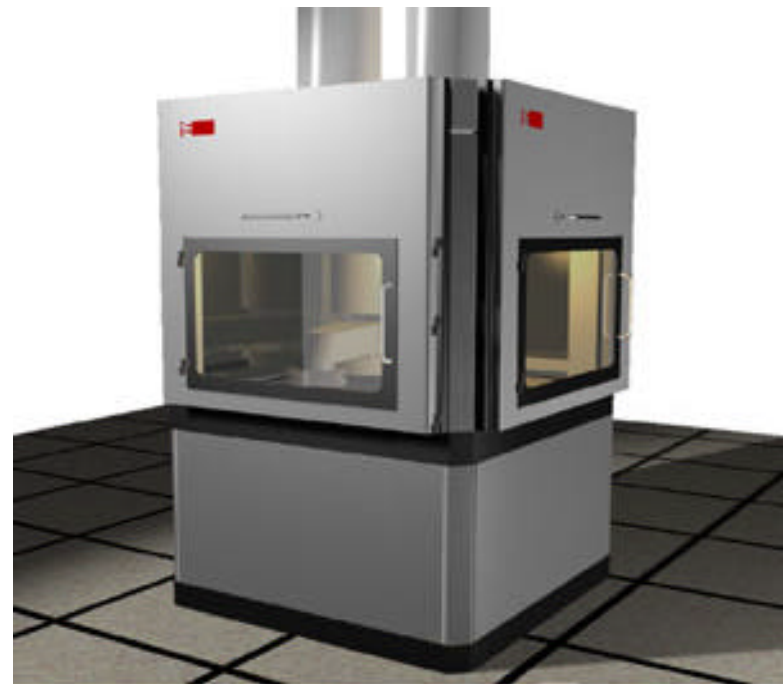


Monitoring Minienvironments



Outline

- **Monitoring Cleanrooms**
- **Special Applications**
- **Monitoring Isolators**
- **Monitoring Minienvironments**
- **Case Studies**
- **Design Tips**



Movement to Minienvironments



- **Semiconductors moving to 300 mm wafers**
 - More chips; reduces manufacturing cost by 35%
 - Requires lower line resolutions (e.g., 0.13 μm)
 - Critical particle size reduced ($0.125 \Rightarrow 0.09 \mu\text{m}$)
- **People are #1 cause of particles**
- **Design Goals**
 - Isolate wafers at “Class 0.01 or 0.1” (*ISO 1 or 2*)
 - Relax cleanroom to Class 100 (*ISO 5*)
- **Solution: Surround tool in enclosure**

Minienvironments Still require monitoring

Conclusion based upon:

- **Contamination Experience**
- **Cost of Late Detection**
- **Specific Design Concerns**



Minienvironments Require Particle Monitoring



Factor #1: Contamination Experience

- **Industry's experience in controlling microcontamination shows that, over time:**
 - Friction from robotic chucks, movement, doors, etc. generate particles
 - Sealants leak
 - Processes go out of spec
- **You can get a minienvironment clean, but you can't keep it clean over time**
- *Without measurement, there is no control.*

Minienvironments Require Particle Monitoring



Factor #2: Increased Cost of Late Detection

- **Losing product is more & more costly**
 - EX: 300 mm wafers cost \$10K/wafer, \$250K/FOUP
 - 1% yield loss @ 30,000/mo. = \$36M/yr.
- **Simply observing yields is reactive**
- **Technology Roadmap calls for reducing time to identify problem from days to hours**
- ***“Detection must be in real-time, thus a real-time monitor...”***
(Cleanrooms; 10/99)

Minienvironments Require Particle Monitoring



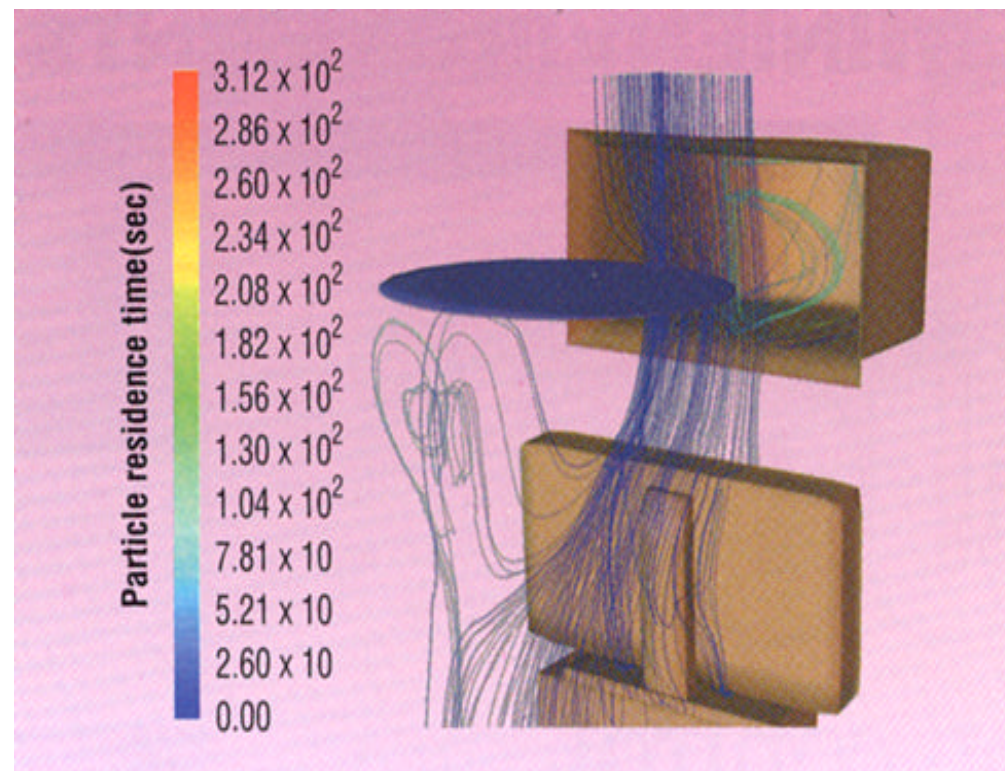
Factor #3: Design Concerns

- **Designs more complex & nearer product**
 - More moving parts
 - More complex air flows
 - Multiple pressure & filtration zones
- **Ex: High initial failure rate**
 - 30-80% of enclosures initially fail 1+ spec
- **Observed enclosure failures**
 - Improper pressure differentials allow infiltration
 - Improper door openings/closings
 - Failures of ventilation system

