Cleanroom Considerations for ESD Control

Christopher W. Long

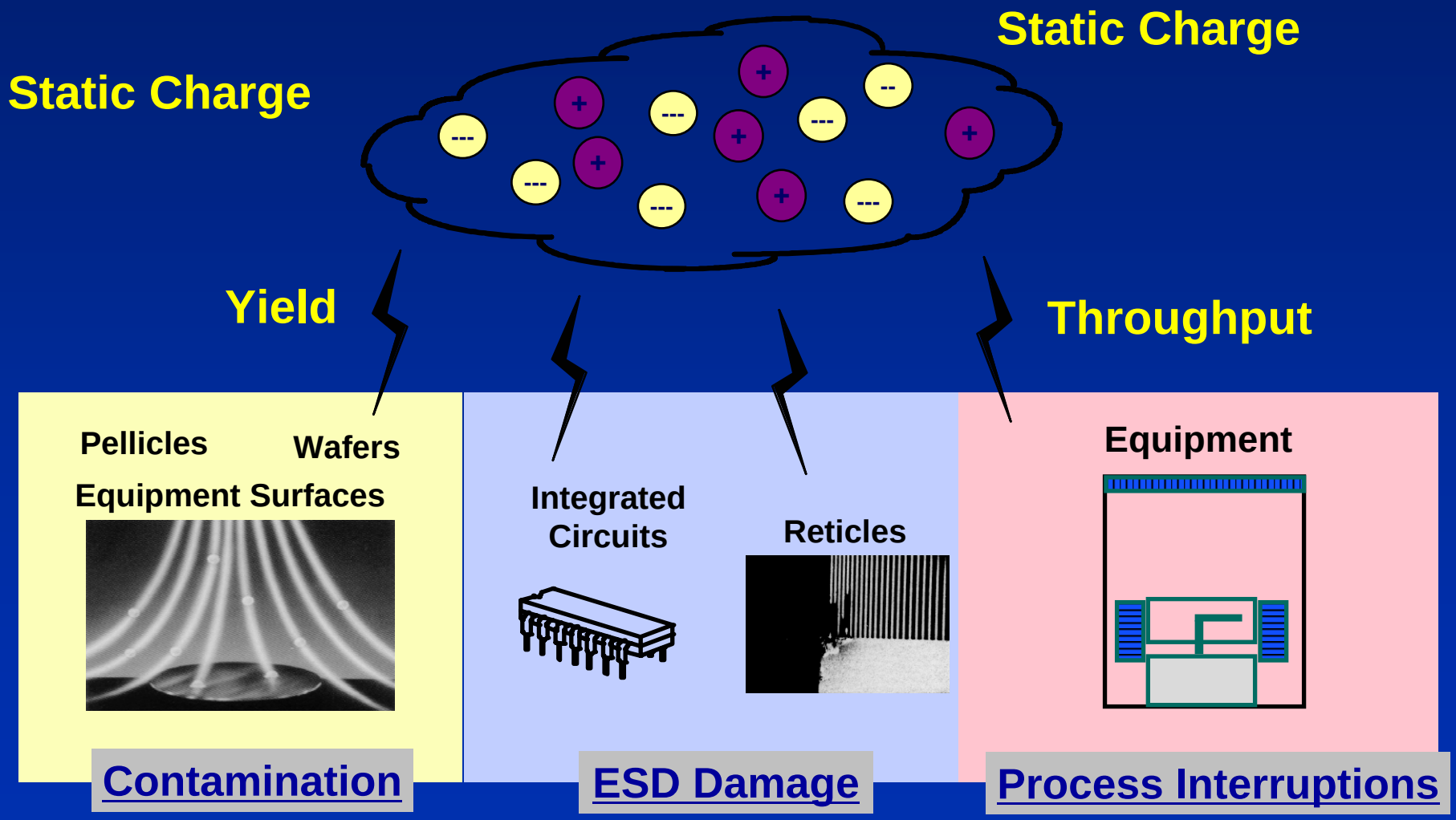
IBM

2007 SEMI NA ESD Workshop

Agenda

- **<u>Cleanroom/Environment Static Charge Challenges</u>**
- Control Strategies
- Case Studies
- Summary and Acknowledgements

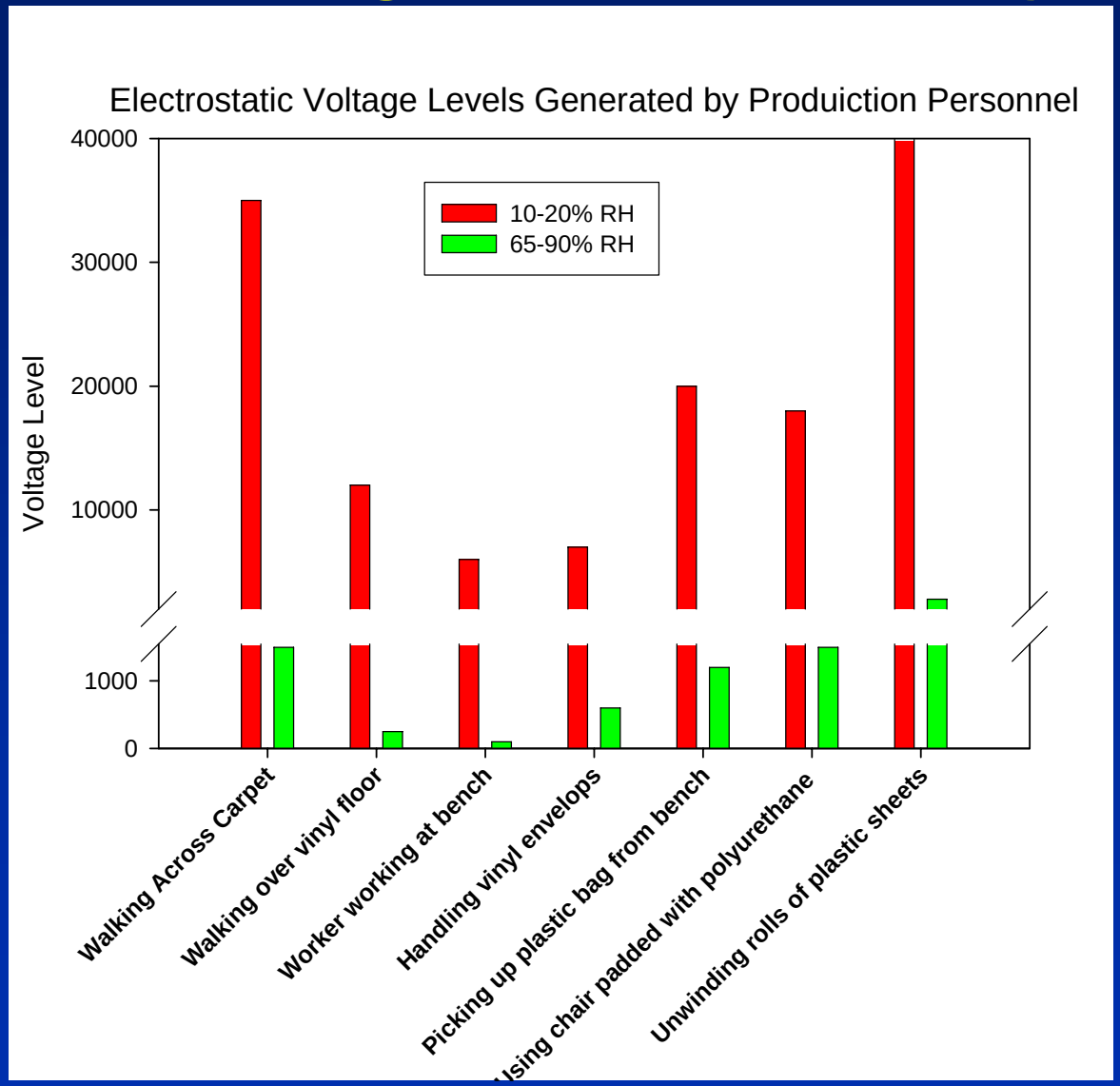
Static Charge Problems: Contamination and ESD



