Part-Per-Trillion Monitoring of Airborne Molecular Contamination (AMC)

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Particle Measuring Systems

What is Molecular Contamination?

- Airborne Molecular Contamination (AMC)
  - Gas-phase substance in air that affects semiconductor product, process, or process equipment
  - Often complex mixture of chemical compounds that are highly variable
  - Acid, Base, Condensable, and Dopant compounds
    - Acids: HCl, HF, Cl_2, SO_2, etc.
    - Base: NH_3, Amines
    - Condensables: Phthalates, Siloxanes
    - Dopants: B, P, As, Sb, Ga, etc.

Part-Per-Trillion Analogies

- What is a part-per-trillion (ppt)?
  - Swimming Pool
    - 1 drop of water in 20 Olympic size (50m) swimming pools
  - Time
    - 1 second in 31,710 years
  - Distance
    - 1 inch in 657 trips around the equator
  - Area
    - 1 square inch in 250 square miles

- Concentrations within semiconductor manufacturing
  - < 70 ppt = detection limits of Ion Mobility Spectrometers (IMS)
  - 100 - 500 ppt = typical AMC concentration downstream of a chemical filter
  - 2,000 – 15,000 ppt = typical ambient AMC concentration in a cleanroom

Drivers of Part-Per-Trillion AMC Monitoring

- **Feature Size**
  - 90nm, 65nm, and 45nm ½ pitch products and processes
  - AMC interaction with product material much costlier at smaller feature sizes.

- **193nm Photolithography**
  - Optics warranties depend on maintaining low AMC levels
  - Process inefficiencies result from optical hazing
  - Reduction of hazing induced downtime of exposure tool optics for cleaning

- **Chemical Filtration**
  - Evaluating efficiency of chemical filters at removing AMC
  - Cost of ownership (COO) - monitoring lifetime of chemical filters

- **Product Storage**
  - Monitoring AMC contribution of FOUP, stockers, & reticle pods contribute to wafer and reticle products which are in-queue, storage, or transport
  - Evaluating effectiveness of storage pod cleaning process

Part-Per-Trillion AMC
Monitoring Methodologies & Techniques

- **Point-of-Use**
  - Current methodology: use of a single AMC analyzer at each sample point
  - Monitors for AMC concentration in real-time directly at the location of concern

- **Manifold**
  - Historical methodology: connecting multiple sample points to same AMC analyzer
  - Rotates through sample points at various intervals
  - When one sample point is being analyzed, all other sample points are not being monitored

- **Preconcentration** (Impinger, Tenax)
  - A technique allowing a contaminant to be trapped into a material by pulling an air sample over a long period of time through the material
  - Utilized for non real-time analytical equipment (IC, GC/MS) which cannot achieve ppt sensitivity without collecting a large sample prior to analysis

- **Real-time** (Ion Mobility Spectrometry)
  - Generally describes an analysis of a given AMC air sample within one to five minutes with sufficiently high sensitivity to not require preconcentration

Part-Per-Trillion AMC Monitoring Methodologies

- Manifold Sampling Systems
  - Strengths
    - Reduces per sample point monitoring costs
  - Weaknesses
    - Low amount of time actually spent sampling each sample point
    - Non-continuous data increases probability of missing contamination events
    - Sample interaction and effects from long sample tubes
    - Long response & cleardown effects when adjacent sample points have different concentrations
    - Minimal ability to use sampling statistics
    - Additional complex hardware and software to maintain
    - Large startup costs

Part-Per-Trillion AMC Monitoring Methodologies

- Point-of-Use IMS Analyzers
  - Strengths
    - Continuous monitoring of a single location – no missed contamination events
    - Better limit of detection with use of minimal sample tubes
    - Ability to use sample statistics to obtain single event or baseline alarms
    - Low cost of ownership
    - Simple design and infrequent maintenance
    - Centralized software for data acquisition and control
    - Analyzer to analyzer matching with a single calibration source
    - Small Footprint
  - Weaknesses
    - Potentially higher initial costs

