

# ESD: The Discharge part of Electrostatic Discharge

Verification of your  
ESD Environment

Dr. Frankenstein's  
ESD Specialist



Credence Technologies, Inc.

# Your Company Has Spent Millions on ESD Protection

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- Your ionizers are within their specification
- Your wrist-straps are OK
- Your equipment is grounded
- You do not see voltage build-up
- Your workers are properly dresses
- Your floors are static-dissipative
- You passed ESD Audit



By now you shouldn't have an ESD problem

- Then why we are all here?



# Assumption vs. Verification

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- All ESD-protective measures are designed to  
**PREVENT**  
ESD Events
- By utilizing them you  
**ASSUME**  
that your ESD problems are solved
- How do you  
**VERIFY**  
it?



# Why the Discharge?

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- It is the discharge that injects energy into the semiconductors and causes irreversible damage
- It is the discharge that generates EMI that locks up sensitive equipment
- ESD-preventive measures are there to prevent DISCHARGES

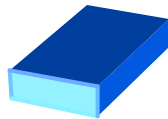
By monitoring DISCHARGES you KNOW, not just ASSUME that your ESD environment is safe



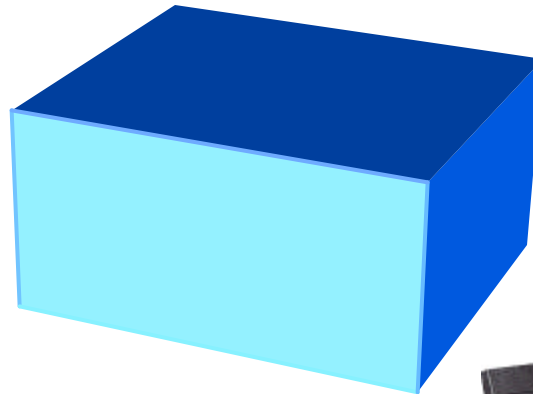
# What do you really learn by measuring static voltage?

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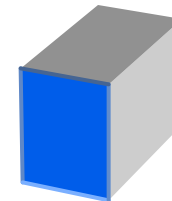
Small Metal Object



Large Metal Object



Plastic Object



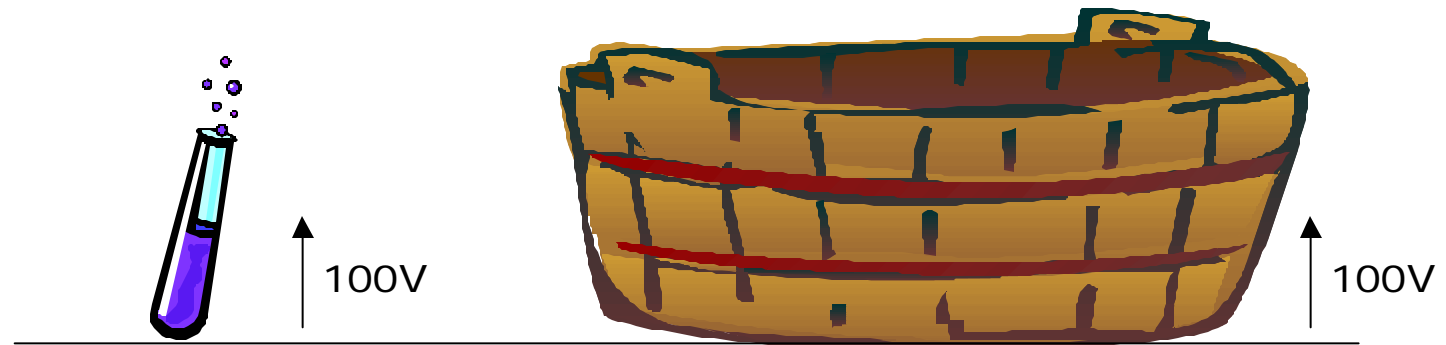
- Which object will cause more damage when discharged?
- Which object will be discharged faster by an ionizer?



# In what case the discharge will be stronger?

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- A test tube and a bucket were filled with water to the same level (i.e. Voltage)
- The bucket can hold more water and can spill more



- By measuring just the voltage (“water level”) you do not know how strong the discharge it can produce and how long it will take to discharge it.

