wafer)

<table>
<thead>
<tr>
<th>Kill Ratio</th>
<th>ESA Related Yield Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>1.40%</td>
</tr>
<tr>
<td>10%</td>
<td>2.80%</td>
</tr>
<tr>
<td>15%</td>
<td>4.20%</td>
</tr>
<tr>
<td>20%</td>
<td>5.60%</td>
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</tbody>
</table>
Case Study I Conclusion

● ESA is a major contributor to contamination in semiconductor processing
● Even in processes that do not generate significant static charge, air ionization provides a measurable improvement in contamination control
  ⇧ PWP improvement: 0.193±0.44 (>200 nm)
Case Study # 2

- ESD Induced EMI Event
  - Problem- ISMT photolithographic stepper shudders when lifting a wafer and then stops.
  - Reboot takes 20 minutes!
The Problem

Wafers leaving the stage were charged to -10 kV and those entering the aligner were charged to +17 kV.
The Solution

Photon Ionizer Aimed at the Aligner and an Aerobar over the load station
Results

• 4 quad bars and 2 Aerobars were not enough!
• EMI was huge and measurable
• Ionization eliminated the EMI and eliminated the lockups!
Case Study # 3

- ESD Impact On In-Process Wafer Die
  - Problem: Oxide Cracking Damage on Center Wafer Die in Spin Dry Process
The Problem

- “Star Cracking” ESD Damage Observed on Center Wafer Die
- Occurred post apply of De-Ionized Water in Spin Dry Process
- Significant yield impact at wafer level
De-Ionized Water

- De-ionized pure water is a poor electrical conductor
  - Resistivity on the order of 18.2 megohms
- Can result in significant tribo-charging of insulators in spin apply processes
- Resistivity of D/I water can be reduced by introducing non-contaminating ions
  - E.G. CO$_2$ Bubbler
  - Concentrations in sub 0.1 PPM level can reduce resistivity to <5 megohms
The Solution

- Implemented CO$_2$ in process D/I water flow
- Drove resistivity < 5 megarhms
- Result:
  - Star cracking problem eliminated
- Points to need to use “static dissipative” materials!
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Summary

- Cleanrooms and Clean Environments have exacting cleanliness requirements
- Methods of attaining those requirements result in substantial ESA/ESD control challenges to process
- Challenges can be met by implementation of rigorous ESA/ESD control programs
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