ESD Class 0 Protection Stress Levels

Their Origin and Application

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ESD Event Classification

- From EMI to EOS - Speed Classification
- EMI caused ESD has short and repetitive pulses with low energy.
- EOS is and ESD event with unlimited Current/Time constrains
- HBM, MM & CDM model typical events in the manufacturing areas.

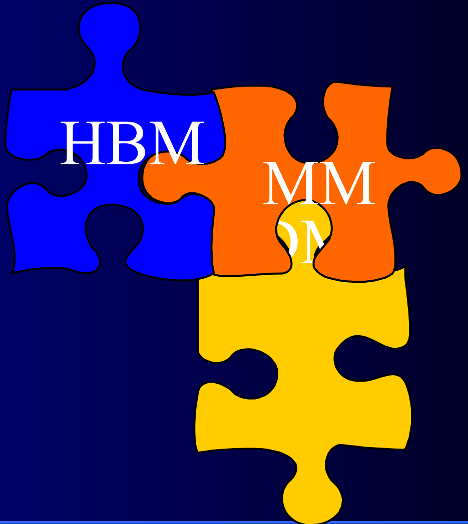
Introduction

- [1] What is an ESD Sensitivity Level?
- [2] How is it obtained?
- [3] Why is it important to the user?
- [4] Why different test models?

Overview

- ESD Models Provide a way to characterize the sensitivity of components to ESD
- The different ESD models simulate the different environments experienced by electronic components during the manufacturing process.
- Parts and assemblies may be exposed to more than one type of ESD event over the manufacturing and test life cycle.

ESD Models:
(differences & interrelation)



Purpose of ESD Models

- Models establish Benchmarks for ESD Sensitivity.
- Different Models are used to simulate different work environments.
- Models provide help to prevent and analyze ESD Failures

ESD Event Test Models

- **Human Body (HBM):** discharging event through the body and the part to ground.
- **Machine (MM)**: discharge voltage through automated handling equipment or hand-tools and the part to ground.
- **Charged Device (CDM)**: discharge into or out of a part due to charge accumulation within the part itself.