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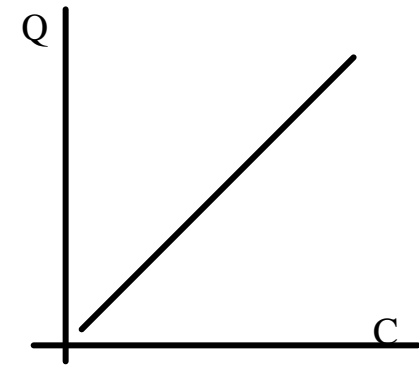


# The “Charge” part of Discharge

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- Conductive Objects:

$$Q = CV$$



Where:

- Q – Charge, q
- C – Capacitance, F
- V – Voltage, V

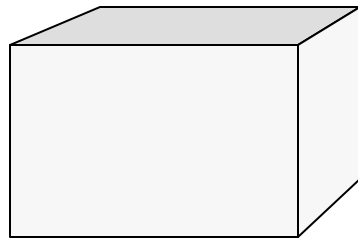
The larger the object, the higher its capacitance, the more charge it stores and the more energy is released during discharge at the same voltages.



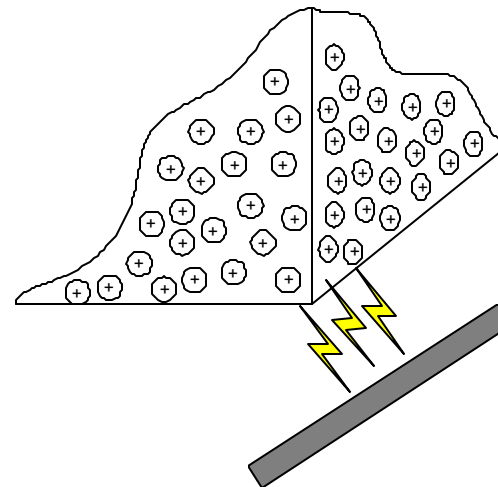
# The “Charge” part of Discharge

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- Insulators (i.e. Teflon):



Charge in an insulator is composed of small independent charged areas



Each molecule of insulative material is an independent charged object. Only small portion of the entire charge in the insulator will discharge. The energy of this discharge is a small fraction of what it would be if it were conductive.



# Different Types of Discharge

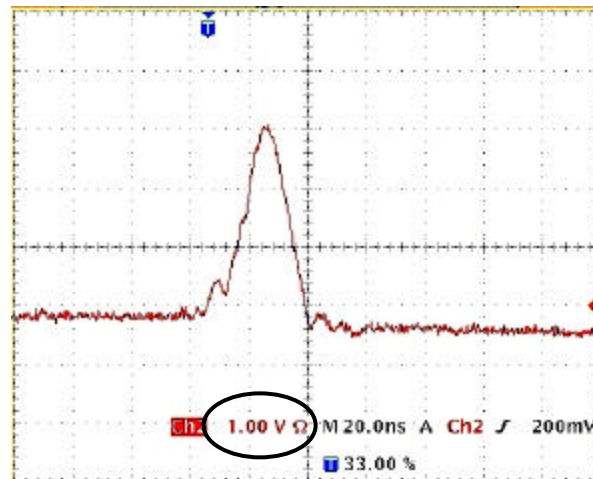
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## •MM

Machine Model

A charged metal object (i.e. robotic arm) is discharged to another conductive object.

Very strong discharge

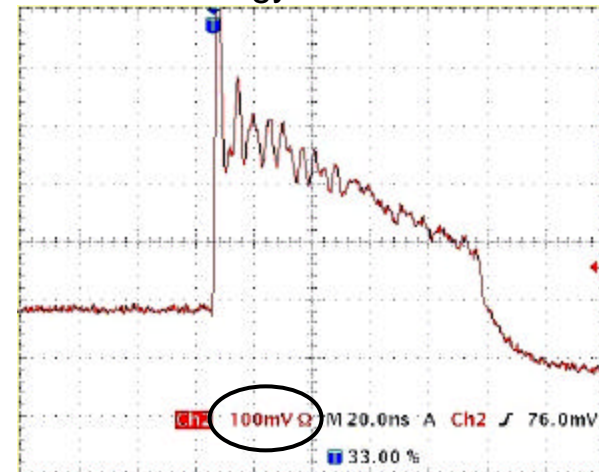


## •HBM

Human Body Model

A “charged” human touching conductive object.

