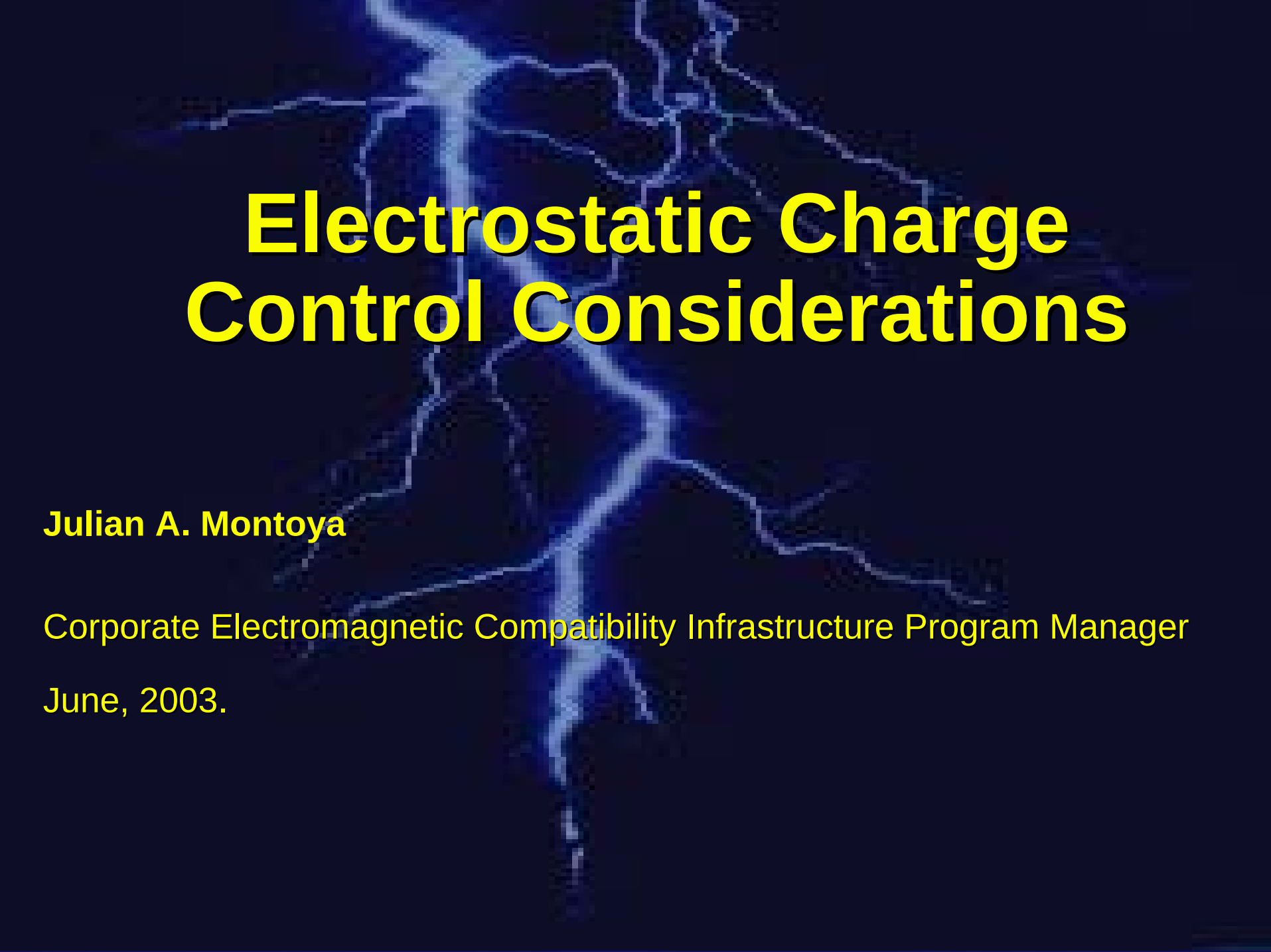

Electrostatic Charge Control Considerations

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June, 2003.