Clean Environments and Static Charge

- Clearly many industries require “Clean Manufacturing”
- But with Clean Manufacturing also comes:
  - Lowered Humidity Levels
  - Process-Required Insulators
  - Ultra-Clean Surfaces
  - Processes which involve product movement
  - Lack of naturally occurring ions
- All of which can be contributors to elevated static charge levels in and around product

Static Charge and Humidity



Source: ***IEST-RP-CC022.2 Electrostatic Charge in Cleanrooms and Other Controlled Environments***

Humidity

- Cleanroom humidity level specs intentionally kept at low levels
  - Typically between 30 and 45% RH
  - Driven by tooling, product requirements
- Humidity can affect levels of generated static charge
  - However provides ineffective method of static control once it exists

Process Required Insulators

- Many insulators in clean environments
- Example items and maximum charge levels
  - Oxide Coated Wafers 5-10KV/in
  - Carriers 20KV/in
  - Enclosure Materials >20KV/in
  - Plastic Films/Tape >10KV/in
  - Teflon >10KV/in
  - Ceramic 10KV/in
- Cannot ground an insulator!

Ultra-Clean Surfaces

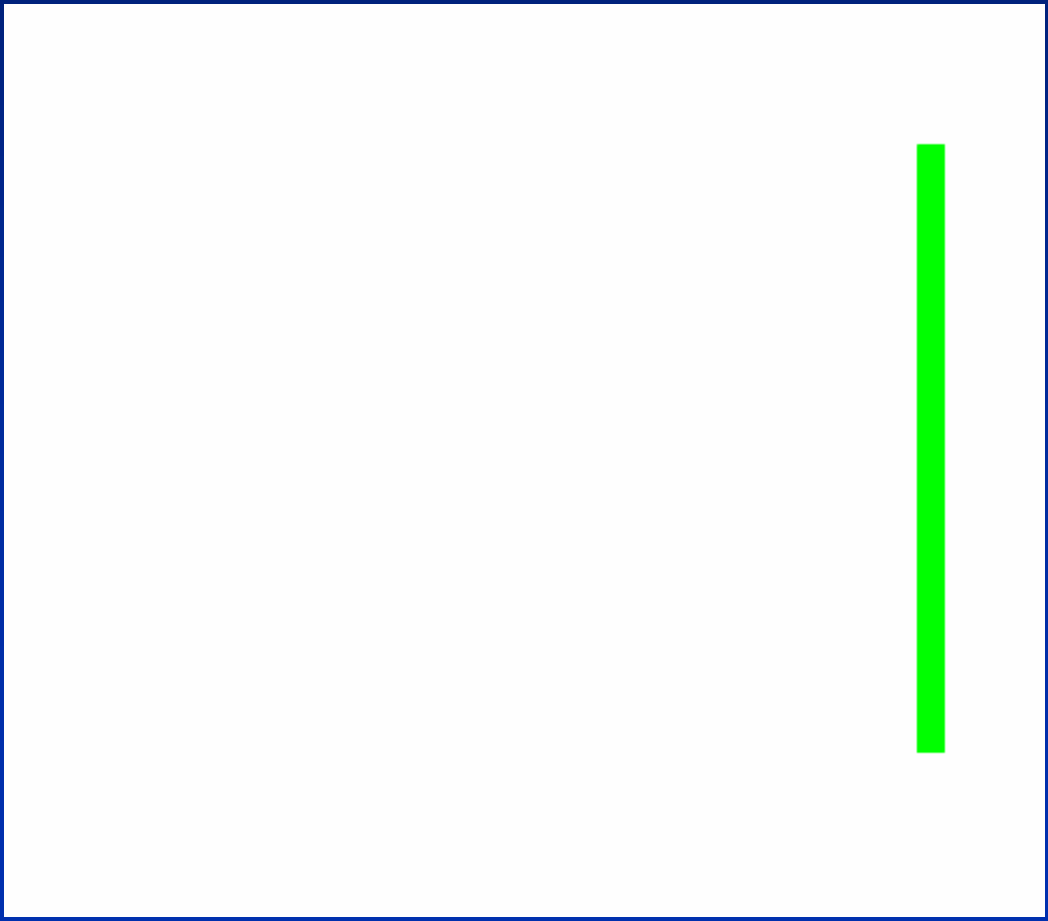
- Cleanroom protocol typically calls for frequent cleaning of surfaces, Result:
  - Minimize conductive film of contamination that helps dissipative charge
  - Act of cleaning/wiping surfaces can itself can result in tribo-charging of insulators

Product Movement and Other Sources of Tribo-Charging

- Product handling/movement
  - Tweezers
  - Robots
  - Pliers
  - Rollers
- Wet and Cryogenic Processes
  - Cleaning
  - Etch
- Wipe Down
- Environmental
  - Low humidity
  - High temperature
- Personnel
  - In chairs
  - On floor
  - Against walls
- Product Storage
  - In/Out of carriers
  - Moving across work surfaces
- Packing/Unpacking
  - Packing material
  - Sheet protectors