Minienvironments Design Concerns



***EX:* Surfaces Disturb Laminar Flow**
Vortices trap particles beneath Wafer

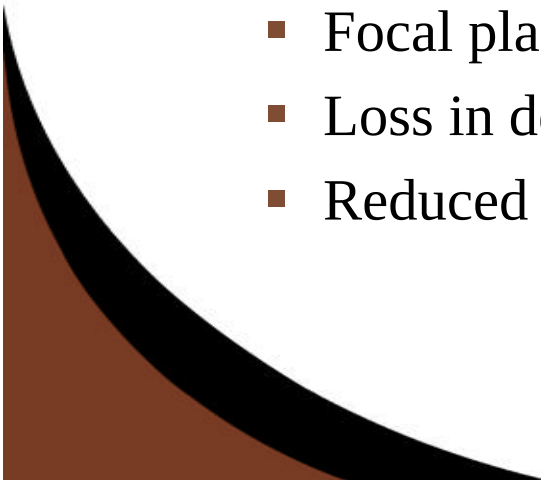


EX: Formation of Vortices



Wafer Backside Contamination

- **Static cling causes particles stick to wafer's back**
- **Difficult to monitor**
- **Difficult to remove**
- **Causes “hotspots” in photolithography**
 - Irregular surface
 - Focal plane deviation
 - Loss in depth-of-focus
 - Reduced yields



Minienvironments Bring New Monitoring Challenges



- **Conventional monitoring often misses particle events**

- Very clean at first qualification
- Much fewer particles, until event occurs
- Particle events generally localized
- Under laminar airflow, particles typically form dirty plume (in the midst of a very clean minienvironment);

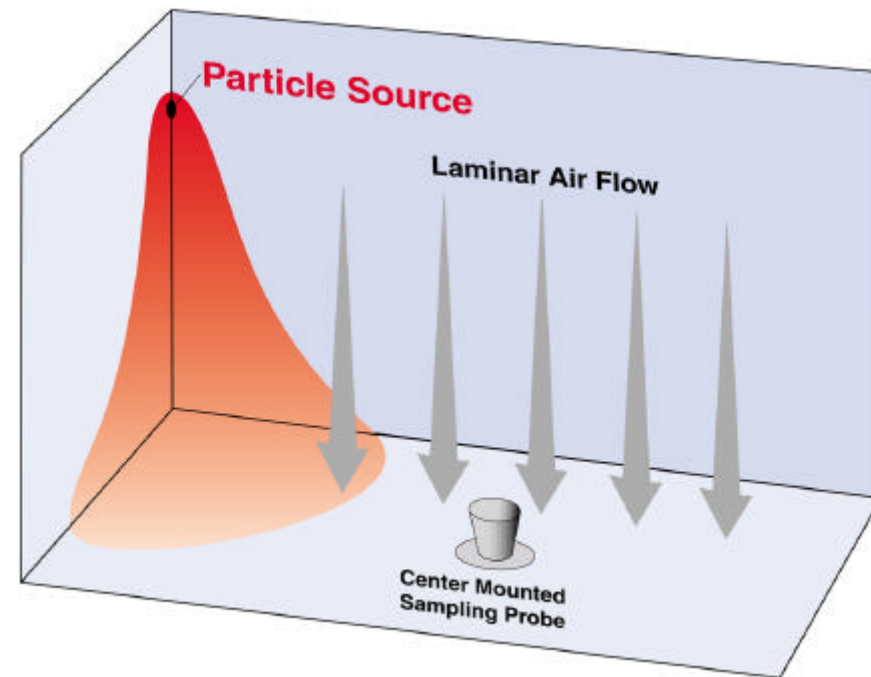
Plume volume may be $< 1 \text{ ft}^3$

- **Need new particle monitoring techniques**

Particle Movement in Minienvironments



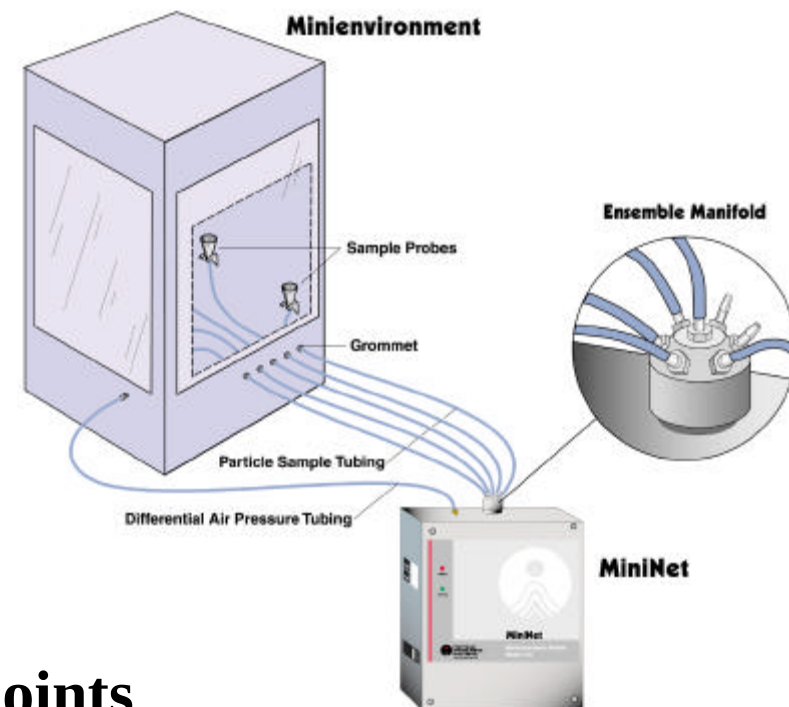
- Lower ceilings + laminar flow = constrained particle plume
- Particles exit quickly
- Center-mounted, single-point sampling can miss particle plume



Improved Monitoring Technique for Minienvironments: Ensemble Sampling



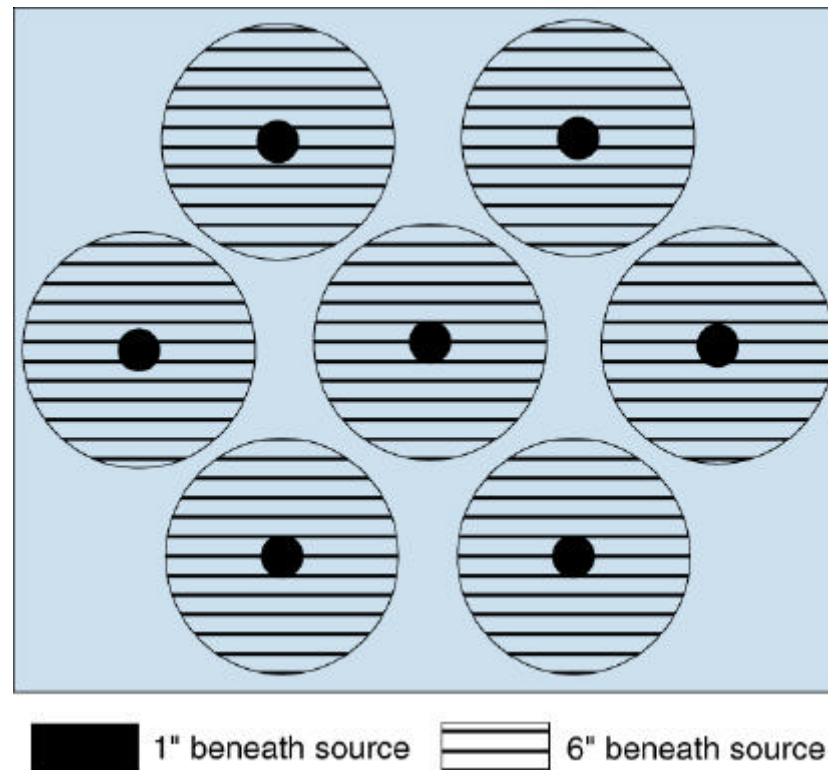
- **Ensemble Sampling**
 - Continuous
 - Simultaneous Multi-point
- **Ensemble manifold**
 - Samples from 5-7 points
 - Passive; suction from particle counter
- **Samples simultaneously from all ports**
- **Monitors *mixed air* from all points**