Slower discharge with plenty of released energy

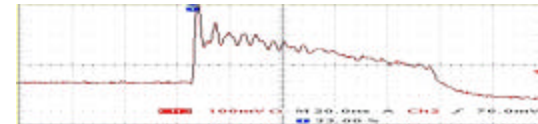
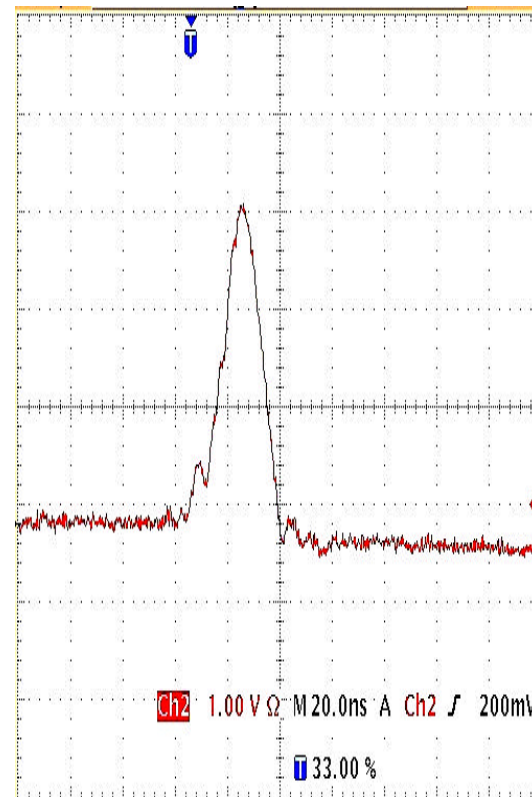


All discharges are 50V  
Note different scales



# Relative Magnitude of Different ESD Events Caused by the Same Voltage

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# Can Electrostatic Voltmeter Be an ESD Event Monitor?

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- ESD Events last nanoseconds ( $10^{-9}$  seconds) – too fast for a static voltmeter
- ESD Event may not always completely discharge accumulated static voltage
- Knowing voltage alone doesn't tell you how strong a discharge would be
- Charged object may never cause ESD Event
- **A static voltage or charge meter cannot serve as a tool for ESD Event monitoring**

"People only see what they are prepared to see."

*-Ralph Waldo Emerson*





# ESD Event Monitoring

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*"The greatest obstacle to discovery is not ignorance - it is the illusion of knowledge."*

*Daniel J. Boorstin*

*"Where facts are few, experts are many."*

*Donald R. Gannon*

# Challenges in ESD Event Monitoring

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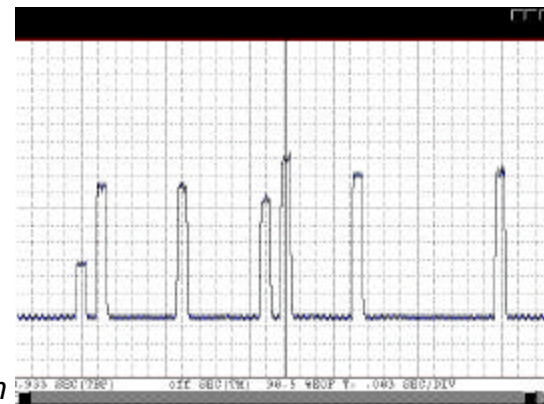
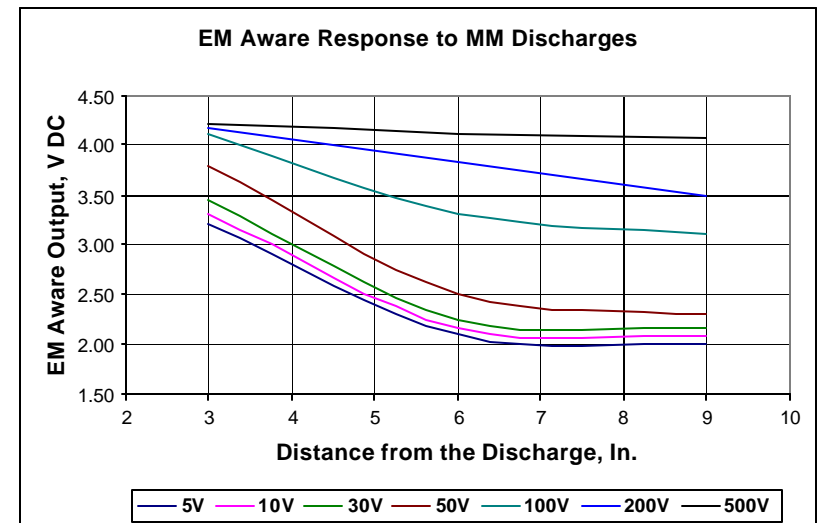
- ESD Events last only nanoseconds -- a challenge to measure their magnitude in an economical way for day-to-day use
- There could be multiple ESD Events microseconds apart and the first event may not be the strongest one
- ESD Events have very large dynamic range
- Information about ESD Events should be presented in easy-to-understand way