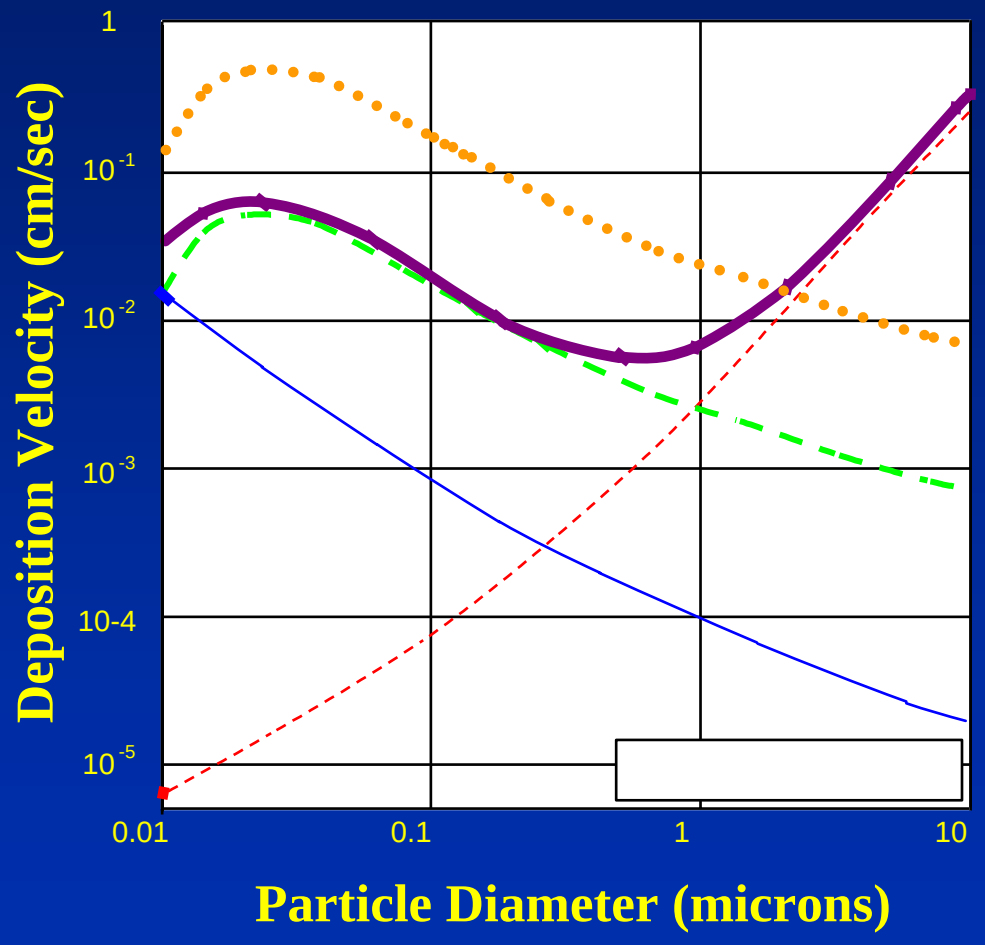
Static Charge is a Contamination Issue

- Charged surfaces attract contamination
- Very difficult to remove!



Deposition Velocity vs. Particle Size

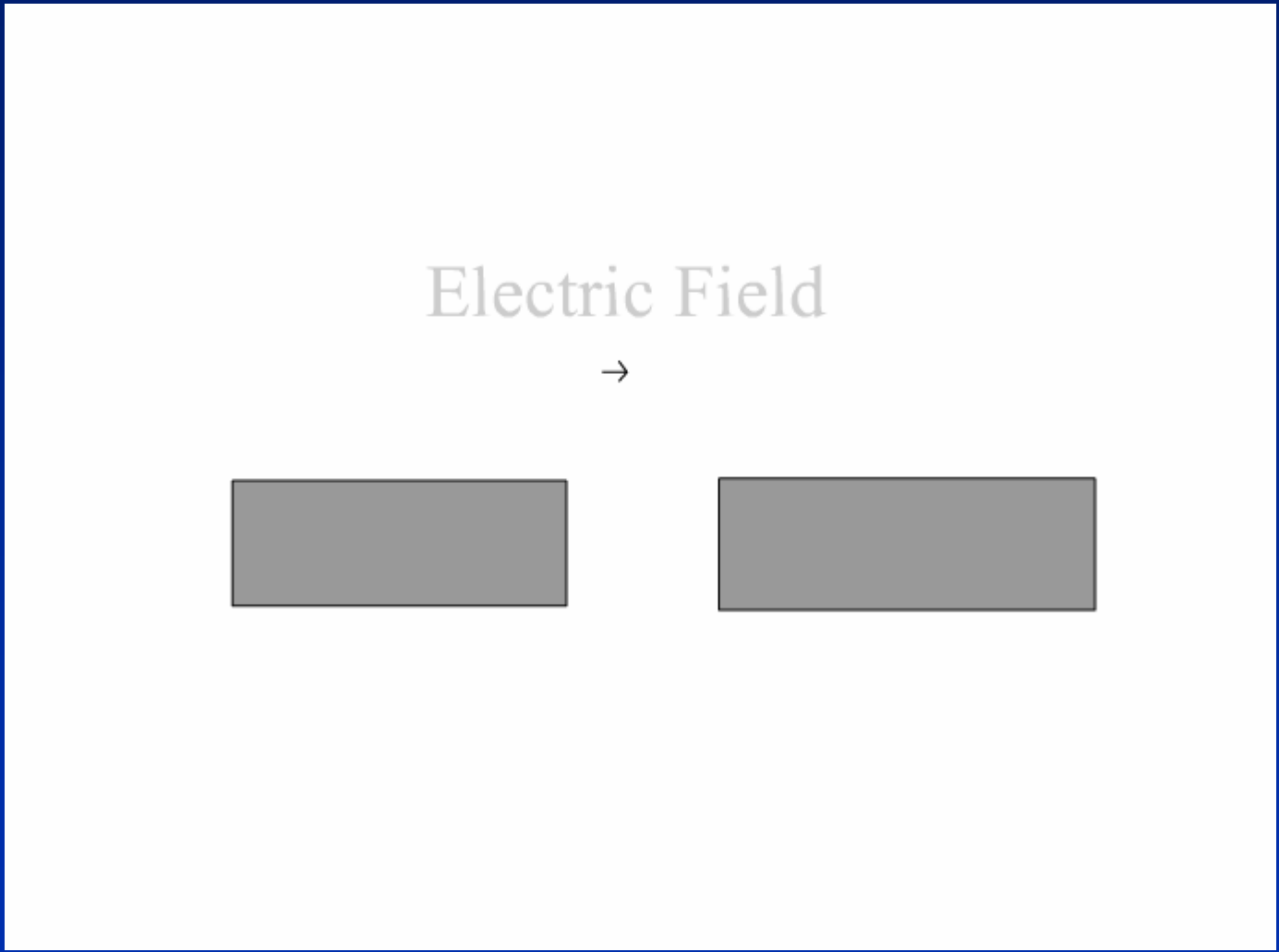
- Deposition velocities shown for:
  - Gravitational
  - Diffusion
  - Electrostatic (at 200 volts/cm and 2000 volts/cm)
  - Combined for 200 V/cm



Gravitational
Electrostatic 200V
Electrostatic 2000V
Diffusion
Combined for 200V

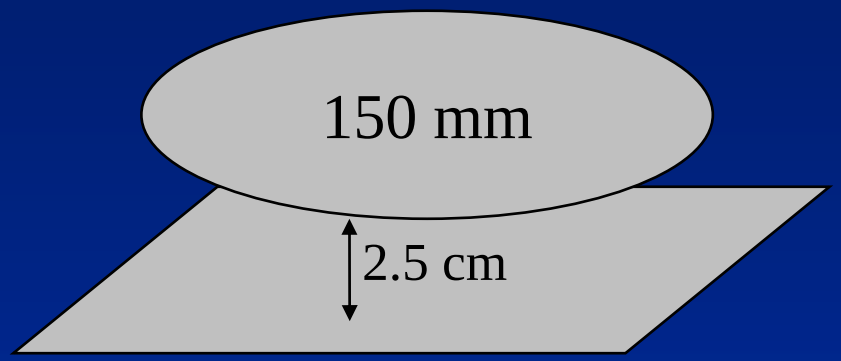
Source: D.W. Cooper, et al
IBM Research Report

Electric Fields Drive Discharges

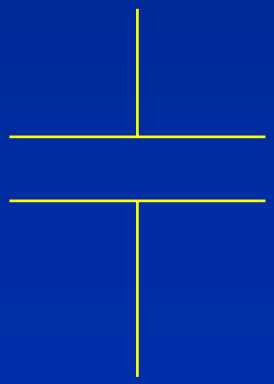


Static charge on plates and adjacent objects (i.e. rollers) drive discharges!