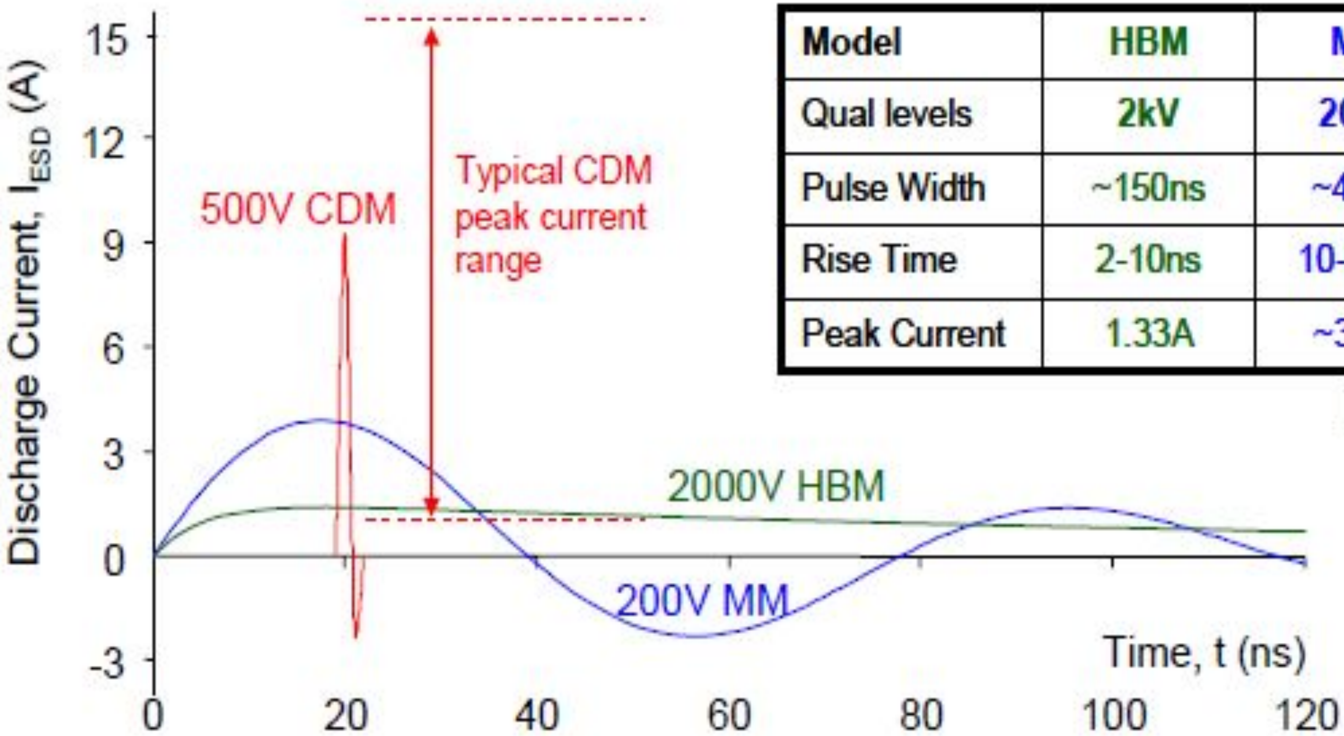
ESD Damage to Die Structure

- Damage types can vary depending on event models.
- Long, higher Voltage HBM event can look like electrical overstress at die periphery.
- Fast, high Current CDM event causes defects in core area which can be latent failures.
  - Must use advanced FA techniques to locate sites.

A Comparison of Electrostatic Discharge Models and Failure Signatures for CMOS Integrated Circuit Devices, M. Kelly, G. Servais, T. Diep, S. Twerefour, *D. Lin, G. Shah, EOS/ESD Symposium 95*

ESD Sensitivity Levels

Human Body Model		Machine Model		Charged Device Model	
Class 0	<250 V	Class M1	< 100 V	Class C1	< 125 V
Class 1A	250 V to< 500 V	Class M2	100 V to < 200 V	Class C2	125 V to < 250 V
Class 1B	500 V to < 1 kV	Class M3	200 V to < 400 V	Class C3	250 V to < 500 V
Class 1C	1 kV to < 2 kV	Class M4	≥ 400 V	Class C4	500 V to <1 kV
Class 2	2 kV to < 4 kV	---	---	Class C5	1 kV to < 1.5 kV
Class 3A	4 kV to < 8 kV	---	---	Class C6	1.5 kV to < 2 kV
Class 3B	≥ 8 kV	---	---	Class C7	≥ 2 kV



Model	HBM	MM	CDM
Qual levels	2kV	200V	500V
Pulse Width	~150ns	~40ns	~1ns
Rise Time	2-10ns	10-15ns	100-500ps
Peak Current	1.33A	~3.6A	1-16A

[Gieser] (modified)

Figure 4: Comparison of current waveforms for CDM, MM, and HBM ESD events.

White Paper 2: A Case for Lowering Component Level CDM ESD Specifications and Requirements, Industry Council on ESD Target Levels, March 2009

Models Comparisons

ESD Models	Z_D	R_C	C_D	L_D	E_S in μJ	5τ in ηs	P_{ave} (W)	I_{PS}
V_c = 1000 V	Typ.#	Req #	Req #	Typ #	$\frac{1}{2}CV^2$	$5R_eC$	E/τ_{eff}	V/R_e
HBM	0	1500	100	0	50	750	~67	0.67
MM	55	2	200	5.0E-07	100	160	625	17.5
CDM	42	25	15	1.0E-08	7.5	5	>750	15

Courtesy of ESDA

ESD Models vs. Sources of Threats

Examples of Sources of Threats	HBM	MM	CDM
Operator	√		√
Work bench	√	√	√
Pick and Place Machine		√	√
Automatic Test Equipment		√	√
Device package			√
Mate/De-mate of harnesses	√	√	√
RF Signals			√

“Class 0” Parts Protection

- “Class 0” has become the generic term to define parts which are very sensitive to ESD.
- It now encompass parts sensitive to HBM <250v as well as parts damaged by EMI
- Sensitivity for these parts needs to be also defined using CDM classifications.

{EPAs as currently implemented at GSFC can protect parts sensitive to ~100 V HBM}

Model Implementation

- NASA-HDBK-8739.21 (in Approval Cycle) **Guide for Creating an ANSI/ESD S20.20 Implementation Plan**
  - Focus is on HBM: emphasis on operator grounding, dissipative surfaces, reduction of triboelectric charging
  - For HBM & MM the methods for protective practices and creating protective spaces are highly reproducible and "low tech"
    - Proper implementation requires training and follow-up
- HBM safety methods have brought HBM & MM failures down (now are ~10% of failures encountered industry-wide)

Model Implementation

– Recent failures of high speed devices (LVDS, FPGAs) drive users to Class 0 HBM…

– …But IC manufacturers calculate that about 90% of the failures from the field are due to CDM ESD events.