# ESD Event Monitoring: Overcoming Challenges

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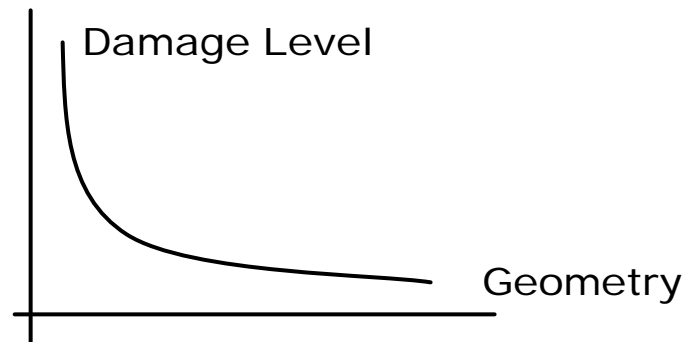
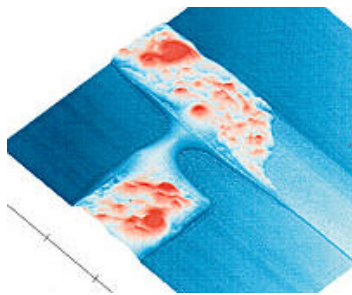
- ESD Event monitor is a miniature calibrated radio-frequency measurement device with broad dynamic range
- ESD Event monitor measures the energy of an ESD Event and represents each event as a pulse
- Magnitude of a pulse is a function of event's strength
- ESD Event monitor is characterized based on type of discharge and the distance from it
- ESD Event monitor measures events in real time, stores data in its FIFO and "dispenses" them at a rate data acquisition or facility monitoring system can accept it.



# Front End: ESD and Reticle Damage

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- Smaller geometries result in smaller gaps between traces – lower breakdown voltages
- Smaller geometries result in thinner traces that are much easier to damage
- Smaller geometries, higher density and die sizes statistically increase probability of discharges
- More complex designs result in relatively longer traces that connect areas of the larger die that can be charged to different voltages
- The damage level is non-linear as geometries get smaller



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# ESD and Reticles: Truth or Consequences

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- Reticle damage may happen anytime
- If damage does unnoticed, the consequences won't be:
  - high cost of repair or replacement of reticle
  - high cost of defective ICs produced with the damaged reticle
  - high cost of lost fab time
  - high cost of damage control and lost customers



# Reticle Damage: Action Plan

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- Monitor ESD Events at every step of reticle handling
- Know which station generates ESD Events so that it can be improved
- Know the exposure of each reticle to ESD and re-route exposed reticles to inspection rather than to production
- Have an ESD “passport” for each reticle -- know its true exposure to ESD
- Manage reticles in a non-emergency way
- Construct and verify your ESD-preventive measures based on factual information



# Monitoring of ESD Exposure of Reticles

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- Suggested locations for ESD Event monitors in reticle handling:
  - stepper load and unload
  - stocker load and unload
  - metrology test load and unload
  - anywhere reticles are handled

Only ESD Event monitors can verify that the reticle was actually exposed to ESD and to what degree