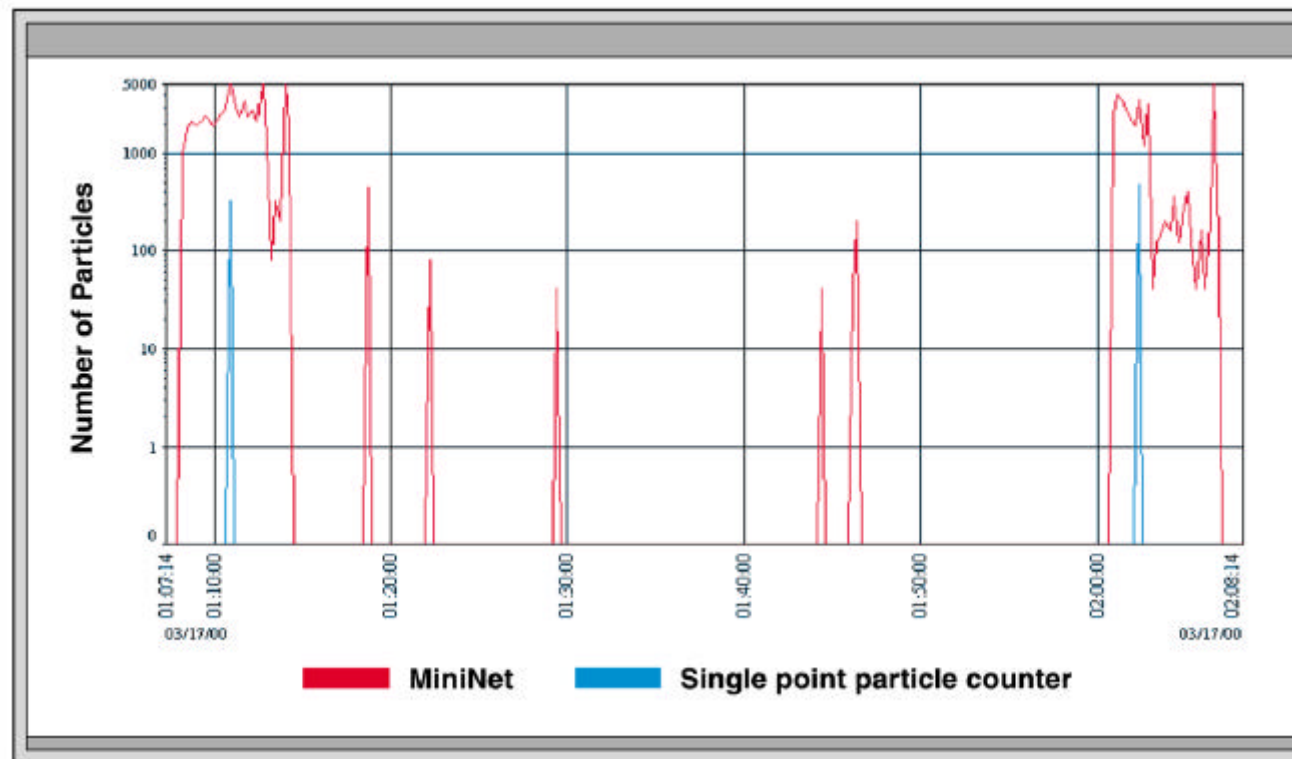
Ensemble Sampling Provides Much Wider Coverage



- **Sample seven sample points instead of one**



Case Study Ensemble Monitoring of Lot Sorter



Case Study A-1

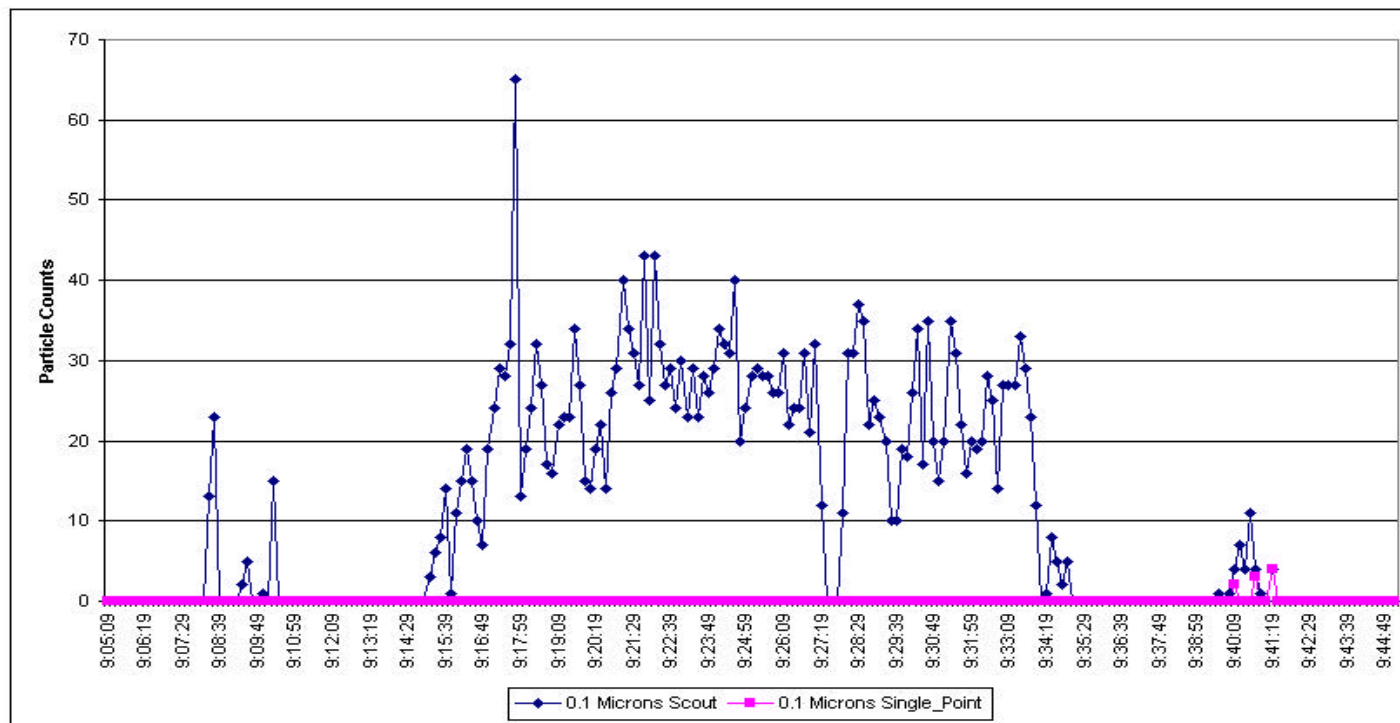
Ensemble Monitoring of Lot Sorter



- **Used on lot-sorter at 300 mm fab**
- **MiniNet provided ensemble sampling**
 - 7 locations sampled simultaneously
 - Approximately 1/7 CFM each
- **Control: Dedicated 1 CFM particle counter sampling from single point in middle of tool**
- **Result: MiniNet detected numerous events missed by single-point particle counter**
 - 10X Higher counts
 - Longer periods