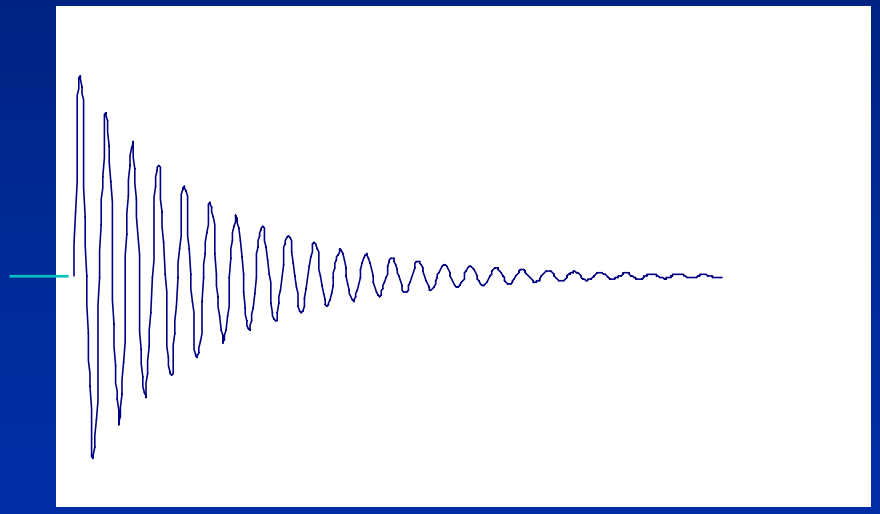
ESD Discharge Currents are Large



q=CV
with V= 5000 V,
q= 100 nC



20 pF.

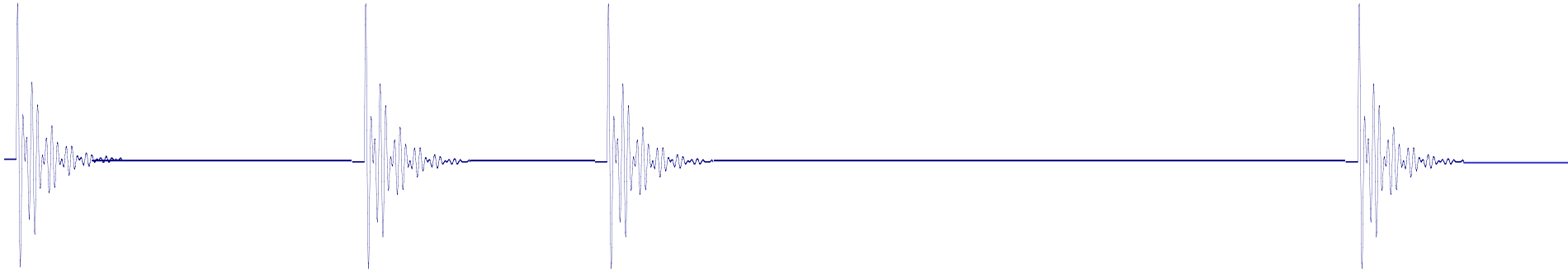


i = 50 Amps !!!

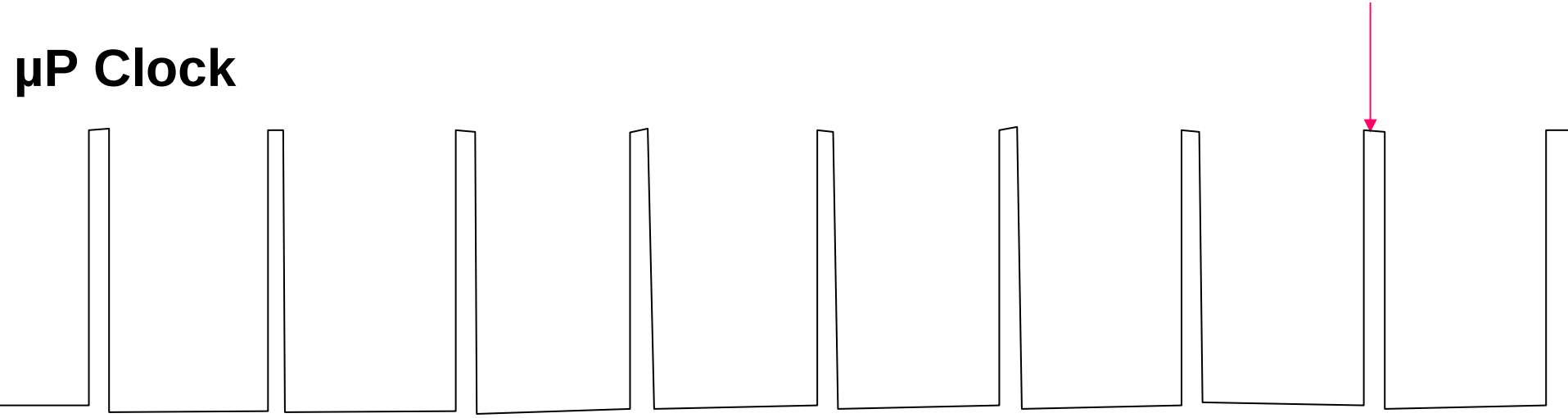
This causes large EMI Transients

Exact Timing to Effect a µP

ESD Events



µP Clock



Agenda

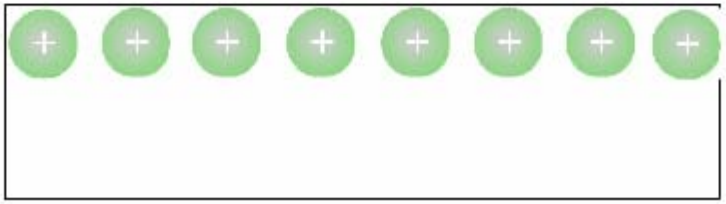
- Cleanroom/Environment Static Charge Challenges
- **<u>Control Strategies</u>**
- Case Studies
- Summary and Acknowledgements

Key Elements of Electrostatic Charge Control

- Ground All Conductors
  - Establish plan to assure that tool components are grounded
- Ground Personnel
  - Static control garments, ESD shoes, Wrist straps as required
- Implement static dissipative materials when possible
- Use room or tool ionization to reduce static charge values to tolerable levels on required insulators

Problem: How To Dissipate Static Charge on an Insulator?

Solution: Make the Air Conductive



Air Ions neutralize surface charge by contact.

Types of Commercially Available Ionizers

- Radioactive - ionizing alpha particles
  - Po^{210} alpha particles which collide with air molecules and ionize them.
- AC Corona Discharge
  - Applies 50/60 Hz AC HV to a grid of emitter points.
- DC Corona Discharge
  - DC of both polarities is fed to discrete emitters for each polarity
- Soft X-ray
  - 5-10 keV photons use the photoelectric effect.
  - Generate ions in a volume not a point

ANSI ESD S20.20 ESD Control Program Overview

Based on three fundamental principles

- Ground/Bond all conductors
- Control Charges on Nonconductors
- Use protective packaging for transit and storage

The "Plan" defines program:

Administrative Requirements

- Documented Plan
- Training Plan
- Compliance Verification Plan

Technical Requirements

- Grounding/Bonding
- Personnel Grounding
- Protected Area Requirements
- Packaging Requirements

IEST RP CC002.2 (2004)

- “Recommended Practices: Electrostatic Charge in Cleanrooms and other Controlled Environments”
- Purpose:
  - Provide guidance in specifying components of overall static control system for clean rooms

IEST RP CC002.2 Basic Methods

- Electrostatic Charge Control (ESCC)/Electrostatic Discharge Control (ESDC) Basic Methods
  - Ground all tool/facilities components
  - Reasonable and appropriate use of conductive/static dissipative materials
    - Includes personnel garmenting
  - Use of local and/or room ionization to control charge on insulators
  - Implementation of personnel training in area of ESD control

