Electrostatic Charge Control Considerations

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Agenda

• Intro to electrostatic compatibility (ESD Control)
  – Introduction to the effects of ESD
  – Technology Trends
  – Electrostatic Compatibility Model
  – ESD Basics Concepts
    – Charge generation mechanisms
    – ESD Failure Models
    – Importance of considering ESD in components manufacturing
• Considerations for control of ESD in components A/T
  – Environmental
  – Basebuild
  – Fit-up
  – Personnel
  – Transport considerations
• ESD program considerations
• Final Comments
Controlling ESD Is Critical

ESD can result in:

- Unsatisfied customers
- Lower revenues
- More rejects
- Higher cost
- Product field failures
- Poor product quality
Motivation for ESD Control

- Advancement in semiconductor technologies which reduces IC geometry, Gate oxide thicknesses, line widths, tend to drive higher ESD sensitivity
- Proliferation of automated systems without proper consideration of the type of materials used have resulted in Charged Device Model type failures
- ESD problems affect product quality and reliability.
# Technology Trends

*(International Technology Roadmap for Semiconductors)*

<table>
<thead>
<tr>
<th>Year</th>
<th>Technology Node</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
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<td></td>
<td></td>
<td>180nm</td>
<td>130nm</td>
<td>115nm</td>
<td>100nm</td>
<td>90nm</td>
<td>80nm</td>
<td>70nm</td>
<td>65nm</td>
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<td>Maximum allowable static charge on devices</td>
<td>2.5-10nC (250-1000V)</td>
<td>1-2.5nC (100-250V)</td>
<td>1-2.5nC (100-250V)</td>
<td>1nC (100V)</td>
<td>1nC (100V)</td>
<td>0.5nC (50V)</td>
<td>0.5nC (50V)</td>
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<table>
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<td>45nm</td>
<td>32nm</td>
<td>22nm</td>
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<tr>
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<td>0.25nC (25V)</td>
<td>0.25nC (25V)</td>
<td>0.10nC (25V)</td>
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ESD Sensitivity Is Projected to Increase As Technology/Time Progresses. We Must Start Preparing For This Upcoming Sensitivity
Electrostatic Charge Effects
In Semiconductor Components Manufacturing

Static Charge
- Wafers
- Integrated Circuits
- Reticles
- Equipment

Contamination
ESD Damage
Process Interruptions

Courtesy of Ion Systems
ESD Defined

• Electrostatic Discharge
  – The sudden and rapid transfer of electrical charge from one object to another object
  – The severity of the electrostatic discharge is dependant on the voltage potential difference between the two objects prior to discharge

ZAP!

Voltage potential difference between Person and Device is large enough lead to Electrostatic discharge
Humans feel ESD at > ~3000\text{v}

Humans hear ESD at > ~6000\text{v}

Humans see ESD at > ~8000\text{v}

Some devices are sensitive to voltages less than 100V. What you can’t feel, hear, or see can cause problems to ESD sensitive semiconductor devices.
Triboelectric Charging

- **Triboelectric charging occurs when two materials:**
  - with different electrical work functions come in contact and are then separated.
  - Charging is affected by relative position in the tribo-series, intimacy of contact, coefficient of friction, and rate of separation.

- **Any material may be charged**
  - Whether it stays charged depends on it being a conductor or an insulator.
  - Rate of dissipation is affected by conductivity of the material, absolute humidity. The higher the conductivity, the faster the material will dissipate charge.

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**Example of Tribo Series**

<table>
<thead>
<tr>
<th>Positive +</th>
<th>Negative -</th>
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<tbody>
<tr>
<td>P-Type Silicon</td>
<td>P-Type Silicon</td>
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<tr>
<td>Water</td>
<td>Water</td>
</tr>
<tr>
<td>Human Hands</td>
<td>Human Hands</td>
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<tr>
<td>Quartz</td>
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<td>Nylon</td>
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<td>Chrome</td>
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<td>Steel</td>
<td>Steel</td>
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<td>Polyurethane</td>
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<tr>
<td>Polyethylene</td>
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<tr>
<td>Polypropylene</td>
<td>Polypropylene</td>
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<tr>
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<td>Silicon</td>
<td>Silicon</td>
</tr>
<tr>
<td>Mylar</td>
<td>Mylar</td>
</tr>
<tr>
<td>Teflon</td>
<td>Teflon</td>
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Charge Generation By Induction

- Does Not require contact for mechanism to occur
- Electrostatic fields from a charged objects can lead to charge separation on semiconductors and conductor
- Works on principal that opposites charges attract and likes repel
Theory: ESD Failure Models

- **Charge Device Model**
  - A charged device discharge into a conductive grounded object or an conductive object with different potential
  - Most common failure modes

- **Machine Model**
  - External charged conductor/machine discharge into the a device by contacting the device through the grounded conductive part of the device
  - Intel does not guarantee customers this failure modes

- **Human Body Model**
  - External human body discharge into a device using a finger to touch the conductive part of device
  - Less likely to happen
Typical Example of ESD Damage
Device Level

ESD Damage “Mouse Bites”
Leading to excessive leakage
Device still worked – walking wounded

Catastrophic ESD Damage causing
Shorting of device. Device did not
Operate after this ESD damage
ESD Control Considerations

Disclaimer

The ESD control considerations that follow may not include all available, or the best, precautionary measures. Intel will not be held responsible for their accuracy or completeness, and we have no duty to update them as more information becomes available.
Components A/T ESD Considerations

Concerned with packaging (Assembly) and Testing of the finished device/apparatus. Product is also sometimes shipped to customer from here.