Case Study A-2

Ensemble Monitoring of Lot Sorter



Ensemble Monitoring Summary

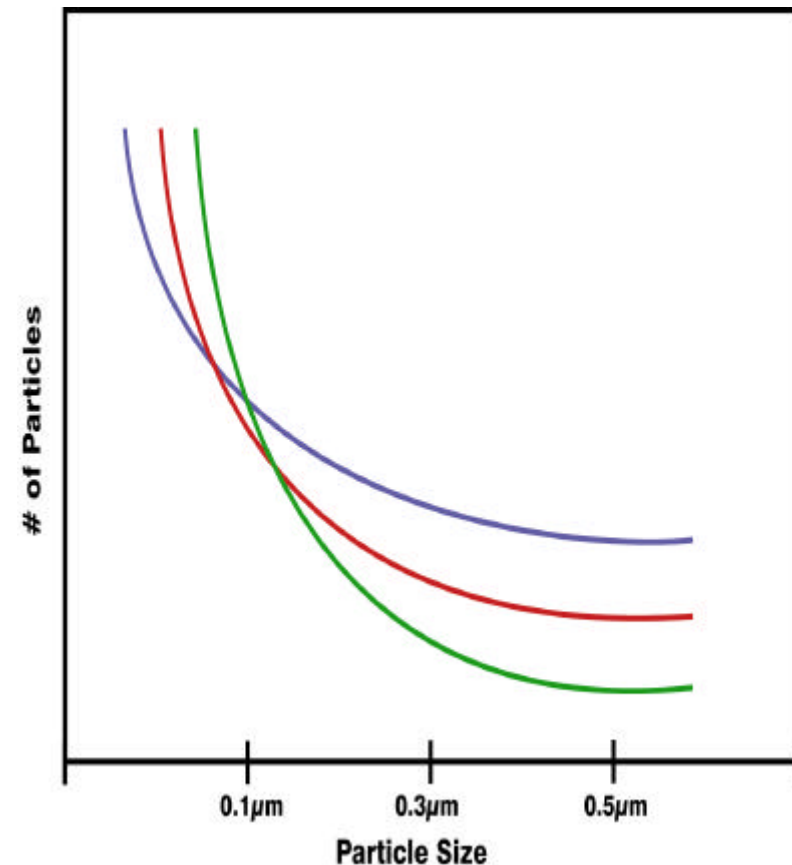


- **Detects particles traditional counters miss**
 - Provides up to seven times the coverage
- **Detects breakdown in enclosure protection**
- **Speeds identification of particle sources**
 - Via monitoring DAP & additional variables
- **Process Monitor (not a particle counter)**
- **Provides tool shut-down alarms**
- **Integrates with facility management software**
- **Provides compact, easy-to-install, single box solution**
- **Cost effective**

Improved Monitoring Technique

Sensitivity vs. Cost-Effectiveness

- Different events generate particles with different size distributions
- *“Detect the particle event, not the smallest particle”*
- 0.3 μm detects most events, costs less
- Use 0.1 μm for tool qualification



Recommended Particle Detection Strategy



USE	EQUIPMENT
Certifying minienvironment (ISO Class 1 or 2)	0.1 um, 1.0 CFM particle counter
Monitoring minienvironment (real-time)	0.3 um, 1.0 CFM ensemble monitoring

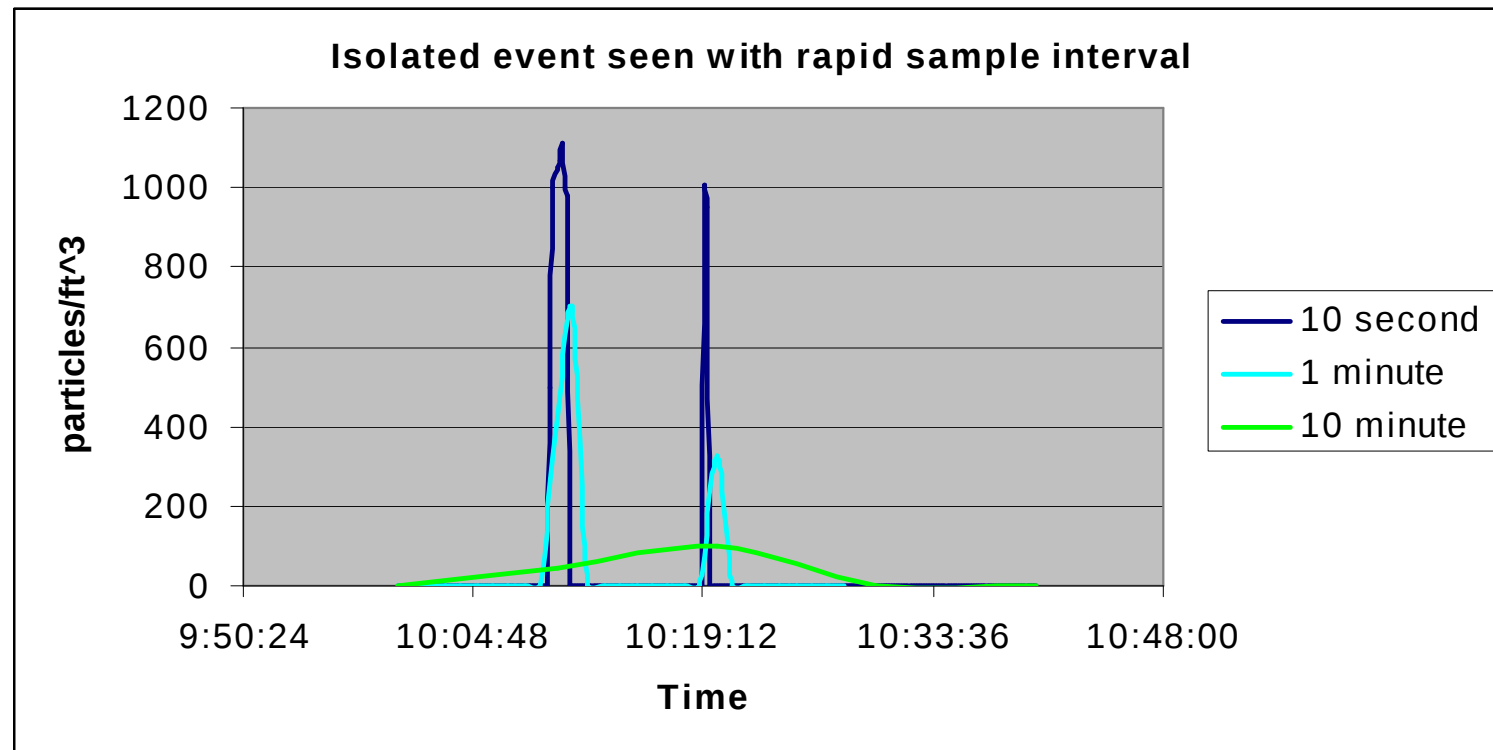
Particle Event Detection at 0.3 μm

[illegible]