– CDM-related field returns are associated with low, medium, and high sensitivity devices.

– Safety methods for CDM are highly customized because the model is less mature (many unknown variables and variable relationships, rapidly changing characteristics

Class 0 & CDM

- Class 0 refers to the HBM model
- Currently most ESD damage is caused by much shorter pulses best defined in the CDM model.
- ESD pulses can be clamped by internal shunts and bypasses at the expense of design complexity and speed.
- There is a limit beyond which the device cannot be internally protected.

Limits of Design-in Protection

- CDM protection by the design is driven by the peak current from the IC package discharge at the CDM voltage targeted.
- The larger the package the higher the peak current of the CDM pulse created.
- The smaller the geometry of the circuit the lower the breakdown voltage of the circuit
- Present Theoretical Limit ≈ 125v CDM

Protection of Devices Sensitive to Class 0 ESD

- "Shalls" related to HBM Class 0 protection:
  - Dissipative chairs and stools
  - Conductive or dissipative floors or floor mats
  - Relative humidity
  - Ionizers
  - Smocks
  - Procedures for Mating and de-mating of harnesses
  - Soldering iron testing
  - Signage

External ESD Control Measures
for Extremely Sensitive Devices

Measure Area Static Charges

↓

Assess Possibilities for Area charge Reduction

↓

Avoid Hard Discharges

Charged Board Events

- CBE are caused when a board is pulled from the bag and place on a conductive surface
- This ESD hazard was often overlooked
- During FA the components failure is usually classified as EOS damage.
- Recent data reported by several Companies indicates that CBEs are commonly missed in FA

Where to Get More Information

- WEB searches under “ESD Models”
- ESDA publications
- Consulting services provide Advice on tough ESD problems and Solutions.

References

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2. ANSI/ESD STM5.2-1999 ESD Sensitivity Testing (MM)
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4. ANSI/ESD SP5.2.2-2004 ESD Sensitivity Testing (SDM)
5. ANSI/ESD SP5.5.1-2004 ESD Sensitivity Testing (TPL)
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12. http://ossma-dev.gsfc.nasa.gov/ESDResources/index.php
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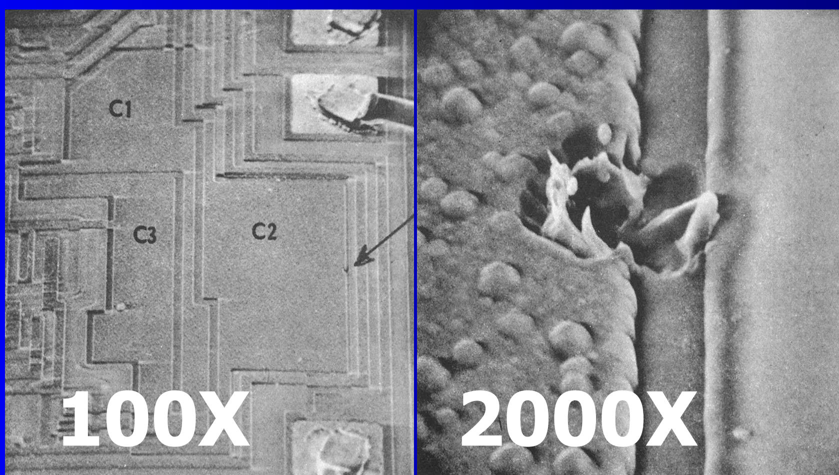
Thank you
Any Questions?

