REMCOM® Electromagnetic Simulation Software

Electrostatic Discharge (ESD) Simulation and Prediction for RF Devices

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Overview

1. Static Electricity and Electrostatic Discharge (ESD)
2. Electrostatic Discharge Testing
3. Prediction of ESD with XFdtd® Electromagnetic Simulation Software
4. Spark Discharge Modeling
5. Multiphysics ESD Analysis
6. Conclusions

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Static Electricity

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Causes:

- Contact / Triboelectric
- Pressure / Piezoelectric
- Temperature / Pyroelectric
- Charge / Electrostatic Induction

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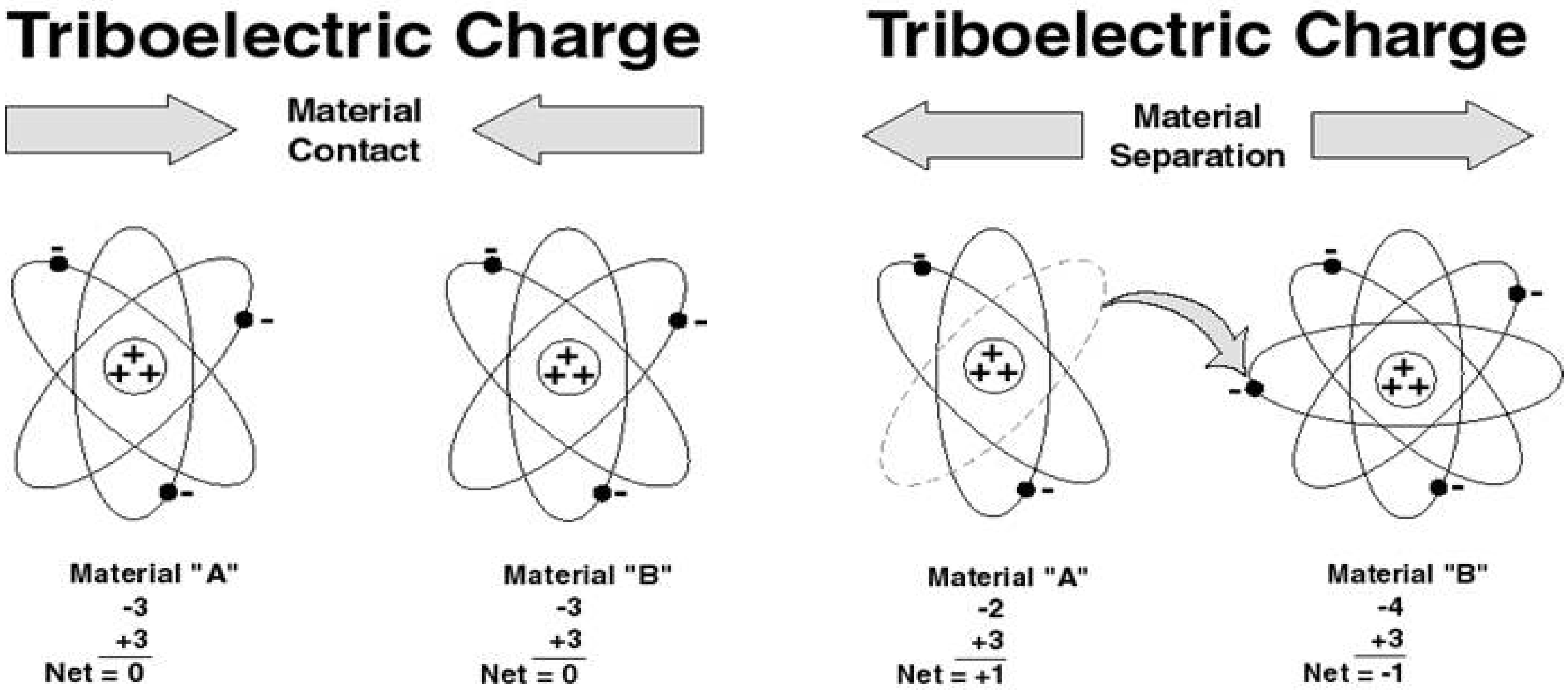
Triboelectric Charge