Improved Monitoring Technique

More Frequent Samples

Give Better Detection



Improved Monitoring Techniques for Minienvironments



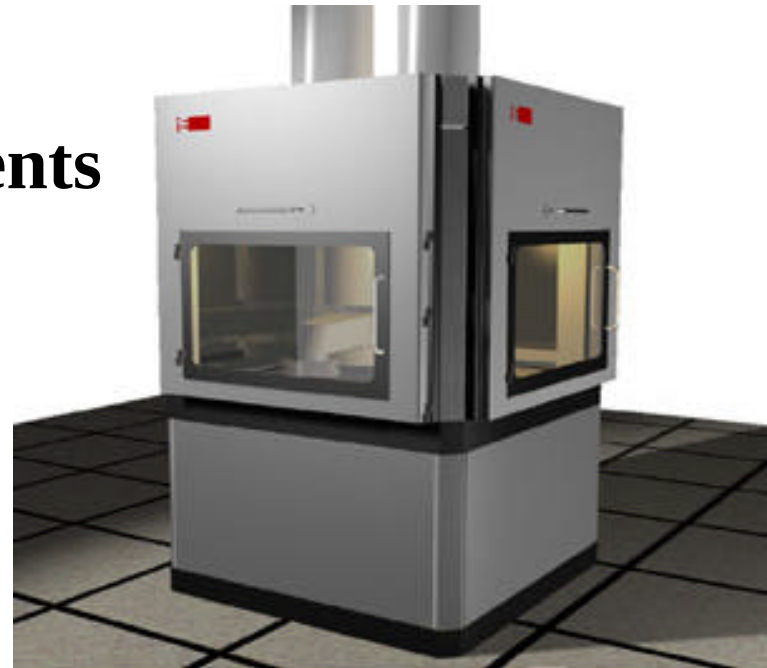
Conclusions

- **Use Ensemble Sampling**
- **Monitor pressure differentials**
 - Changes with door/port openings
 - Look for correlation with particle events
- **Monitor additional correlated variables**
 - Temperature, RH, ESA, AFV, additional DAP
- **Improve detection with shorter sample intervals**
- **Monitor cost-effectively at 0.3 μm**

Outline



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- **Design Tips**



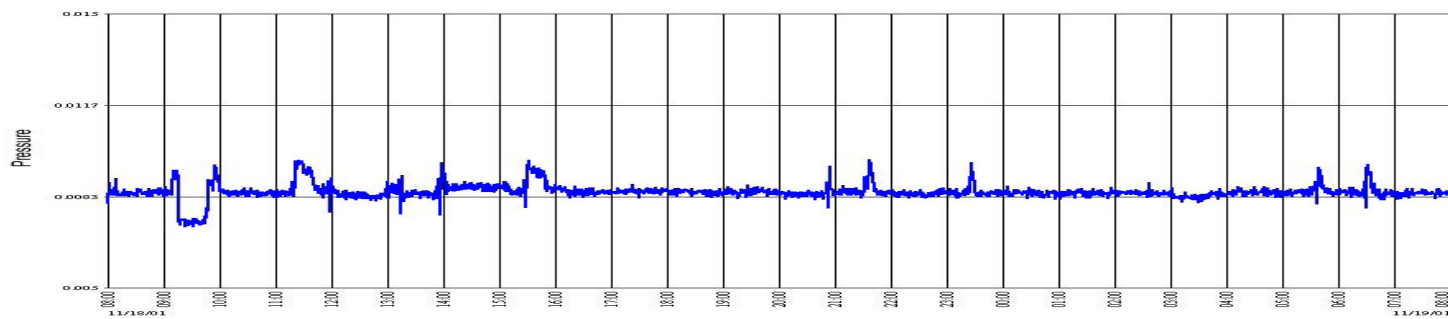
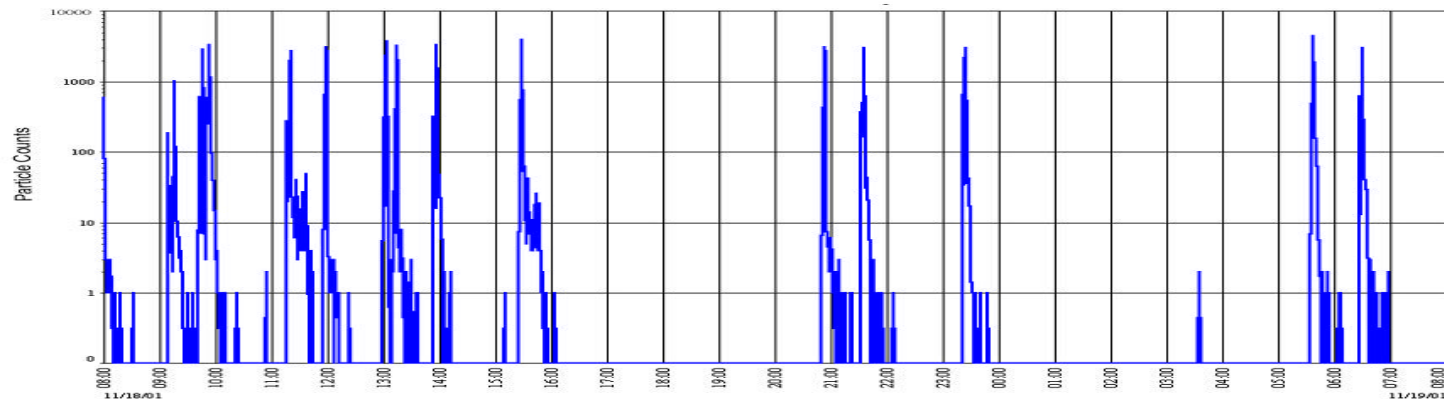
Case Studies from 200 & 300 mm Fabs



- **Wafer Prober #1**
- **Wafer Prober #2**
- **Wafer Prober #3**
- **Photolith Tracker**
- **Ion Implanter**