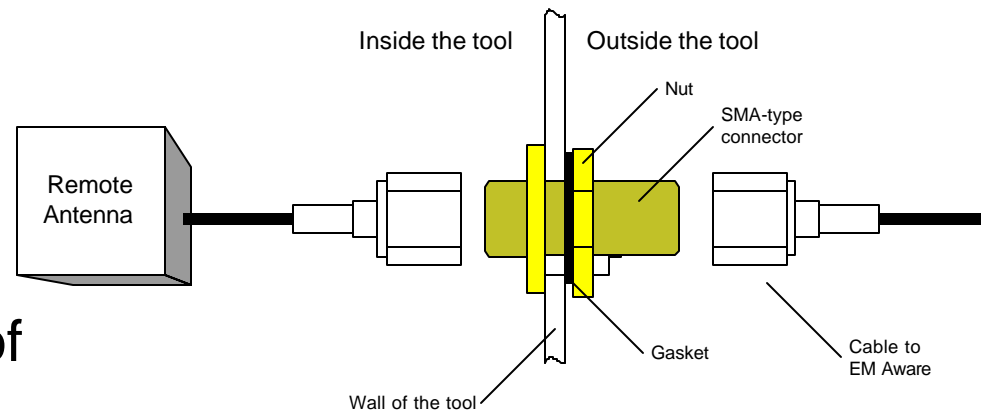


# Monitoring of ESD Events Inside the Tool

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Antenna for monitoring ESD Events can be placed inside the tool without violating integrity of the tool

Special antennae can handle up to 150°C



# Integrating ESD Verification into Reticle Handling

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- Output of ESD Event monitor is connected to the tool controller
- Database is created for each reticle vs. exposure to ESD Events
- Reticle with significant exposure is marked and sent to inspection
- Real-time response to ESD problems is now possible



# Back End: Trends in IC Handling -- 1

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- Geometry is getting smaller ( $0.10\mu$ ) – higher sensitivity to ESD
- Conventional ESD protection measures do not handle well high-speed signals due to high capacitance
- Lower operating voltages (i.e. 1.8V) push the limits on protective clamping devices
- Increased number of I/O pins statistically increases probability of IC failure
- Larger die size in VLSI ICs make losses expensive
- Increased pressure for “time to volume” puts additional motivation to reduce test time, increasing probability of ESD damage
- ICs exposed to ESD may not fail right away -- latent damage causes losses and alienates customers



# Back End: Trends in IC Handling -- 2

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Increasing cost pressure demands reduced test time

The results: ICs move faster

- Static voltage is accumulated extremely fast
- Ionizers cannot handle such rapid movement: it takes several seconds for an ionizer to discharge IC to a safe voltage level. In these few seconds several ICs will be tested and moved away from the test area.
- It is not possible to increase discharge rate by increasing air flow because it cools down the ICs that are supposed to be tested at controlled elevated temperature
- The only feedback is the yield figure



# IC Testers: Scene of a Crime

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- Typical places of occurrences of ESD Events:
  - IC is placed on the test pad
  - IC is lifted from the test pad
  - IC is placed in exit shuttle
- ICs get damaged at the most expensive stage of production
- ICs get damaged **AFTER** they were tested and marked “good”