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:

more rejects
higher cost

unsatisfied
customers

lower revenues

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 - Static Charge Limits for Test, Assembly, and Packaging

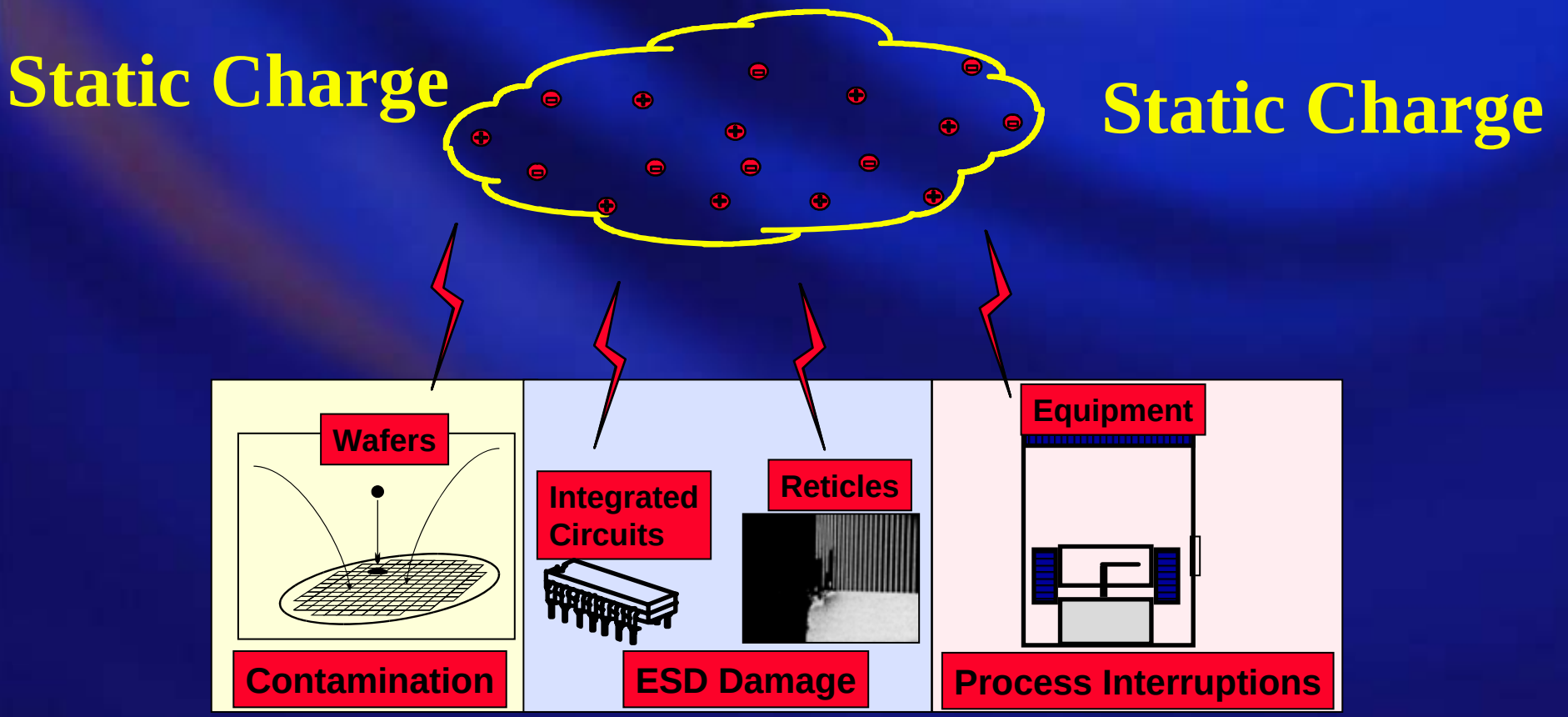
Year Technology Node	2000	2001	2002	2003	2004	2005	2006	2007
	180nm	130nm	115nm	100nm	90nm	80nm	70nm	65nm
Maximum allowable static charge on devices	2.5-10nC (250-1000V)	1-2.5nC (100-250V)	1-2.5nC (100-250V)	1-2.5nC (100-250V)	1nC (100V)	1nC (100V)	0.5nC (50V)	0.5nC (50V)

Year Technology Node	2010	2013	2016
	45nm	32nm	22nm
Maximum allowable static charge on devices	0.25nC (25V)	0.25nC (25V)	0.10nC (25V)

ESD Sensitivity Is Projected to Increase As Technology/Time Progresses. We Must Start Preparing For This Upcoming Sensitivity