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Triboelectric Charge

$$q = CV$$

q – Charge (Coulombs)

C – Capacitance (Farads)

V – Voltage (Volts)

$$E = \frac{1}{2}CV^2$$

E – Energy (joules)

Examples of Static Generation - Typical Voltage Levels		
Means of Generation	**10-25% RH**	**65-90% RH**
Walking Across Carpet	35,000V	1,500V
Walking Across Vinyl Tile	12,000V	250V
Worker at a Bench	6,000V	100V
Poly Bag Picked up from Bench	20,000V	1,200V
Chair with Urethane Foam	18,000V	1,500V

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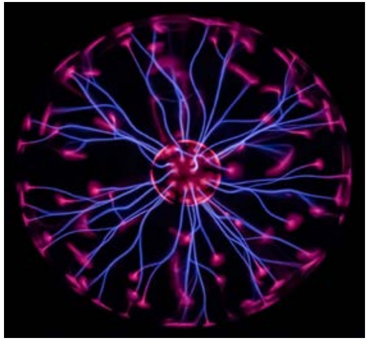
Electrostatic Discharge



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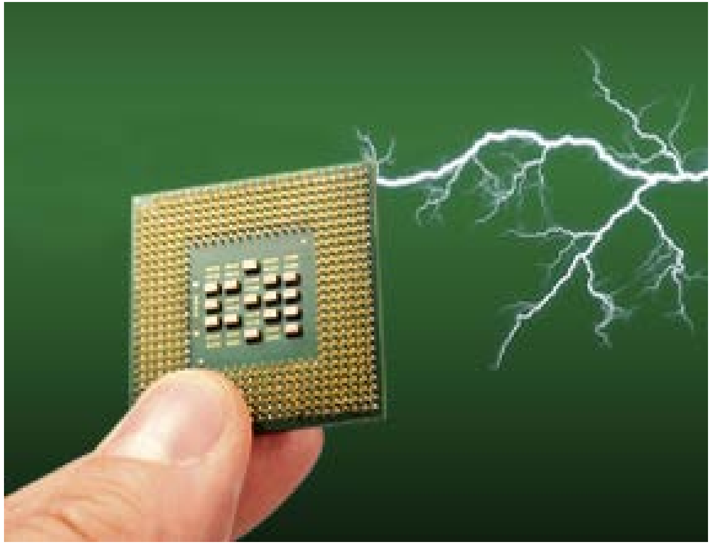
ESD Cost

"… in the electronics industry, losses associated with ESD are estimated at between a half billion and five billion dollars annually."

- In reality, total ESD cost is very difficult to determine.
- Facts:
  - Multiple Prototypes
  - Warranty Claims
  - Loss of Consumer Confidence

Reference: [2]



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ESD Testing

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Standards:

- ANSI/ESD, IEC, JEDEC, MIL, etc.

Test Models:

- Human Body Model (HBM)
- Charged Device Model (CDM)
- Machine Model (MM)
- etc.