# IC Handling: Action Plan

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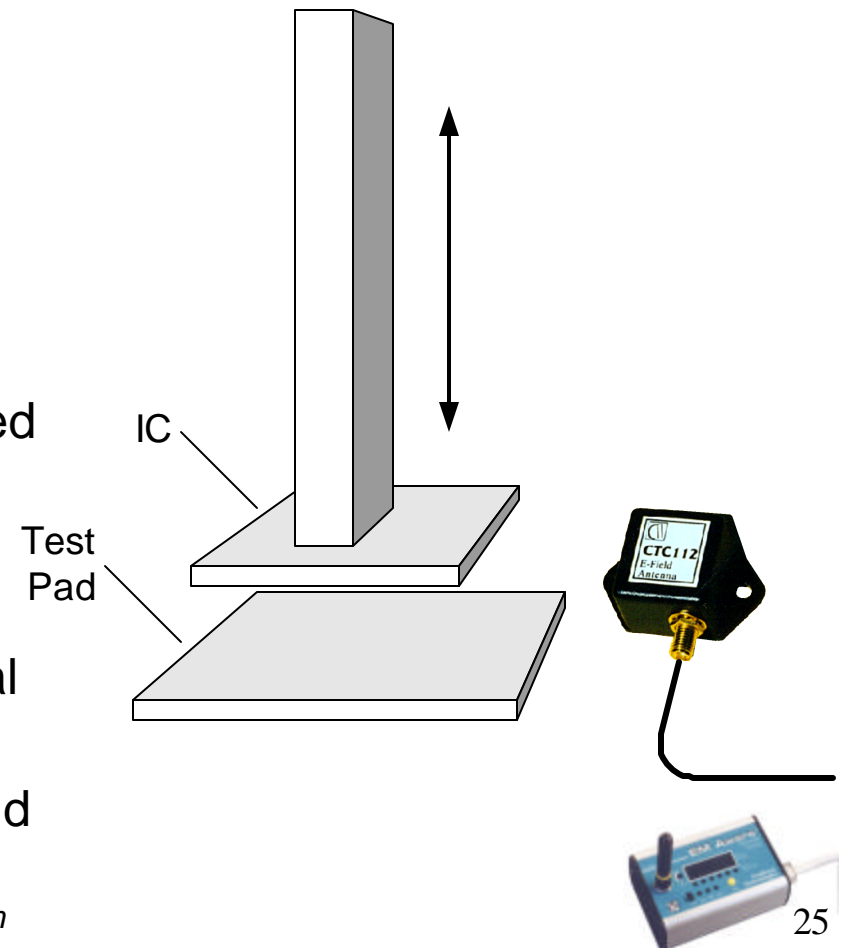
- Monitor ESD Events wherever there is a possibility of harmful ESD damage
- Every time a significant ESD Event is registered, mark the IC as a “suspect”
- Every time a significant ESD Event is registered, investigate “why” in real time
- Collect statistics and correlate with latent damage
- Stop killing ICs



# IC Testers: Practical Application

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- A remote antenna is placed next to the pad
- Output of ESD Event monitor is connected to IC tester
- Every time the ESD Event exceeds the set threshold IC tester identifies the IC as exposed to dangerous level of ESD and places it in separate bin
- Real-time response helps to improve ESD environment in real time
- Statistics is collected on yield and latent damage



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# ESD Audit

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Is your ESD Audit made to test just your preventive measures or your actual ESD environment?

ESD Audit checks for everything except the for very phenomenon it supposed to prevent: ESD Events

# ESD Audit: Going by the Facts

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## ESD Audit Report (*Assumption*)

- Wrist straps ✓
- Ground ✓
- Ionizers ✓
- Dissipative floors ✓
- Dissipative garments ✓
- Static voltage levels ✓
- Gloves ✓
- Tweezers ✓
- Packaging ✓
- Shelving ✓

## ESD Audit Report (*Facts*)

- 12 ESD Events stronger than 1nJ observed at tool # 5 during 8hrs. shift
- Maximum strength of ESD Event was 2.2nJ
- ESD Events were correlated with new materials arrival and handling
- Correction and verification to follow immediately



# Continuous Monitoring of ESD Event

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- ESD Events happen with all the preventive measures working perfectly well
- ESD Events are unpredictable. They last very short time and leave no residual signal.
- Each ESD Event is an indication of a potential failure of an IC or a reticle
- Each ESD Event is an indication of a failure in your ESD preventive measures



# ESD Event Monitoring at Work

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- ESD Event monitors become part of your process, not just add-on stand-alone instruments
- Network of ESD Event monitors can provide you with statistics about actual ESD environment on your production floor
  - what happened
  - when happened
  - magnitude of each event
- Easily obtain “ESD maps” of your facilities
- Know where to apply ESD preventive measures
- Know where to improve ESD preventive measures
- Correlate your yield with historical information of ESD environment at each station
- Include ESD Event data in your SPC