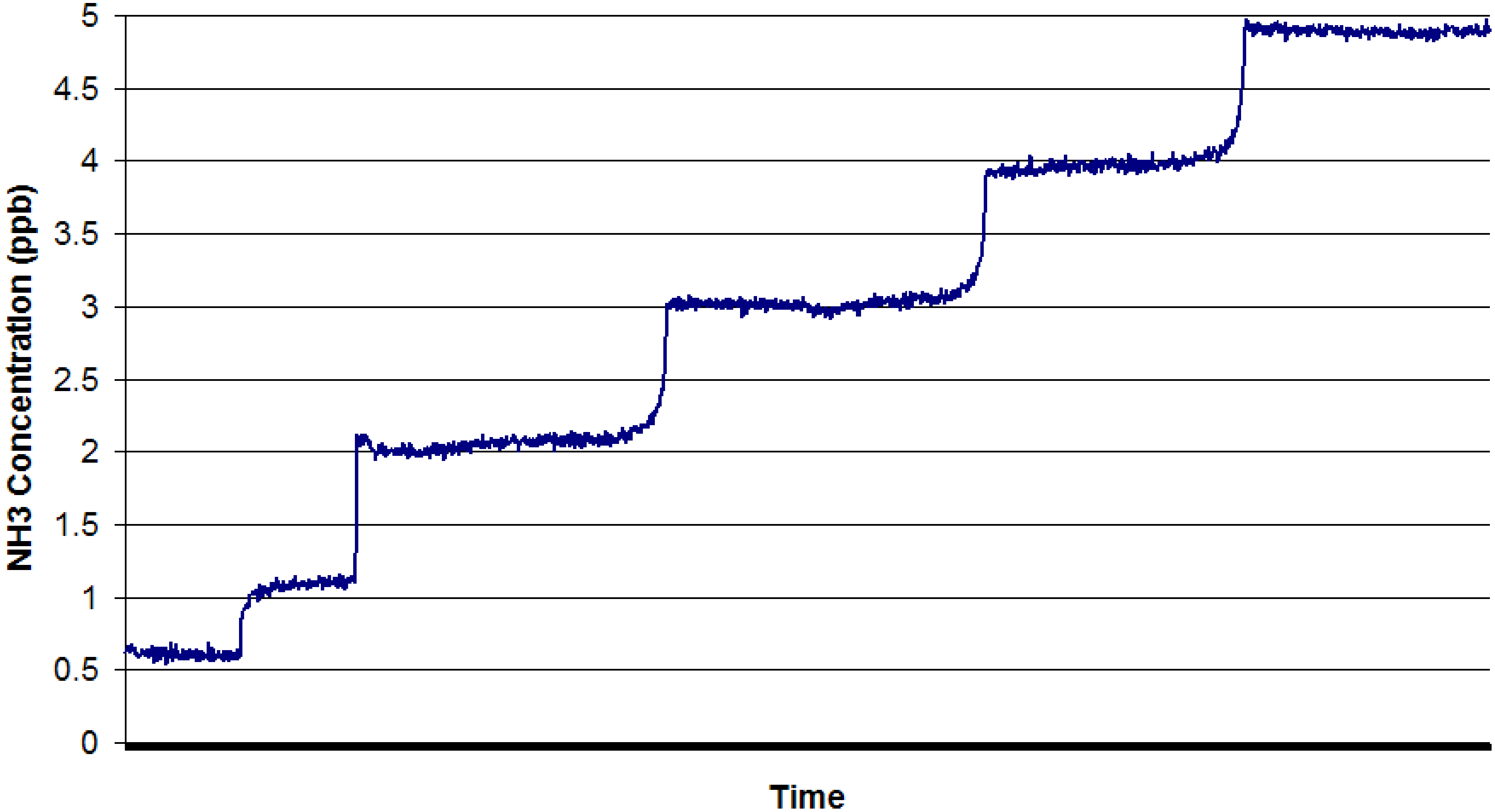
Point-of-Use Benefits

	Technology	% Time Measuring Each Sample Point Per Day	% Time NOT Measuring Each Sample Point Per Day	Sample Transport Effects (typical tube lengths)	Detection Limit
Conventional Manifold (60 Points)	Adaptation of complex laboratory instrumentation	0.17 % 2.4 Min.	99.83 % 1438 Min.	50 M. Significant	300 ppt
Conventional Manifold (16 Points)	Adaptation of complex laboratory instrumentation	0.62 % 9 Min.	99.38 % 1431 Min.	25 M. Significant	300 ppt
AirSentry-II (POU)	Simplicity of design	100.0 % 1440 Min.	0.0 % 0 Min.	2 M. Minimal	< 70 ppt (5 min avg.)
AirSentry II Benefits:	**Better Reliability**	**Continuous Data Obtained**	**No Missed Contamination Events**	**Better Response and Clear Down** **Better Accuracy**	**Better Detection Limits**