High Counts Generated Normal Operation - 300mm Wafer Prober #1

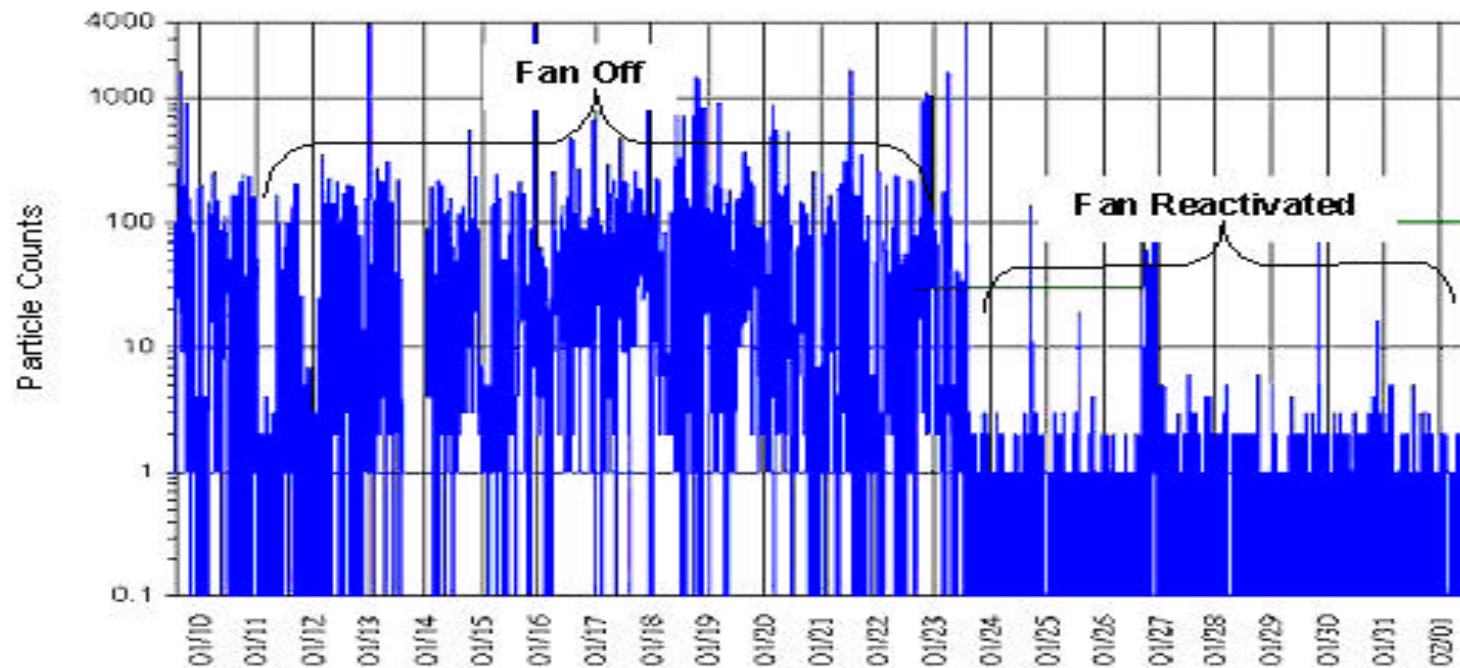


Case Study: Use of MiniNet with Wafer Prober

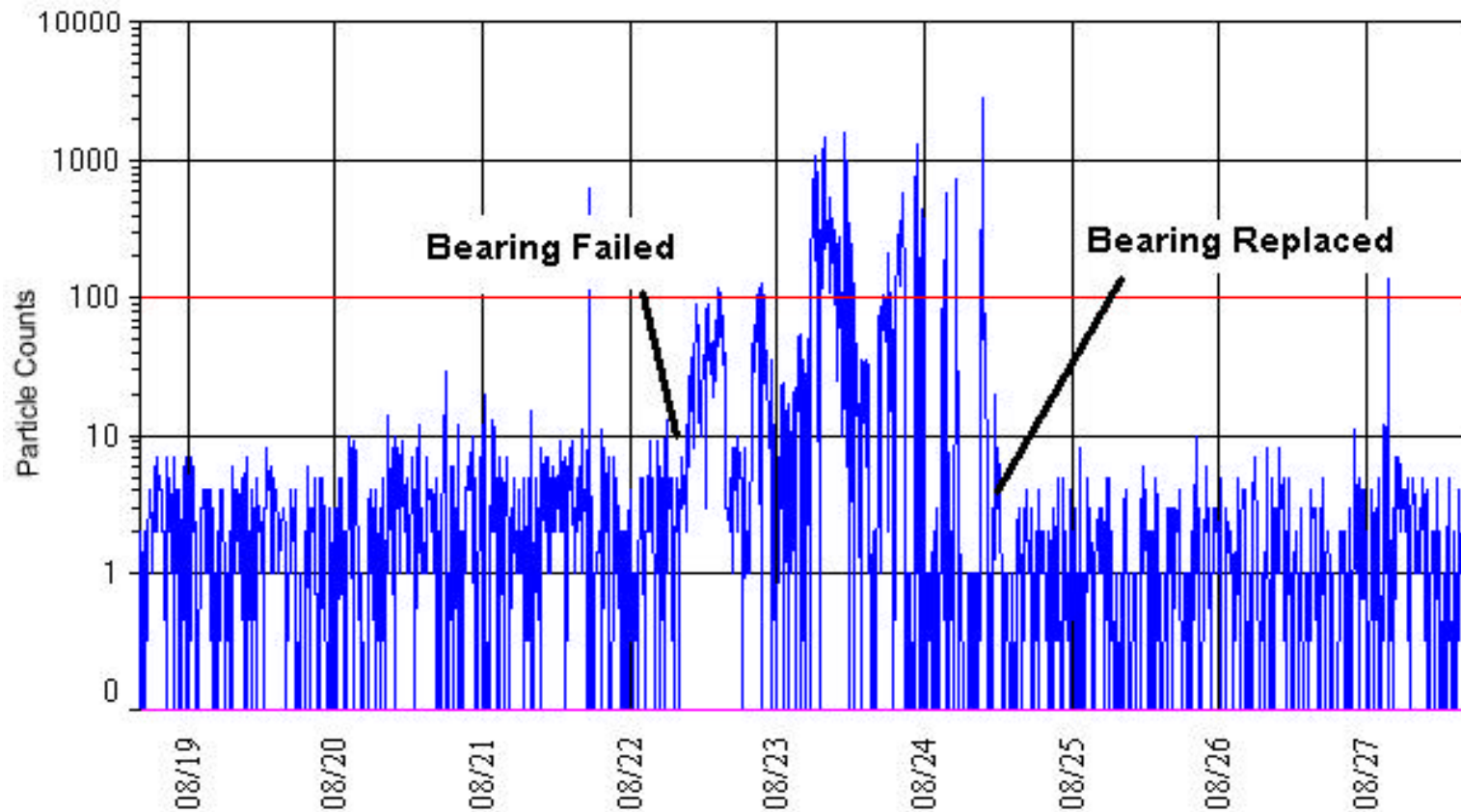


- **Wafer prober tests electrical performance of each circuit on wafer**
 - Last test before packaging
 - High cleanliness is critical
- **MiniNet successfully observed high levels of particles**
 - E.G., 4000 particles $\geq 0.3 \mu\text{m}$ in 10 sec
 - Correlation of DAP with particle events
- **NORMAL operation of wafer prober**