Typical HBM Generated Failures



Courtesy of JPL

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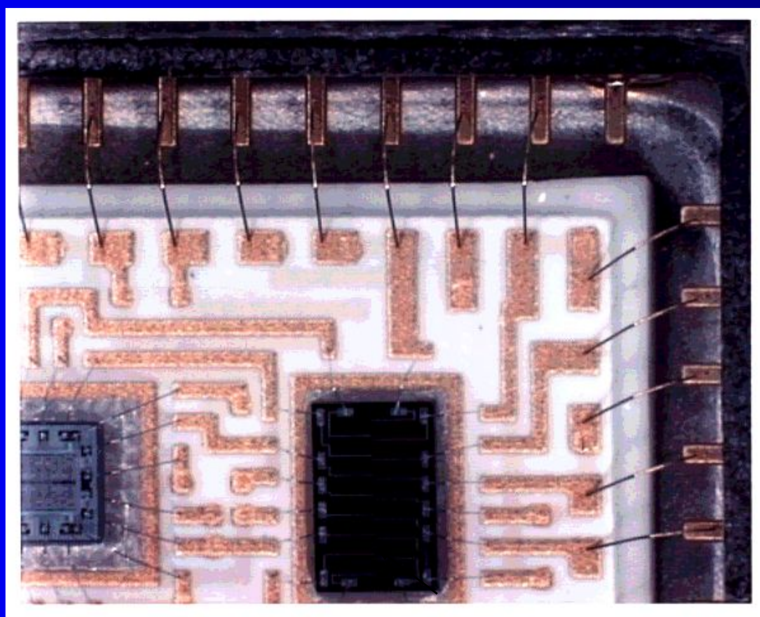
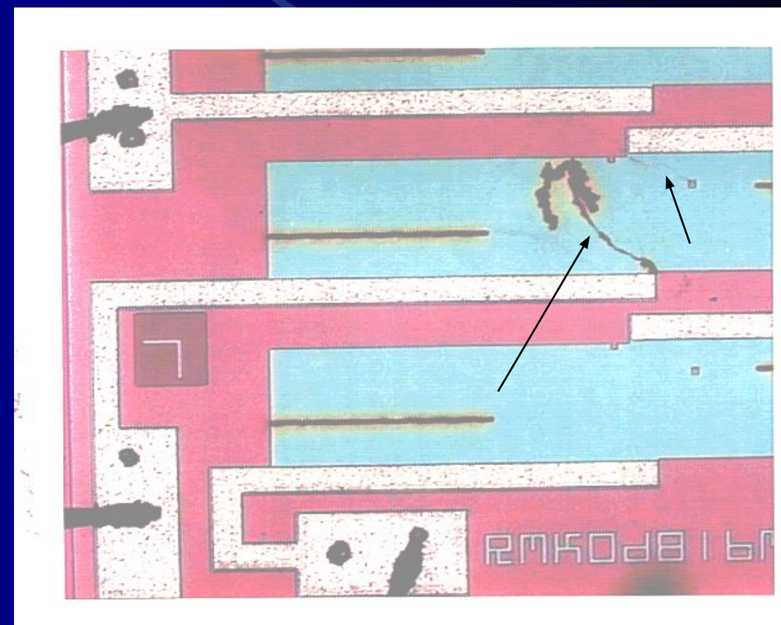
Typical MM ESD Stress Failure





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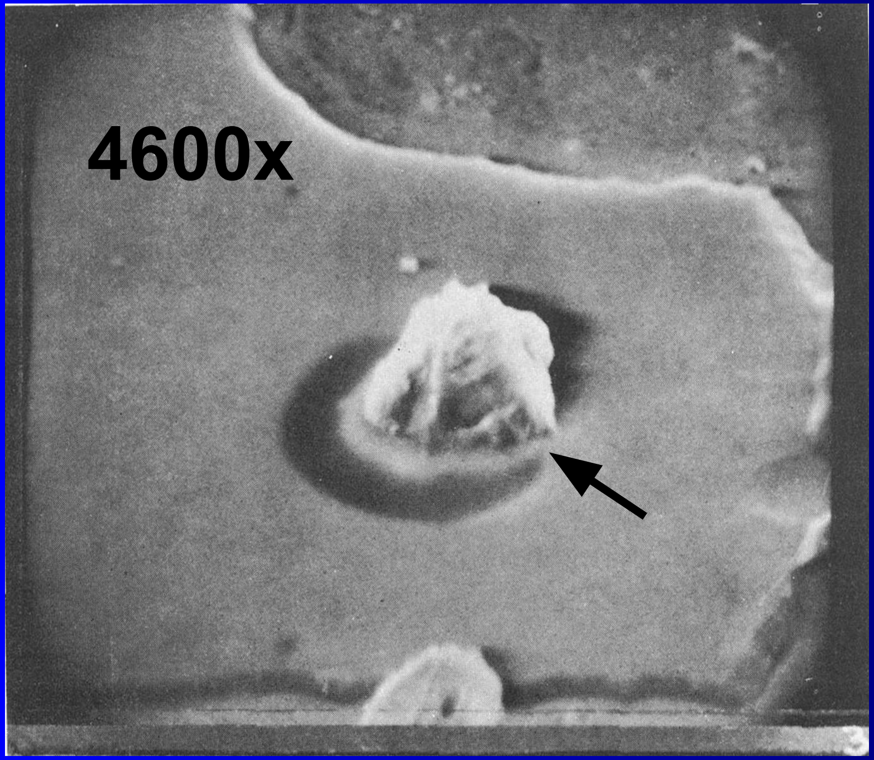
Typical CDM generated failures