Agenda

- Cleanroom/Environment Static Charge Challenges
- Control Strategies
- **Case Studies**
- Summary and Acknowledgements

Case Study # 1

- International SEMATECH (ISMT) and ION Systems study of static control on particle adders in semiconductor photolithographic process
  - *"Measurement of Effects of a Static Control Program on ESA in the Photolithographic Process" SEMICON West 2000, Andy Rudack, Intl. SEMATECH & Larry Levit, ION Systems*

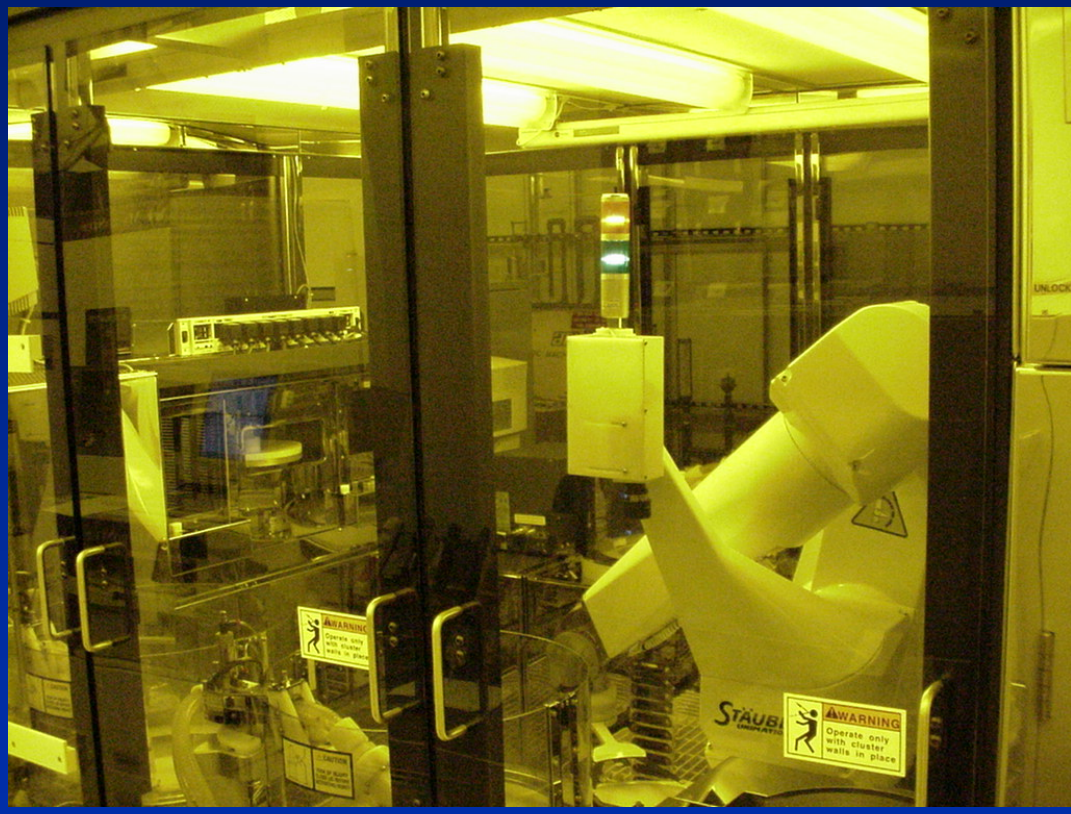
ISMT Litho Bay Study

- Focus on ISMT litho bay consisting of:
  - 193nm DUV Stepper
  - Photo Resist Coat/Develop Track for 193nm support
  - 248 DUV Scanner
  - 248 DUV Photo Resist Coat/Develop Track
  - In-Line CD SEM
  - In-Line Tilt SEM
- Ionizers installed as follows:
  - Room ionization on 8’ centers throughout $80m^2$ bay
  - Ionizer bars in all tools

ISMT Litho Bay Study Experiment

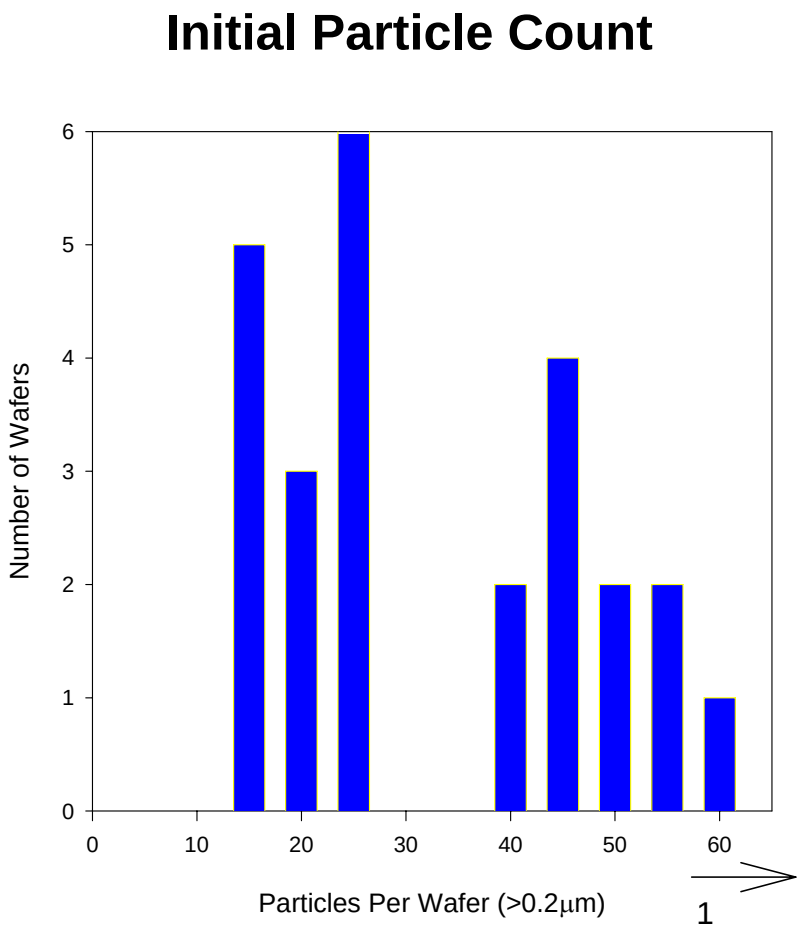
- 25 test monitor wafers pre-scanned for defects
  - 6000A oxide insulator coating on each wafer
  - Pre-Scanned on KLA-Tencor 6420 SurfScan
- Wafers cycled 23.5 hours in 193nm Track
  - Ionization turned on and allowed to equilibrate
  - 1050 number of wafer passes
  - Rescanned on KLA-Tencor 6420
- Wafers cycled 10.5 hours in 193nm Track
  - Ionization turned off and allowed to equilibrate
  - 562 wafer passes
  - Rescanned on KLA-Tencor 6420