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HBM & CDM Models

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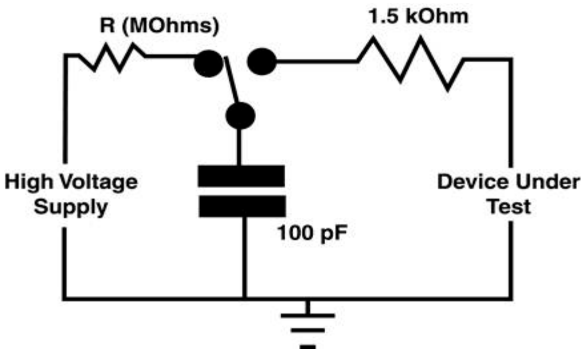
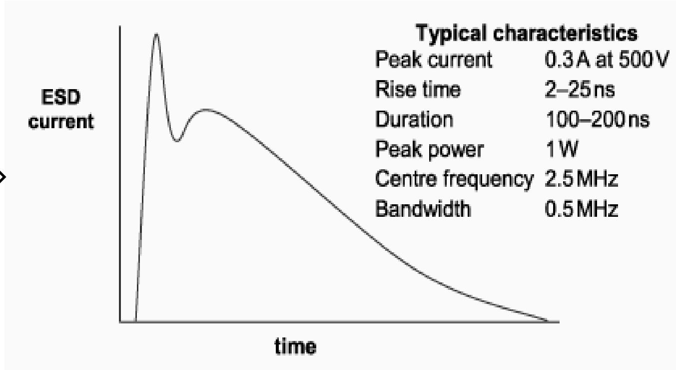
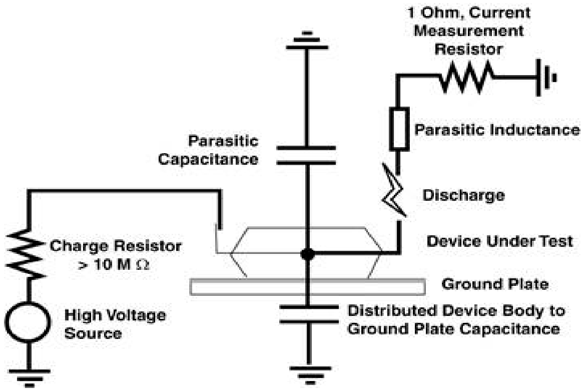
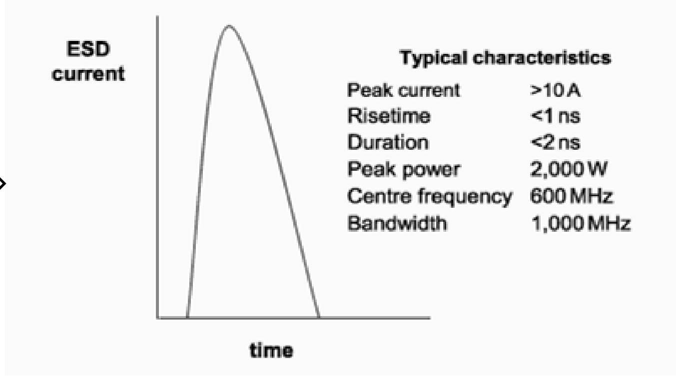
HBM





CDM





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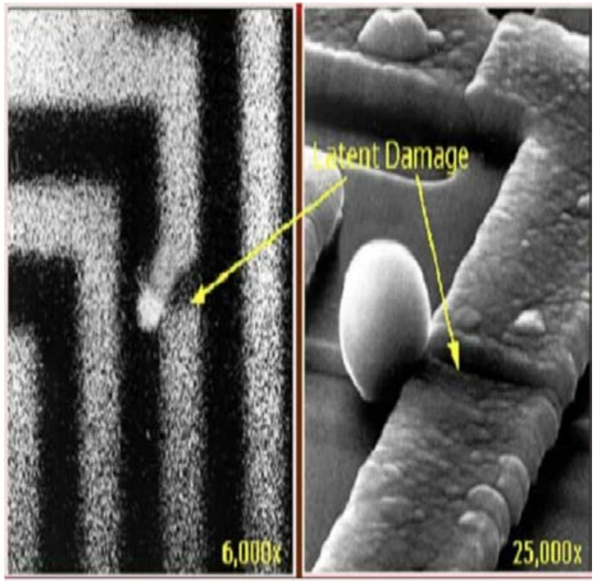
ESD Damage