Electrostatic Charge Effects

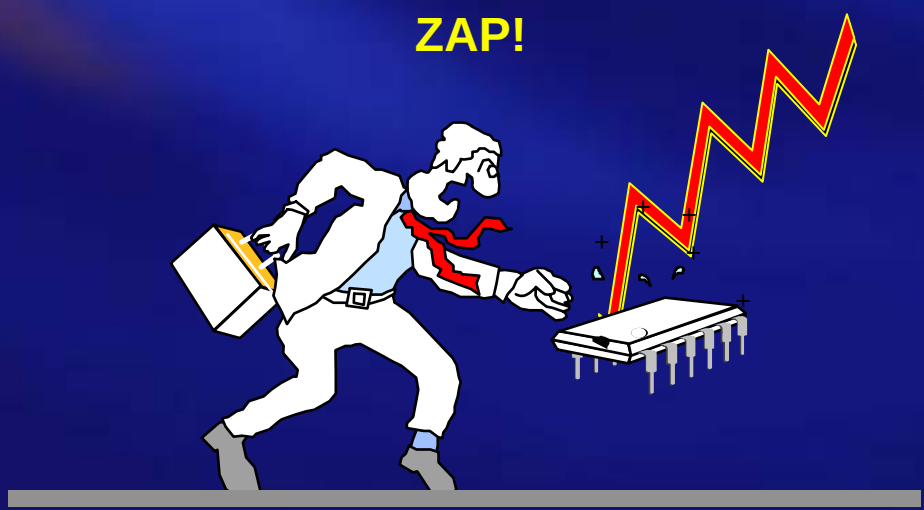
In Semiconductor Components Manufacturing



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

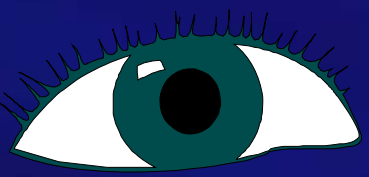


Voltage potential difference between Person and Device is large enough lead to Electrostatic discharge

ESD And The Human Senses

Humans feel ESD at > ~3000v

Humans hear ESD at > ~6000v



Humans see ESD at > ~8000v

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

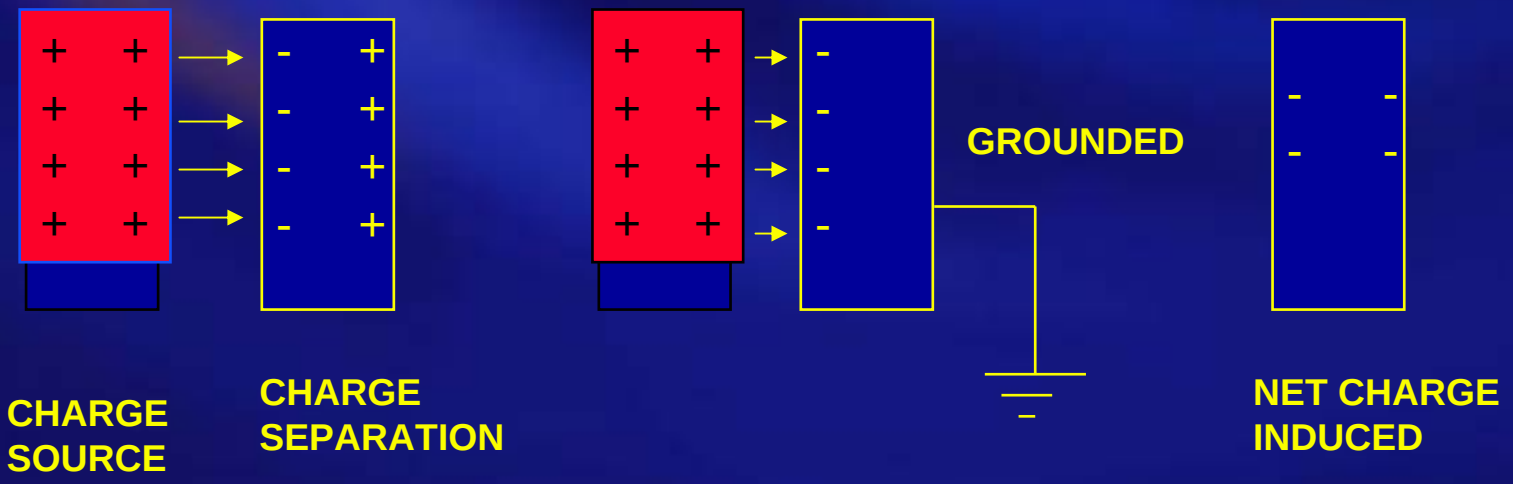
- **Triboelectric charging occurs when two materials:**
  - with different electrical work functions come in contact and are then separated.
  - Charging is affected by relative position in the tribo-series, intimacy of contact, coefficient of friction, and rate of separation
- **Any material may be 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 high the conductivity the faster the material will dissipate charge