Ionizer Installation



In the Room
As well as in Tool

Distribution of Initial Particle Counts

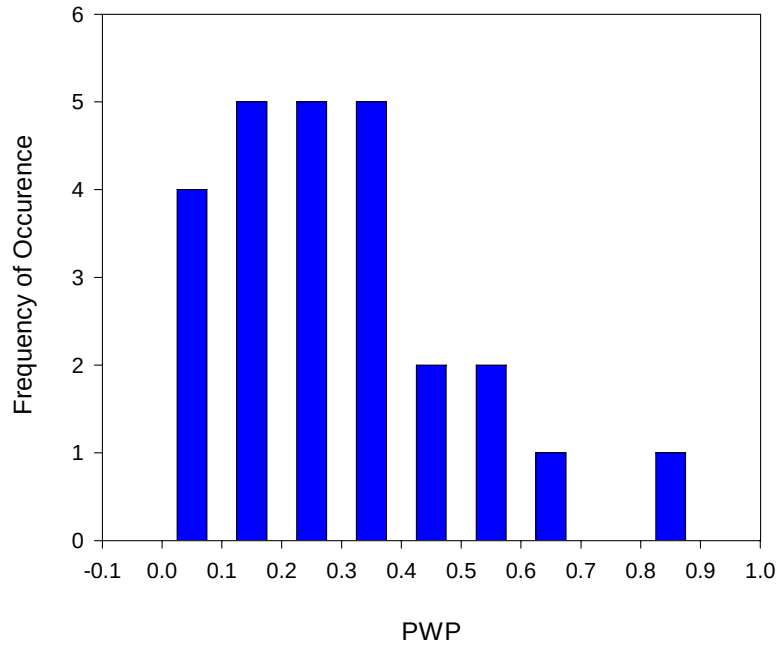


Net: Relatively clean incoming wafers

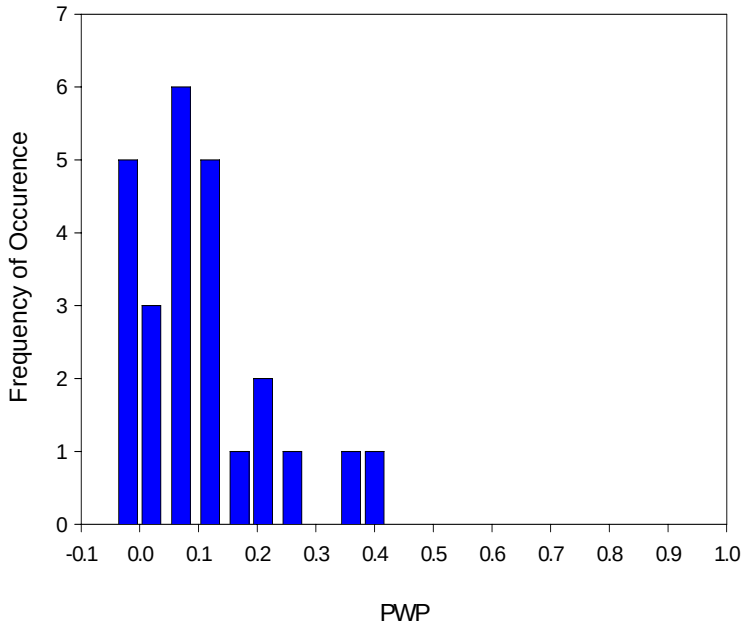
Distribution of PWP Values

- PWP: Particles per Wafer Pass
- PWP=(particles$_{before}$-particles$_{after}$/number of passes)

PWP Histogram with Ionization Off



PWP Histogram With Ionization On



Summary of Results

State	PWP Mean
Ionization On	0.117
Ionization Off	0.31

- PWP Delta = 0.193 +/- 0.044
- T-Test T Value of 2.35
- 2.3% chance that difference driven by statistical fluctuation at 98% confidence level

Discussion of Results

- Assume we have a .13um technology process
  - Critical defect size – 0.065um
- Scaling ESA induced PWP value to critical size
  - 0.193 PWP @ 0.2um => 1.83 PWP @ 0.065
- Assume 30 lithography steps in process
- ESA-related yield loss for varying kill ratios (200 die/wafer)

Kill Ratio	ESA Related Yield Loss
5%	1.40%
10%	2.80%
15%	4.20%
20%	5.60%

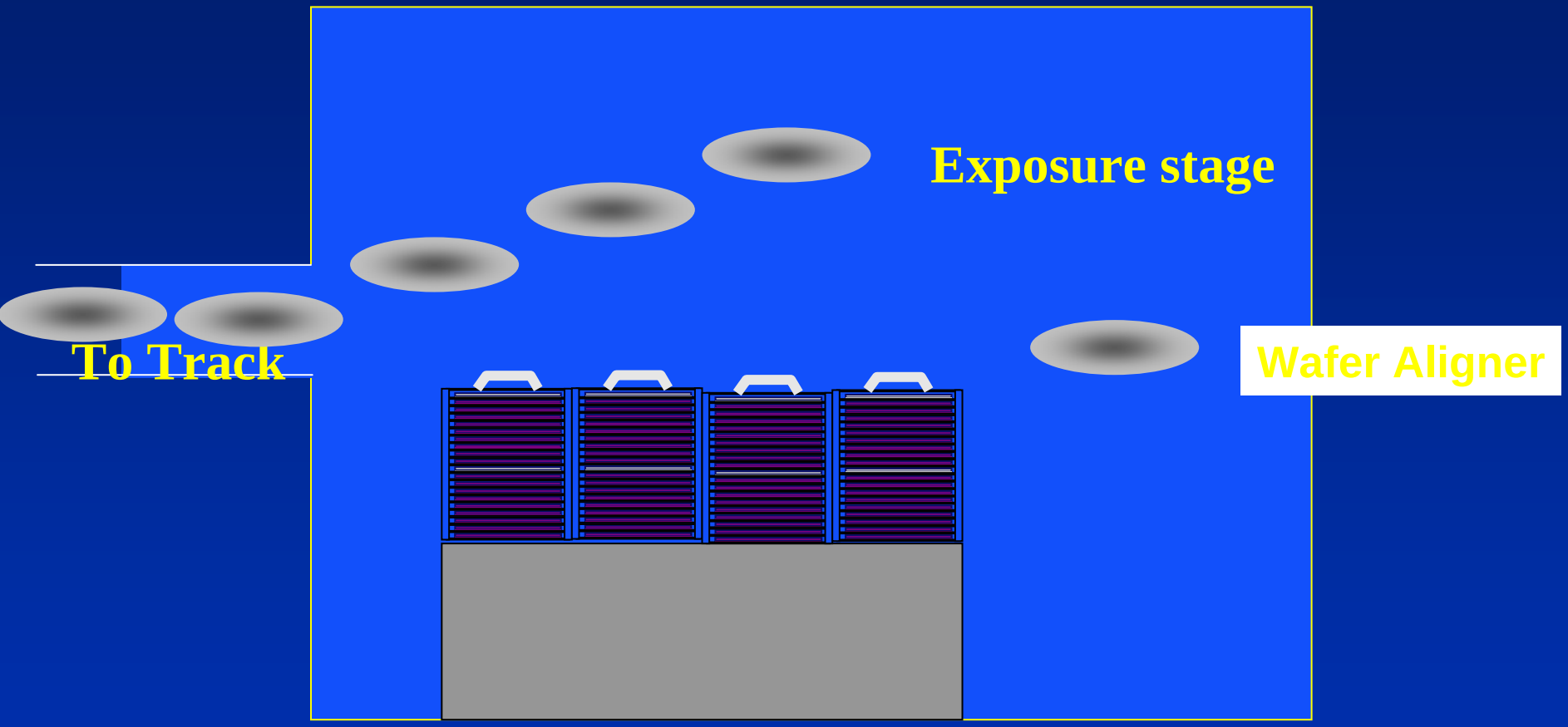
Case Study I Conclusion

- ESA is a major contributor to contamination in semiconductor processing
- Even in processes that do not generate significant static charge, air ionization provides a measurable improvement in contamination control
  - PWP improvement: 0.193±0.44 (>200 nm)