Catastrophic

Latent



Upset

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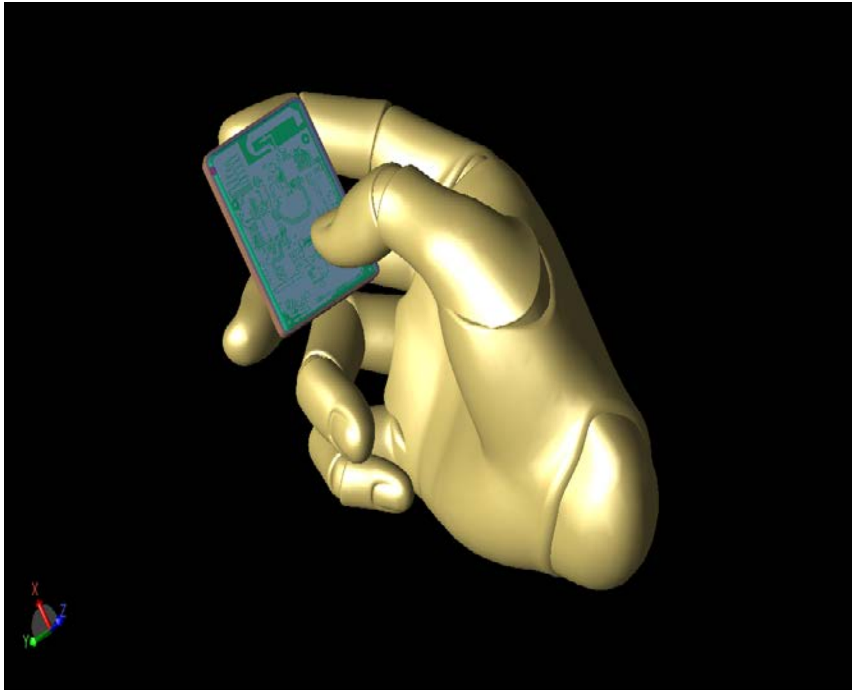
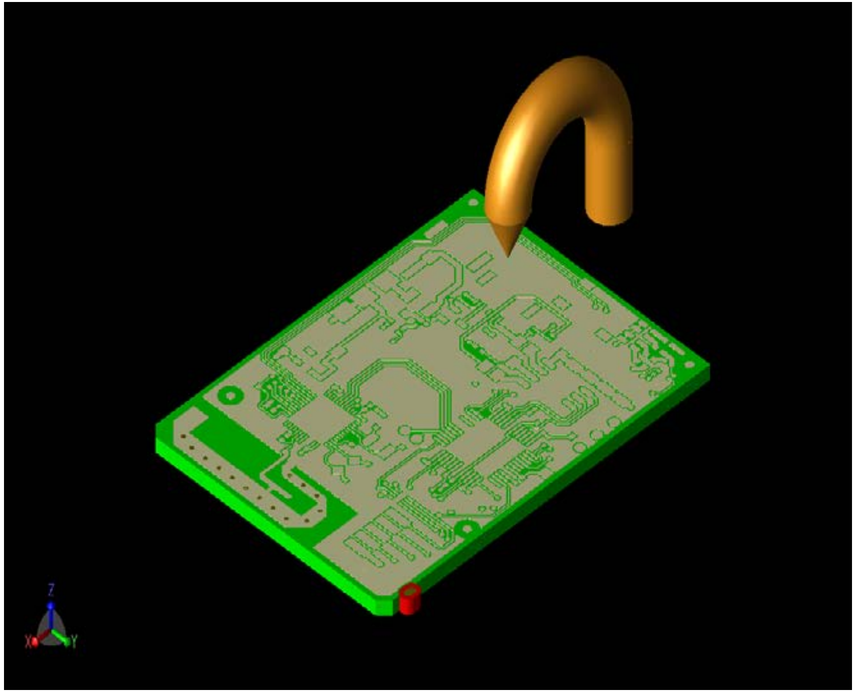
XFdtd Case Study





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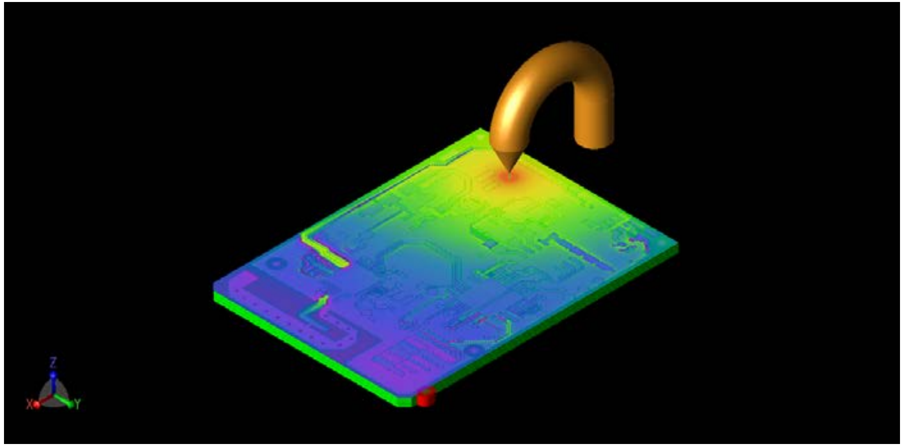
New XFdtd Functionality