All Areas MUST be considered ESD Sensitive!
Environmental Considerations

- Relative Humidity although important is not as important as Dew Point (Absolute Humidity)
  - Controlled experiments indicate that Dew Point is a major contributor to charge generation
  - Dew point, or absolute humidity as it is also known, directly ties to the number of water molecules in a given volume of air and is what really counts when talking about ESD, or charge dissipation
- Major paradigm shift for ESD control
Environmental Considerations

Effect of Altitude On ESD

- Altitude plays a significant role in the ESD event itself.
  - Spark gap potential is inversely proportional to atmospheric pressure
  - For a given spark gap, the higher you go in altitude (less pressure), the less voltage required to initiate an arc/spark
Basebuild Considerations

Flooring

- Flooring
  - All areas within components A/T where devices will be exposed to the environment should consider incorporating either static dissipative or conductive flooring
  - Make sure that concrete substrate is properly prepared and dried before placement of ESD floor, or you may have issues with bubbling/delamination
  - Proper care of floor is essential for long term performance of floor.
    - Follow manufacturers recommended cleaning procedures
    - ESD wax can be used with good results on non-ESD floor substrates, but the downside is that it requires re-application on a periodic basis
Fit-up Considerations

Entrance Requirements

- At entrances to all areas deemed ESD sensitive ..........
  - ESD caution signs complying with EOS/ESD Association Standard
  - Footwear checkers at all entrances (Assuming that ESD footwear is being used)
    - Provide detailed illustrated instructions on wall near checker
    - Incorporate into calibration program
    - Provide sufficient attire to accommodate employees as well as managers and guests.
    - Provide illustrated instructions on how to wear/use
Fit-up Considerations
Tables/Work surfaces

- All tables and work surfaces within ESD sensitive area should be static dissipative.
  - Avoid conductive and insulative surfaces
  - Ground according to EOS/ESD Association standard
    - Make sure to periodically clean the work surfaces using the recommended cleaning practices provided by manufacturer
Fit-up Considerations

Chairs

- All chairs used within ESD Sensitive areas should be static dissipative (assuming you are not using wrist straps), and have low charge generation capability when used with attire worn in the area
  - A minimum of 1 wheel/caster per chair should be conductive
  - When static dissipative wheels get dirty, their performance is impacted, and in many cases the chair becomes insulative with respect to the floor
Fit-up Considerations
Transportation Carts

- All transport carts used within ESD Sensitive area should be capable of providing a path to ground for items held on or in cart
  - A minimum of 1 conductive wheel per cart is preferred to drag chain when considering grounding
    - Unless you use a heavy gage chain there will not be sufficient pressure between chain and floor to provide good path to ground for charge dissipation
    - If devices outside of ESD protective packaging will be placed on carts, then the surface should be static dissipative
Personnel Considerations

ESD shoes/heel straps

- If ESD flooring is used, all personnel entering into the area should use either ESD shoes or heel straps
  - Shoes are preferable because they provide contact with the floor across length of foot.
    - Provide Locker space and cleaning/washing protocol
  - Heel straps work nice, but when heel is raised during walking there is possibility for heel strap not to contact floor and leave person ungrounded
    - Assure they are worn on both feet
    - Provide illustrated instruction on use
Personnel Considerations

Smocks/Gowns

• ESD smocks or gowns should be used when entering into ESD sensitive areas
  – Cross hatched pattern provides good results in containing electric fields emanating from personnel
  – Select smocks or gowns that have good continuity from sleeve to sleeve
    – Pay special attention to stitching at seams around shoulder/arm
  – Provide illustrated instructions on proper use at location where smocks/gowns will be put on
Personnel Considerations

Gloves

- Gloves are a vital part of the ESD control program in Components A/T, and must be selected carefully
  - If gloves are not required, eliminate them. Bare skin works best
    - Must consider contamination, fingerprints, and cuts when eliminating gloves
  - If gloves are required, use static dissipative gloves with anti-static properties
    - Avoid Latex, Vinyl, and other insulative glove materials
      - If required due to process constraints, be very careful
Personnel Considerations

Wrist Straps

- Wrist straps are primarily used when no ESD floor/chairs are available, or the device is sensitive enough to warrant additional grounding
  - Wrist straps are very constraining to operators
    - If they can get away without wearing them, they will
  - If wrist straps are used it is a good idea to have full monitoring capability in place
Transport Considerations
Containers and Bags

- Packaging and transport of devices requires special consideration
  - Only utilize anti-static / static dissipative materials for device trays, device tubes, etc…
  - For instances where the devices will leave the ESD controlled area, the device should be housed in a sealed shielded ESD bag/container/box
Final Thoughts

• It is anticipated that the future will bring us more ESD sensitivity in Components A/T

• Controlling ESD in Components A/T is crucial and it is anticipated that it will only become more crucial as we migrate to future technologies
  – Must start planning on that sensitivity and designing facility, equipment, and all associated ESD control systems/programs to accommodate that anticipated sensitivity
ESD Control In Components Manufacturing

The Bottom Line

If ESC is ignored until the facility becomes operational, the costs associated with product loss, impacts to equipment availability, and costs associated with retrofit become overwhelming.

Numerous design choices available early in the design of the facility, but diminish as time/project proceeds.

ESC MUST be considered early in design to achieve a cost effective implementation!

Cost to implement ESC solutions is minor if thought of during initial design and increases as time into project increases.

As facility becomes operational, ESC choices available are diminished and hard to implement.

Choices
Cost

Time