Example of Tribo Series

Positive +	P-Type Silicon
	Water
	Human Hands
	Quartz
	Nylon
	Aluminum
	Chrome
	Steel
	Polyurethane
	Polyethylene
	Polypropylene
Negative -	PVC (Vinyl)
	Silicon
	Mylar
	Teflon

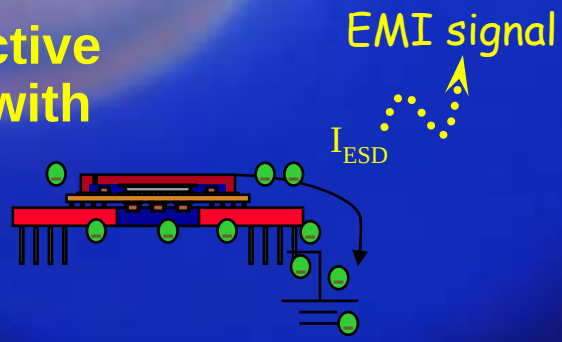
Charge Generation By Induction

- 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

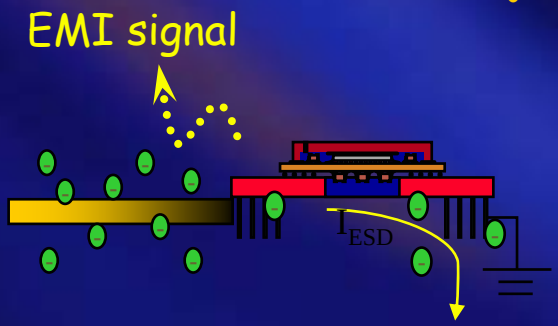


Theory: ESD Failure Models

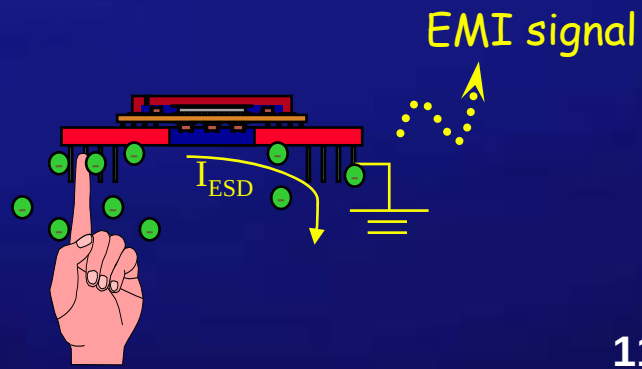
- Charge Device Model
  - A charged device discharge into a conductive grounded object or an conductive object with different potential
  - Most common failure modes