# ESD Events and SEMI E78

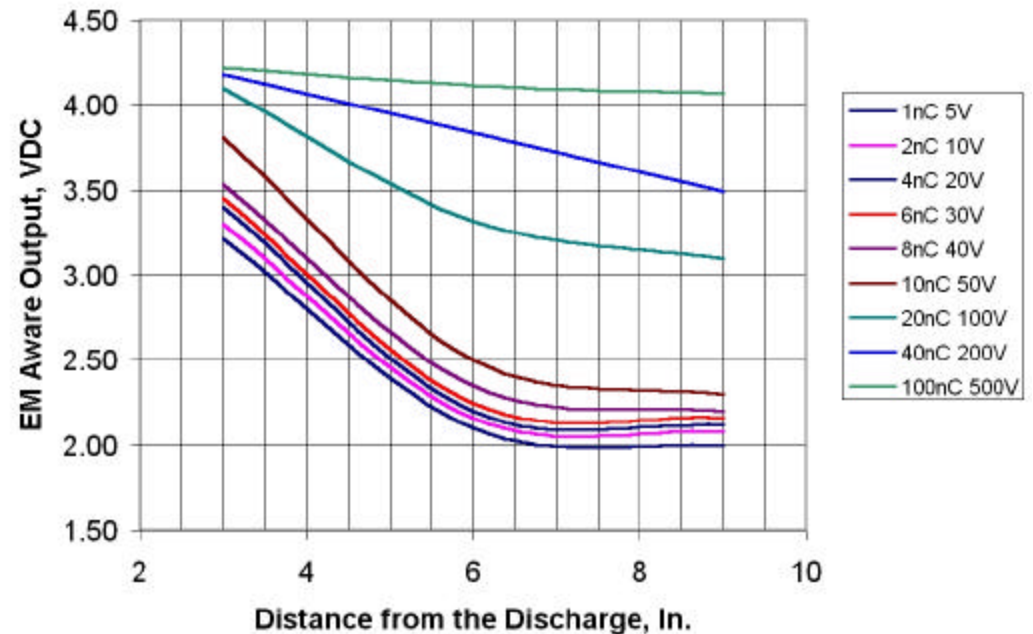
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- Now we got our wish: SEMI E78
- How do we verify compliance?

	ESD Control (nC)	Equipment Malfunction
Level 4	100	1200
Level 3	50	400
Level 2	10	300
Level 1	1	150

- Why not verify it by measuring energy of discharge?

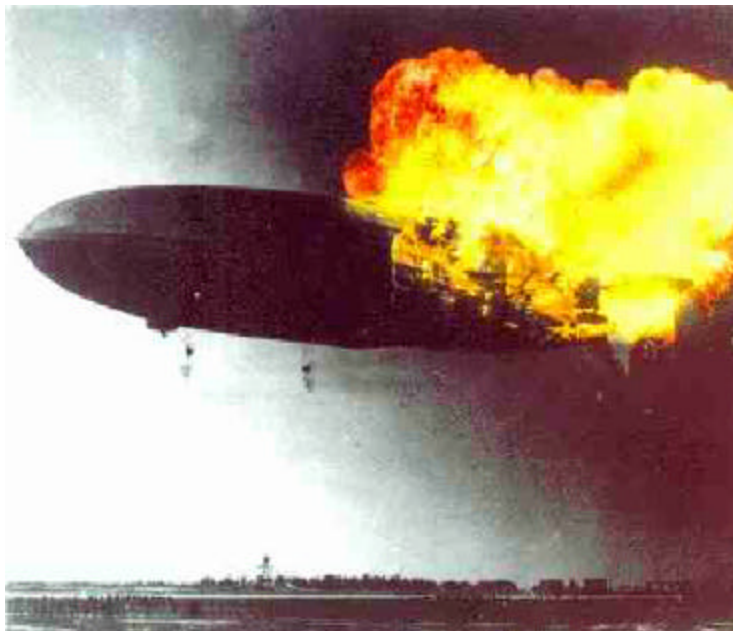
EM Aware Response to MM Discharges



# ESD Event Detector (circa 1937) Hindenburg

# ESD Event Detector (2000) EM Aware<sup>®</sup>

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On May 6 1937 Hindenburg, the biggest blimp ever, was making a landing in Lakehurst, N.J. after its transatlantic trip. Atmospheric electric storm charged hydrogen-filled Hindenburg. When a landing “anchor” was dropped to the ground, Hindenburg detected an ESD Event in a spectacular manner, providing audio and visual indication for miles. Data logging of this event was provided by the press.

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A smaller, cost-effective ESD Event monitor provides audio and visual indication, as well as ESD Event count (it was 1 in the original design) and magnitude of each event, however big or small it is. And you don't need press coverage for collecting the data.



# Verification of your ESD Environment

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- Assess your existing ESD Environment by monitoring **actual** ESD Events
- Determine the **real** needs for ESD-preventive measures
- Verify their **actual** effectiveness
- Manage your ESD budget based on **facts**
- **Know** what is **really** happening with ESD
- Cross out the word “**assumption**” off your vocabulary – you don’t need it anymore.



# Contact Information

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