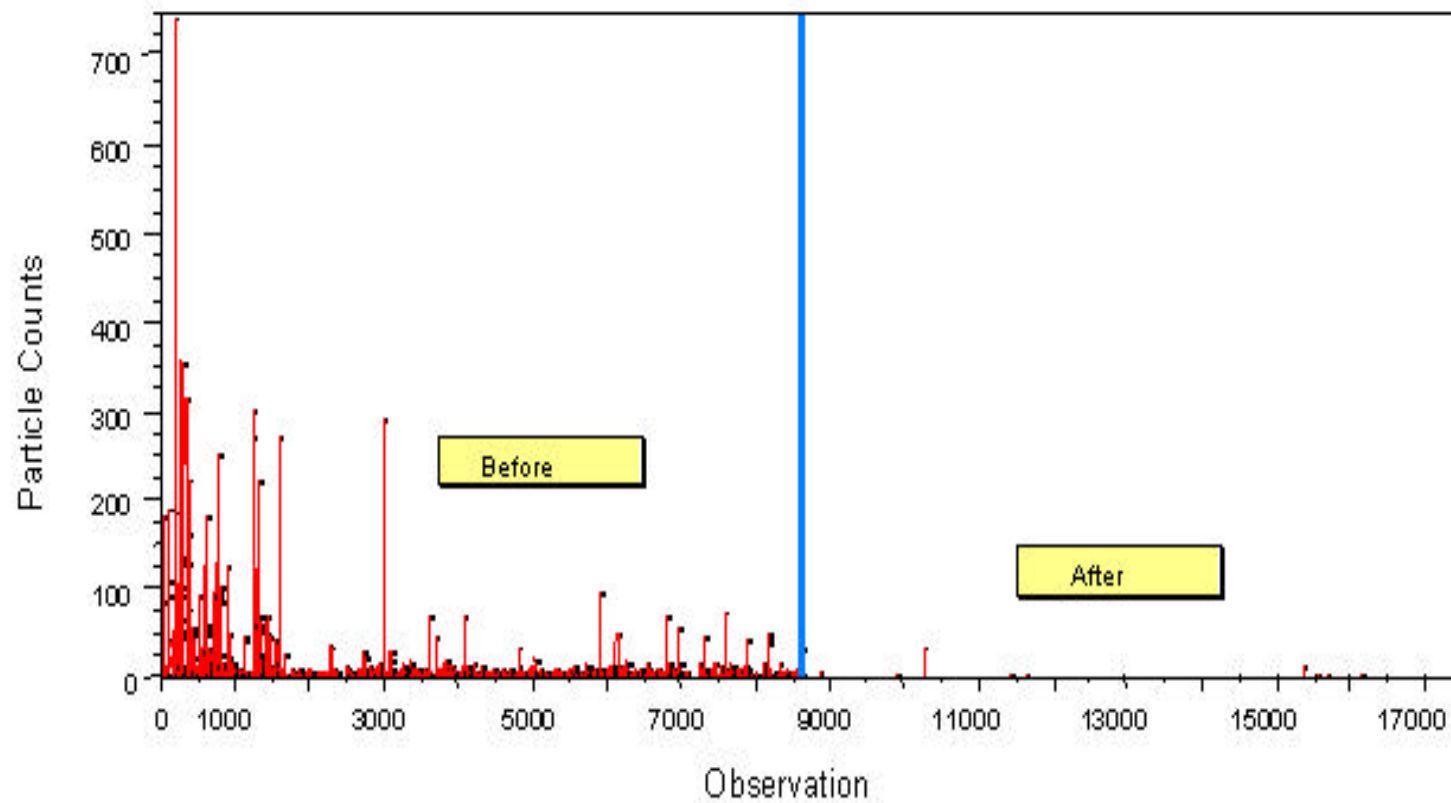
Fan Failure 200 mm Wafer Prober #2



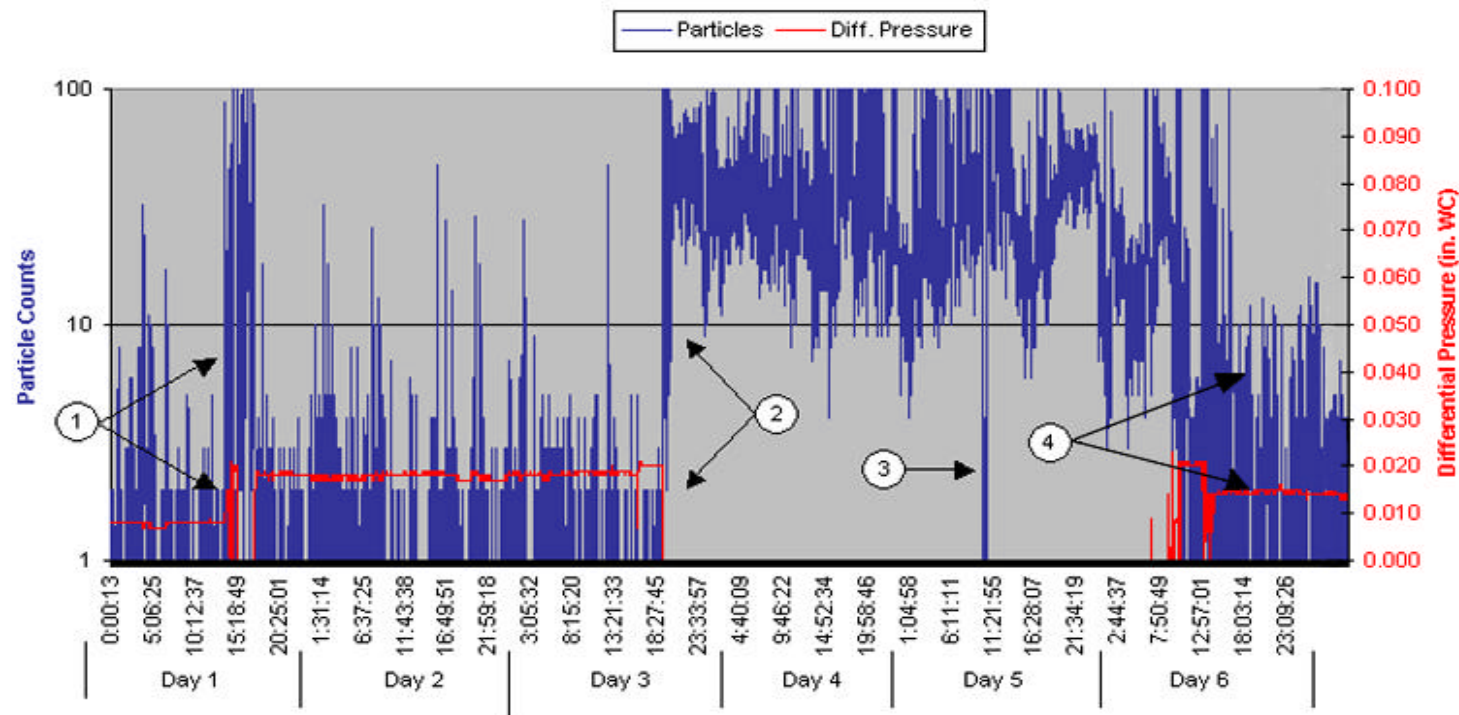
Bearing Failure 200 mm Wafer Prober #3



Filter Gasket Leak 200 mm Photolith Tracker



Fan Failure 300mm Ion Implanter



Case Study

Fan Failure in Ion Implanter

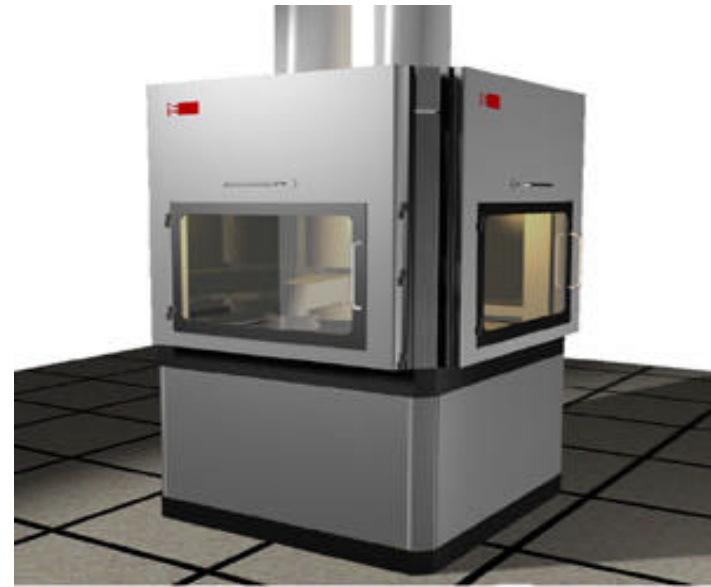


- Fans automatically shut off due to electrical problem; no alarm
- Visually, implanter appeared to be working
- Particle counts rose: $<10 \Rightarrow 30-400$ ($\geq 0.3 \text{ um}$)
- Diff. pressure dropped from 0.02 to 0.0
- Both zero count and filtered input tests confirmed MiniNet readings were correct
- MiniNet successfully detected particle event, plus gave information on possible sources

Monitoring Strategy 300 mm Fabs



- **What is the recommended strategy for monitoring 300 mm fabs?**



Monitoring Strategy 300 mm Fabs



- **Ensemble monitoring @ 0.3 μm & 1 CFM**
- **Frequent sampling (every 10 to 60 sec)**
- **Monitor correlated environmental variables**
- **Key points to sample**
 - Stockers
 - Sorters
 - Wafer probe/test tools
 - Ion Implanters
 - Photolithography steppers
 - Load/unload ports of wet process tools

Monitoring Strategy 300 mm Fabs



- **Long-Term: Monitor every tool**
 - Ensemble Sampling superior in efficacy & cost (vs. 300 mm test wafer every shift)
- **Short-Term: Locate DAP monitor on load port**
(to ensure clean areas have higher pressures than dirty areas)
 - Etchers (dry)
 - Deposition tools
 - Ashers or Resist Strippers

Monitoring Minienvironments Final Observations

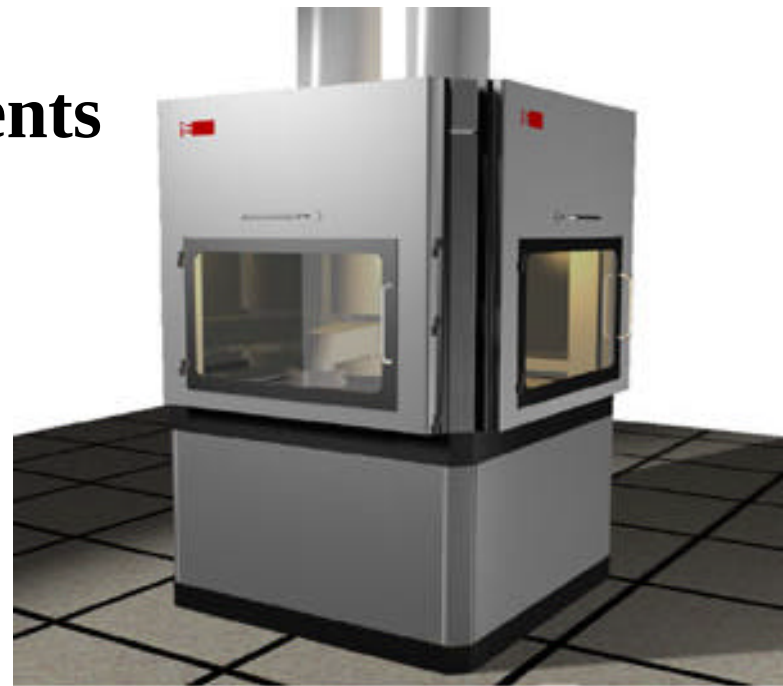


- **Just like cleanrooms, minienvironments require monitoring**
 - Particle mishaps can prove very costly
 - If you don't monitor, you can't control
- **Monitoring minienvironments requires special techniques**