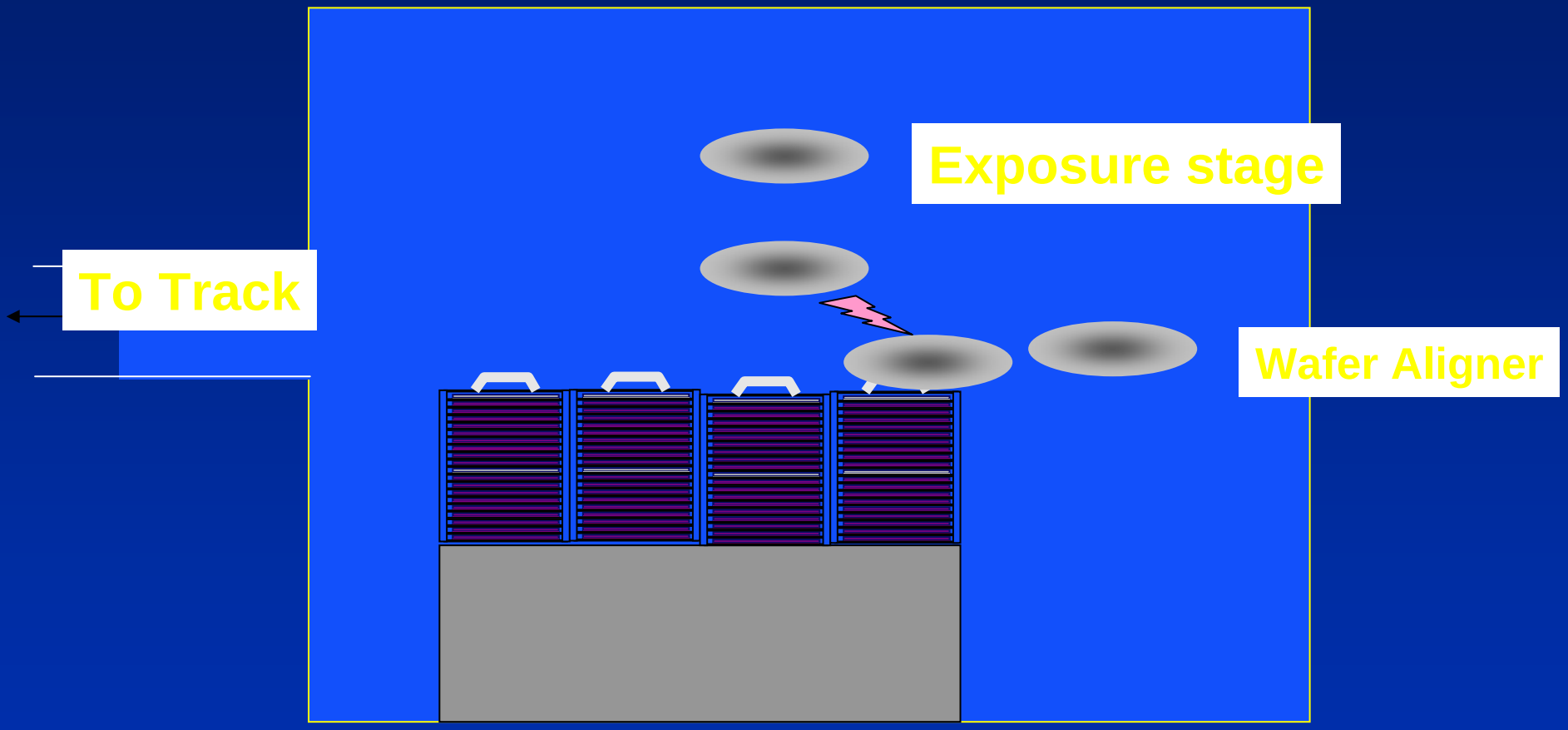
Case Study # 2

- ESD Induced EMI Event
  - Problem- ISMT photolithographic stepper shudders when lifting a wafer and then stops.
  - Reboot takes 20 minutes!