- ESD Waveforms
  - HBM, CDM, MM, etc.
- Material Parameter
  - Dielectric Strength
- Circuit Components
  - Rated Voltage/Current
- Result Sensor
  - Dielectric Breakdown



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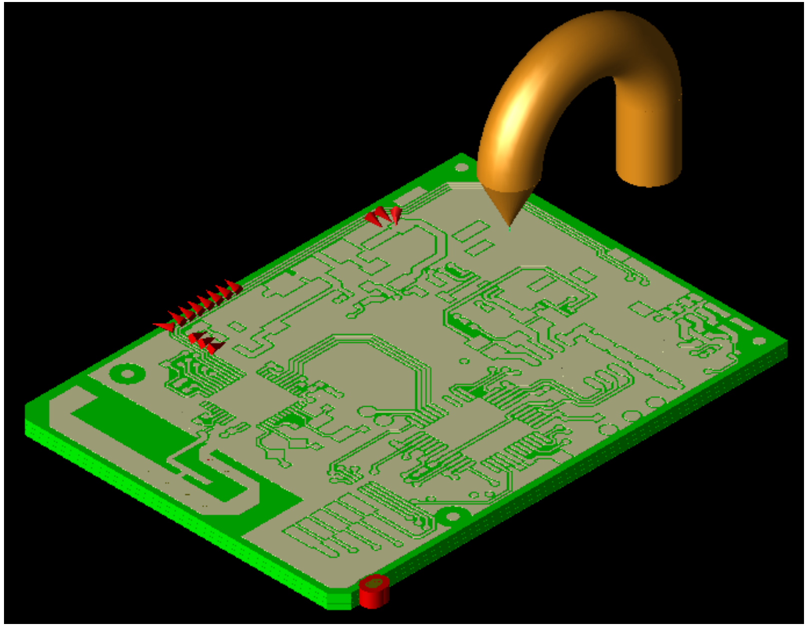
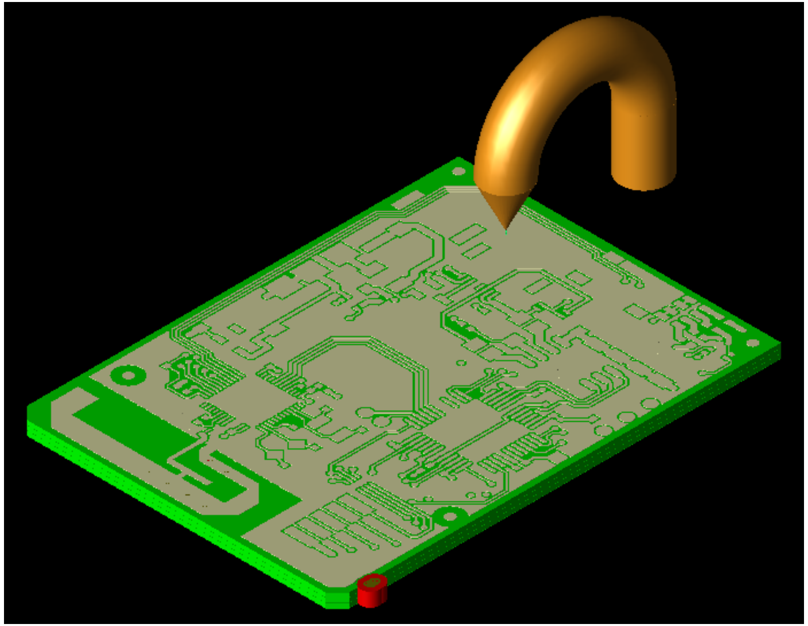
XFdtd ESD Design