- 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

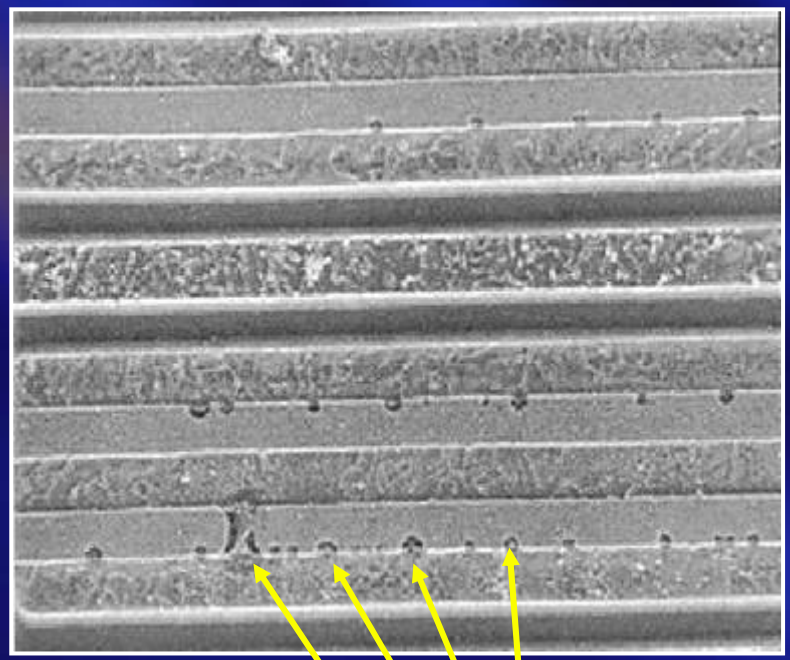


- Human Body Model
  - External human body discharge into a device using a finger to touch the conductive part of device
  - Less likely to happen

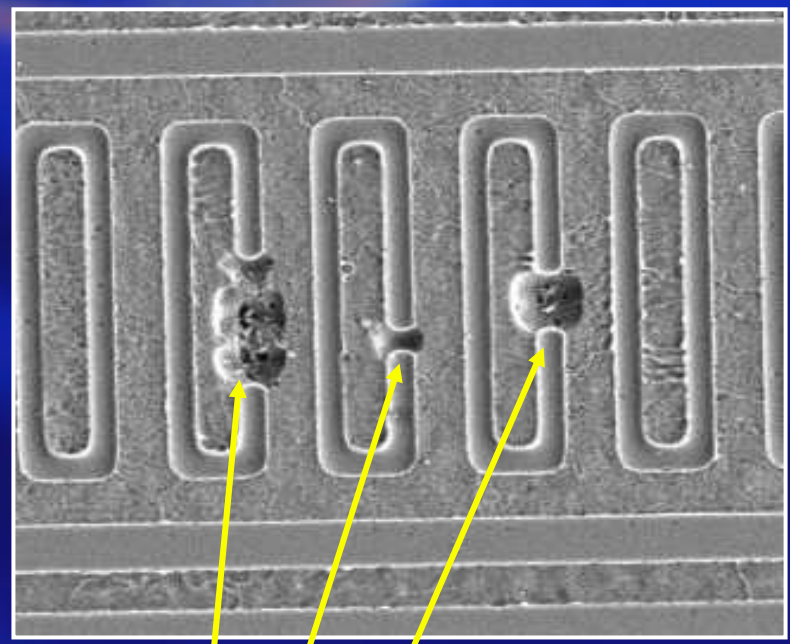


Typical Example of ESD Damage

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

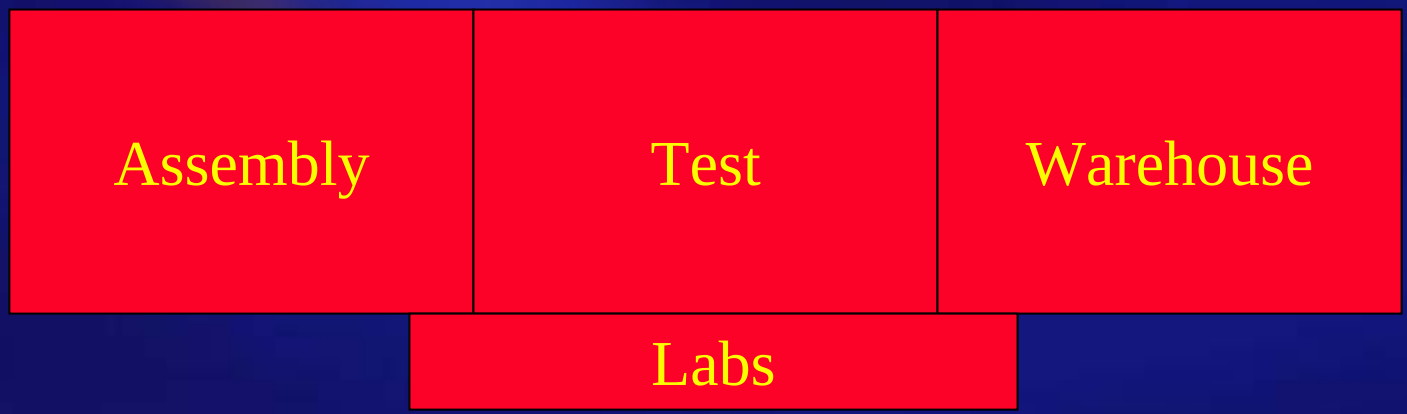
Disclaimer

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!