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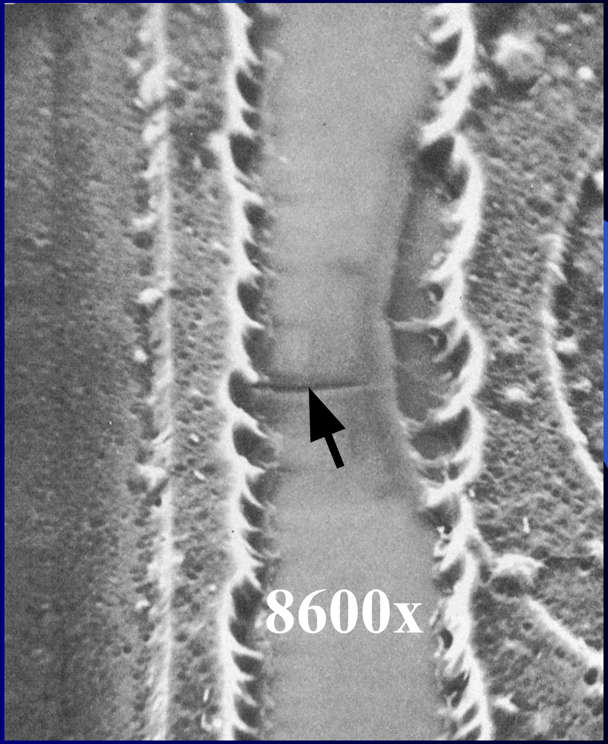
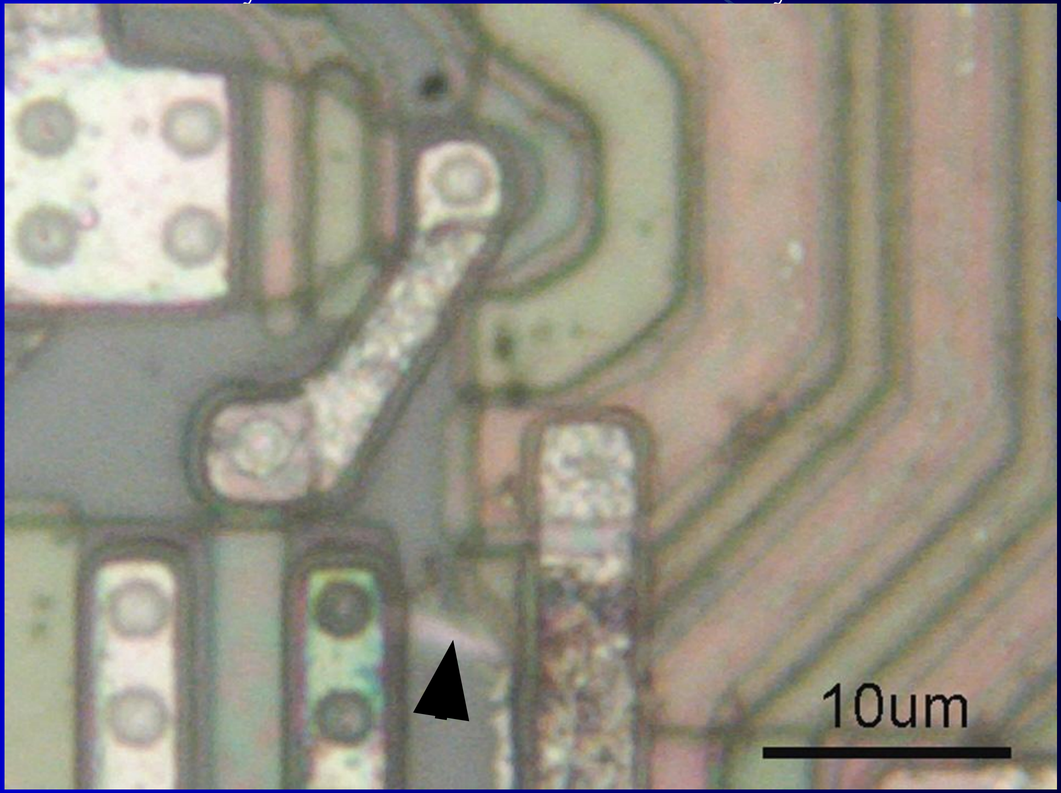


Courtesy of JPL

Typical CDM Generated Failure

Courtesy of Frederick Felt GSFC Part Analysis Lab.



ESD event (~1 KV) shown at arrow after parallel Polishing