Potential Dielectric Breakdown



After ESD Design Optimization



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Spark Discharge

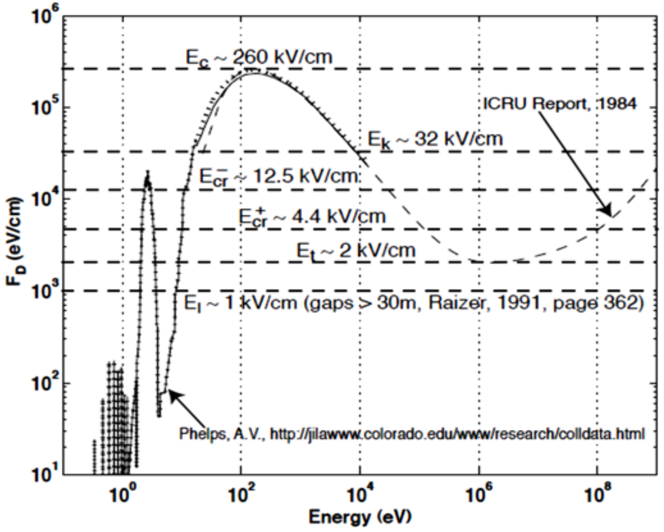
- Lorentz Force Law

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

- Plasma Modeling
  - Fluid or Kinetic
- $f(\vec{v}, \vec{r}, t)$ - Electron Energy Distribution Function
- Boltzmann Equation

$$\frac{\partial f}{\partial t} + \vec{v} \cdot \frac{\partial f}{\partial \vec{r}} + \frac{\vec{F}}{m} \cdot \frac{\partial f}{\partial \vec{v}} = \left(\frac{\partial f}{\partial t}\right)_c$$

Dynamic Friction Force of Air



Thermal Runaway:	$E_c \sim 260$ kV/cm	Positive Streamer:	$E_{cr}^+ \sim 4.4$ kV/cm
Conventional:	$E_k \sim 32$ kV/cm	Relativistic Runaway:	$E_t \sim 2$ kV/cm
Negative Streamer:	$E_{cr}^- \sim 12.5$ kV/cm	Leader:	$E_l \sim 1$ kV/cm

Source: [5]

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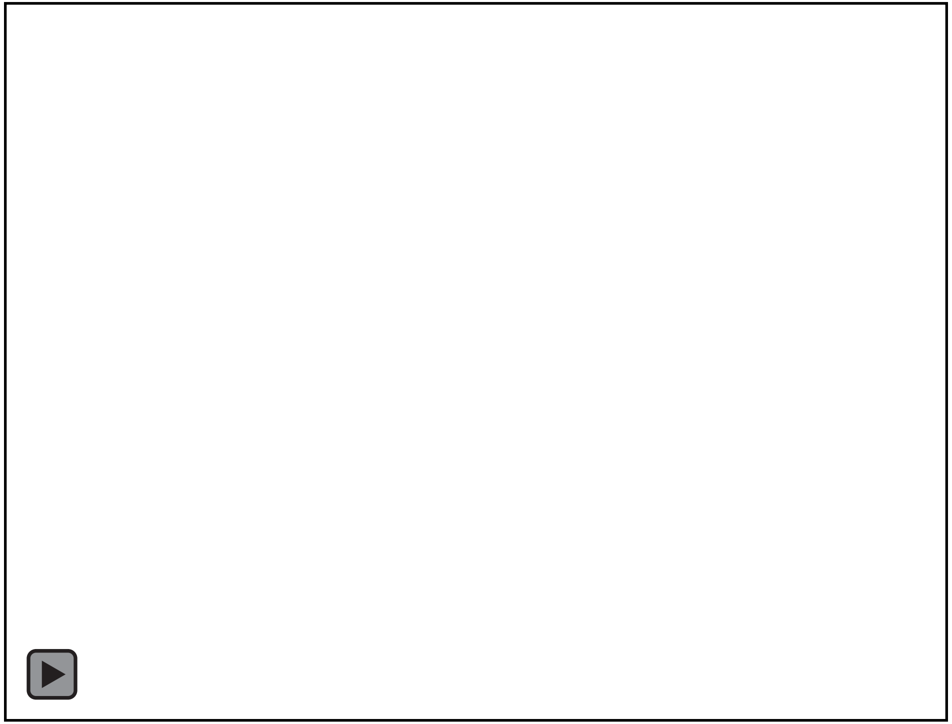
Boltzmann Solutions