Stepper Process Schematic

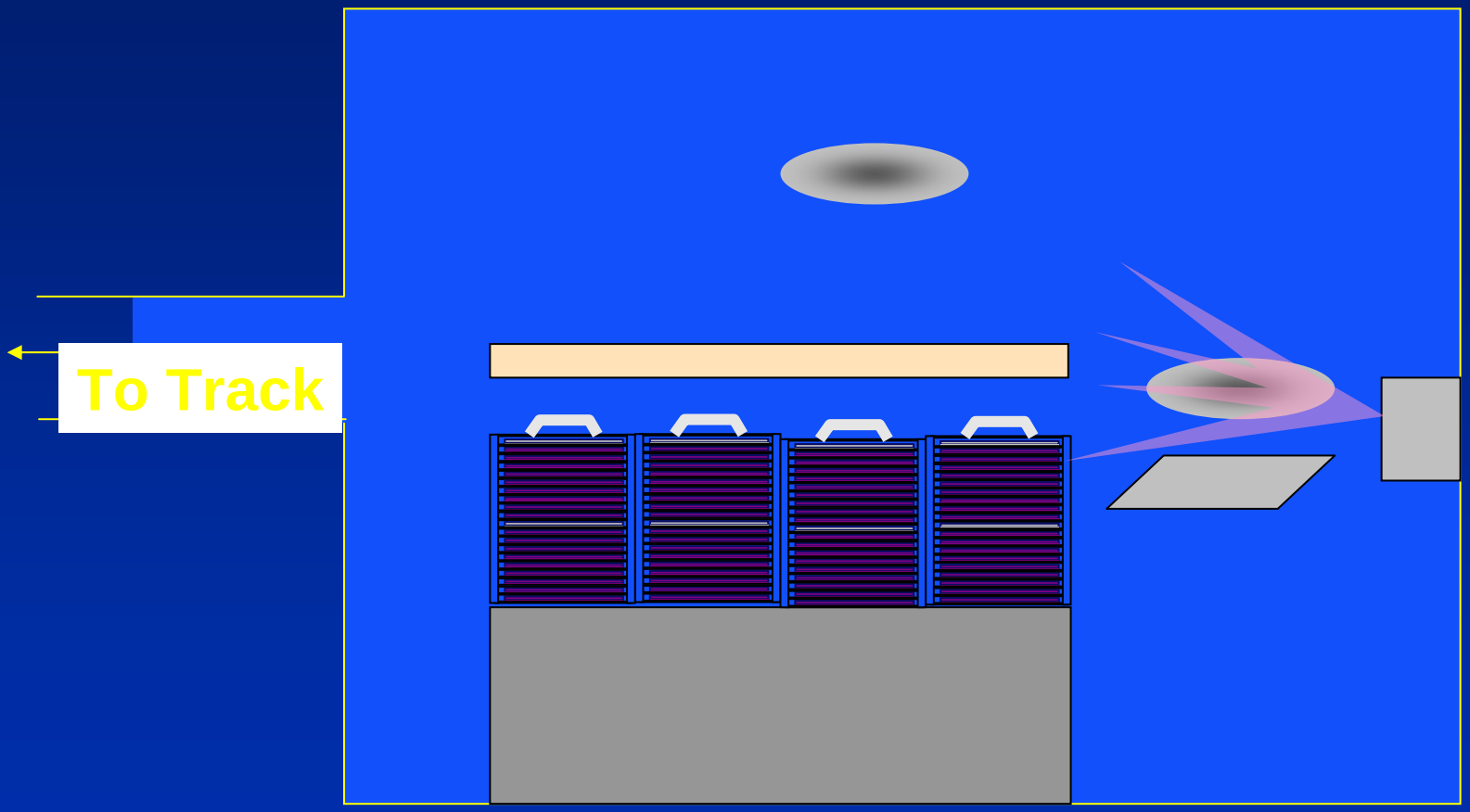


The Problem



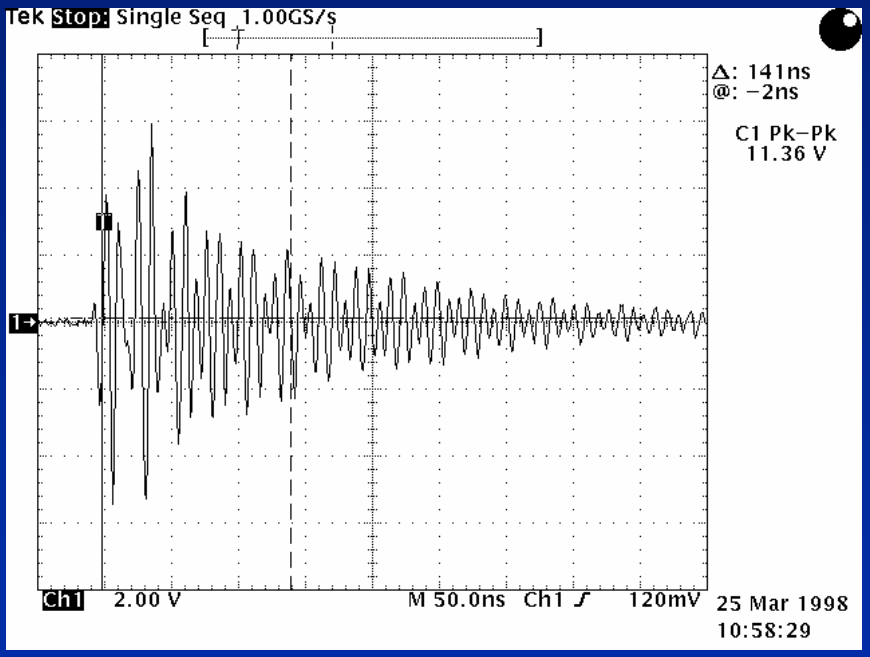
Wafers leaving the stage were charged to -10 kV and those entering the aligner were charged to +17 kV.

The Solution



Photon Ionizer Aimed at the Aligner and an Aerobar over the load station

Results



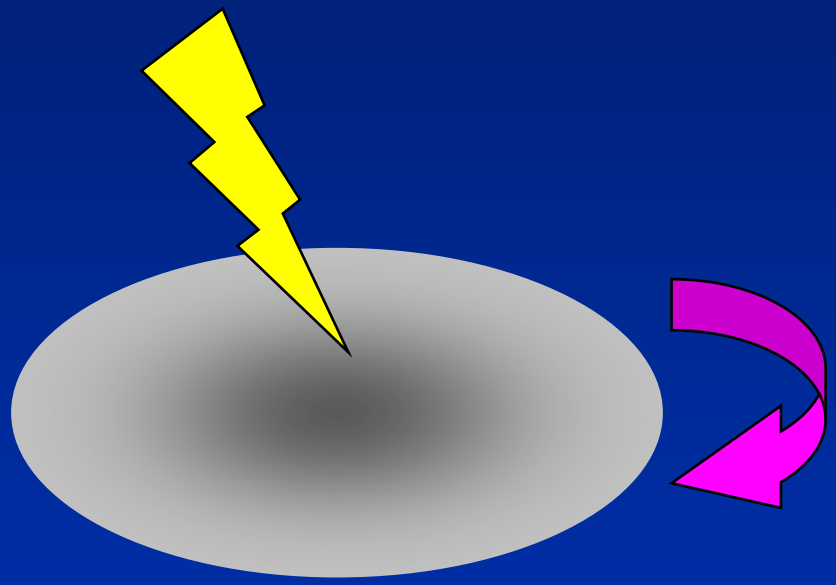
- 4 quad bars and 2 Aerobars were not enough!
- EMI was huge and measurable
- Ionization eliminated the EMI and eliminated the lockups!

Case Study # 3

- ESD Impact On In-Process Wafer Die
  - Problem: Oxide Cracking Damage on Center Wafer Die in Spin Dry Process

The Problem

- “Star Cracking “ ESD Damage Observed on Center Wafer Die
- Occurred post apply of De-Ionized Water in Spin Dry Process
- Significant yield impact at wafer level

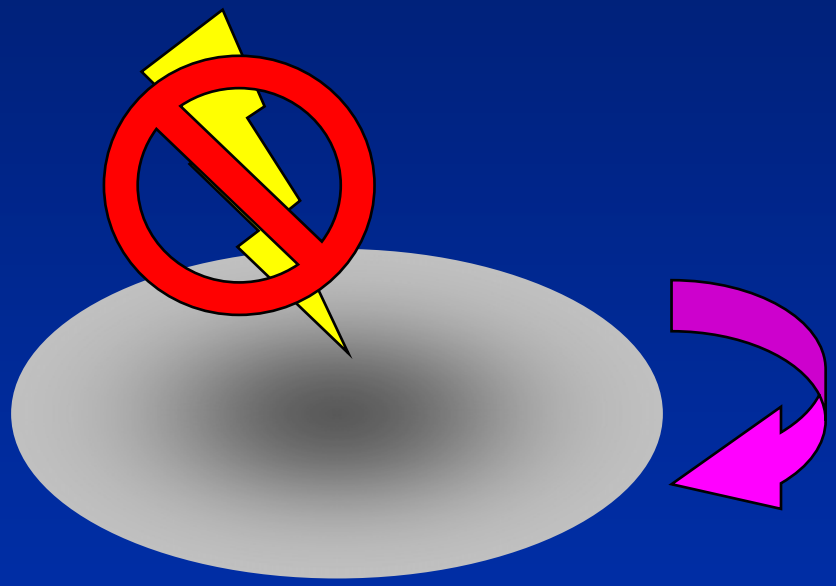


De-Ionized Water

- De-ionized pure water is a poor electrical conductor
  - Resistivity on the order of 18.2 megohms
- Can result in significant tribo-charging of insulators in spin apply processes
- Resisitivty of D/I water can be reduced by introducing non-contaminating ions
  - E.G. CO_2 Bubbler
  - Concentrations in sub 0.1 PPM level can reduce resistivity to <5 megohms

The Solution

- Implemented CO_2 in process D/I water flow
- Drove resistivity < 5 megohms
- Result:
  - Star cracking problem eliminated
- Points to need to use "static dissipative" materials!



Agenda

- Cleanroom/Environment Static Charge Challenges
- Control Strategies
- Case Studies
- **Summary and Acknowledgements**

Summary

- Cleanrooms and Clean Environments have exacting cleanliness requirements
- Methods of attaining those requirements result in substantial ESA/ESD control challenges to process
- Challenges can be met by implementation of rigorous ESA/ESD control programs

Acknowledgements

- Jeff Jimmo – One Source Environmental Test
- Larry Levit – MKS, Ion Systems
- Andy Rudack – Intl. SEMATECH
- John Kinnear - IBM