- **Good monitoring requires good design**

Outline



- **Monitoring Cleanrooms**
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Particle Monitoring Design Tips



- **Monitor where it counts!**
- **Monitor more (more sample points, more continuously, greater time resolution) when:**
 - More critical process (more sensitive to particles)
 - More potential particle generators
 - Potential failure points closer to product
 - More complex airflows
 - More potential infiltration points
 - Product moves through more stages, or longer distance, or is exposed for longer time

Particle Monitoring Design Tips



- **Locate particle counter, manifold, power sources, cabling, etc. outside clean area (as possible)**
- **Do not pull or exhaust sampled particles over product**
- **Minimize tubing lengths & bends**
 - Minimize particle fallout
- **Careful placement of sample points**

Design Tips Sample Point Placement



- **Point ISP into the sample flow**
- **Don't sample at locations generating false alarms**
- **Sample points**
 - At work level
 - Inside fill stations, isolators or minienvironments
 - Where product is exposed
 - At critical points (must evaluate risk)
 - Process is at risk to contamination
 - Total time spent exposed in process or tool

Design Tips Sample Point Placement



- **Cleanest cleanrooms (highest ISO classification)**
 - Goal is to detect any particles
 - Sample points are typically located below product
- **Pharmaceutical processes**
 - Goal is to detect excessive levels of particles (as defined by FDA, *et al*)
 - Doesn't require same level of cleanliness
 - Smaller particles (less than 0.5 um) not a problem
 - Avoid sampling recirculated particles
 - Sample points are placed higher, nearer air filter outlets -- mostly counting “zeros”