- Analytic
  - Not practical for most applications
- Direct Numerical
  - ELENDIF, BOLSIG+, etc.
- Particle Simulation
  - PIC + Monte Carlo



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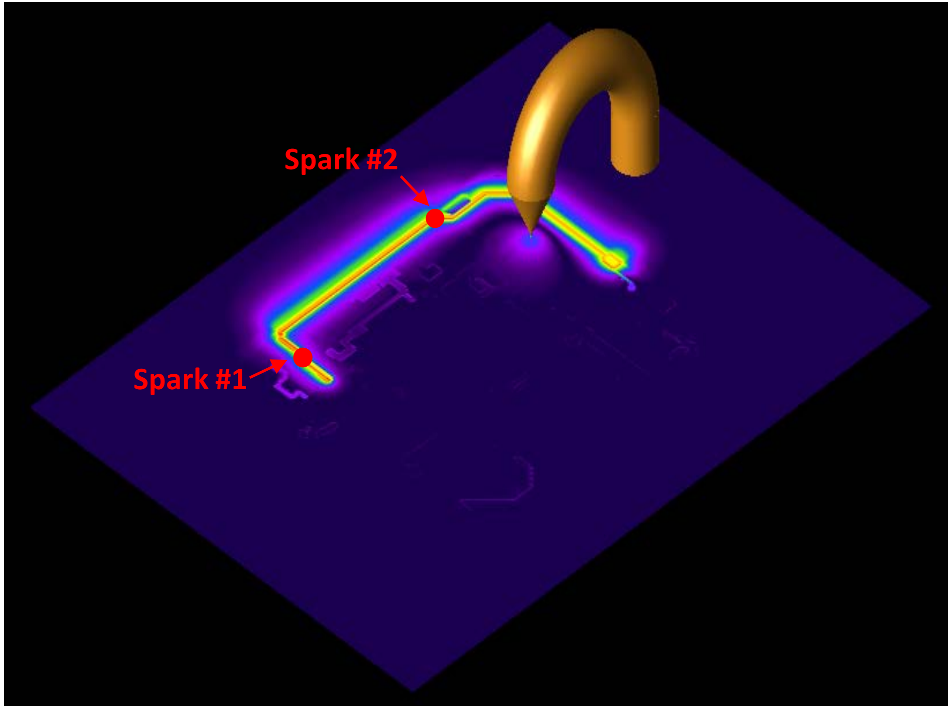
Multiphysics ESD Analysis

- Model subsequent spark discharges and overcurrents
- Pinpoint device/pin failure with transient FDTD/Circuit co-simulation
- Predict thermal damage utilizing FDTD/Thermal co-simulation



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Conclusions

- ESD simulation does not replace hardware testing.
- ESD simulation does allow engineers to predict potential ESD problems and optimize ESD protection in the design phase.
  - Reduce number of hardware prototypes
  - Reduce product development cost
  - Reduce time to market
  - Improve product reliability

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References

1. https://esda.org/about-esd/esd-fundamentals/part-1-an-introduction-to-esd/

2. http://incompliancemag.com/article/the-qrealq-cost-of-esd-damage/

3. https://esda.org/about-esd/esd-fundamentals/part-5-device-sensitivity-and-testing/

4. http://www.mtarr.co.uk/courses/topics/0215_esdw/index.html

5. Moss, G. D., V. P. Pasko, N. Liu, and G. Veronis, “Monte Carlo model for analysis of thermal runaway electrons in streamer tips in transient luminous events and streamer zones of lightning leaders,” *J. Geophys. Res.*, 111, A02307, 2006.

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