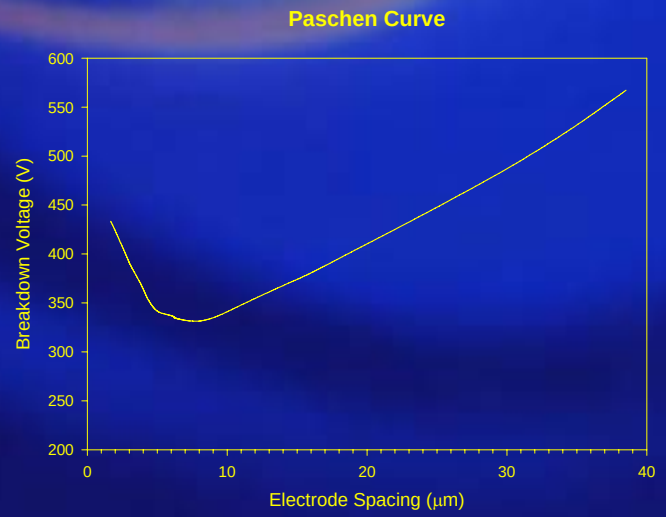
Environmental Considerations

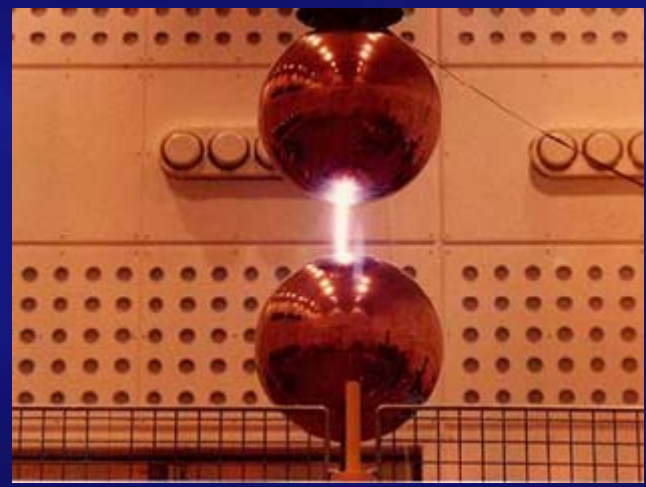
- **Relative Humidity although important is not as important as Dew Point (Absolute Humidity)**
  - Controlled experiments indicate that Dew Point is a major contributor to charge generation
    - Dew point, or absolute humidity as it is also known, directly ties to the number of water molecules in a 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

ESD Caution Sign

Footwear Checker

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

Typical ESD Workstation

Fit-up Considerations
Chairs

- All chairs used within ESD Sensitive areas should be static dissipative (assuming your 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

ESD Chair With Conductive Casters

Fit-up Considerations
Transportation Carts

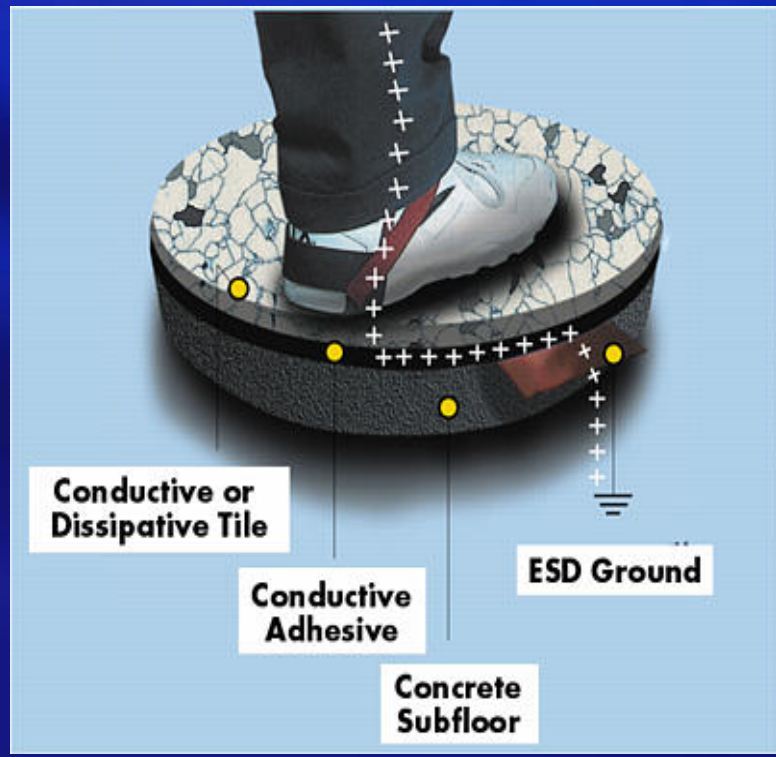
- All transport carts used within ESD Sensitive area should be capable of providing a path to ground for items held on or in cart
  - A minimum of 1 conductive wheel per cart is preferred to drag chain when considering grounding
    - Unless you use a heavy gage chain there will not be sufficient pressure 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

Transport Cart With Conductive Wheels

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



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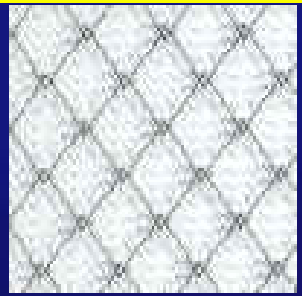
Personnel Considerations
Smocks/Gowns

- 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

Typical ESD Smock

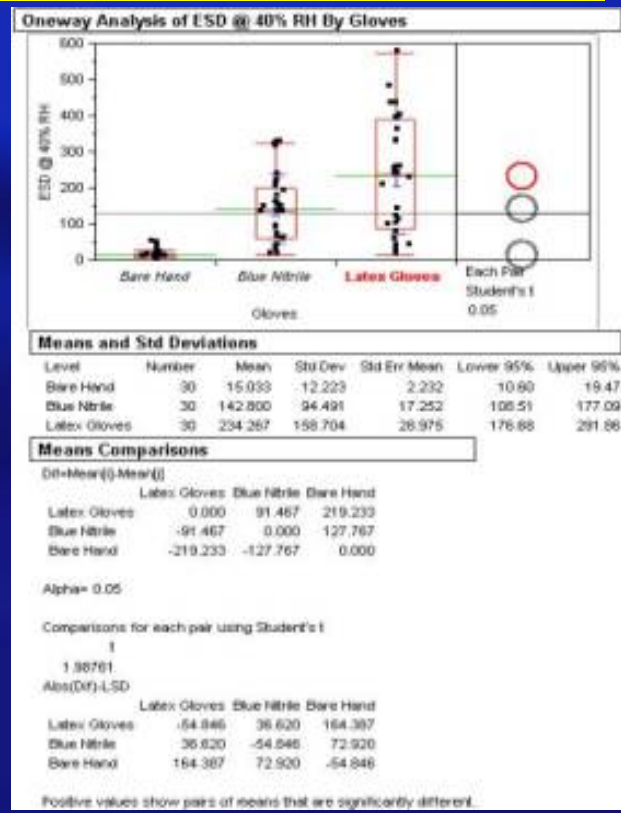
Cross-hatch Pattern



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

Voltage Generation By Gloves



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Bare Hand	30	15.033	12.223	2.232	10.60	19.47
Blue Nitrile	30	142.800	94.491	17.252	108.51	177.09
Latex Gloves	30	234.267	158.704	28.975	176.88	291.66

Means Comparisons

Dif=Mean(i)-Mean(j)

	Latex Gloves	Blue Nitrile	Bare Hand
Latex Gloves	0.000	91.467	219.233
Blue Nitrile	-91.467	0.000	127.767
Bare Hand	-219.233	-127.767	0.000

Alpha= 0.05

Comparisons for each pair using Student's t

t
1.98761

Abs(Dif)-LSD

	Latex Gloves	Blue Nitrile	Bare Hand
Latex Gloves	-54.846	36.620	164.387
Blue Nitrile	36.620	-54.846	72.920
Bare Hand	164.387	72.920	-54.846

Positive values show pairs of means that are significantly different.

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**

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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