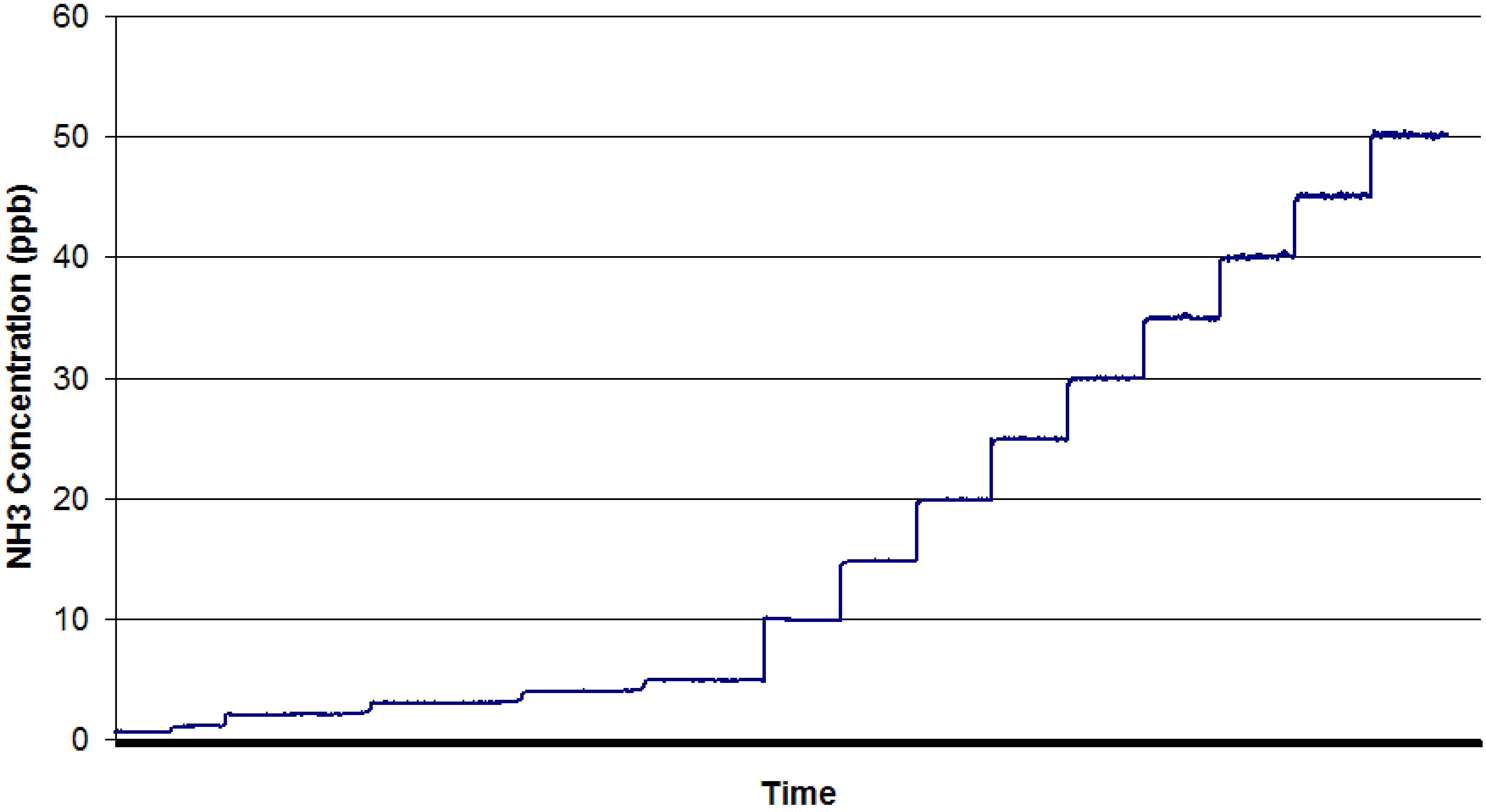
AirSentry II AMC Analyzer

- Point-of-Use Methodology
  - < 70 ppt limit of detection
  - Continuous sampling
  - Simplified electronics and pneumatics
  - Small footprint
  - Centralized software
  - Cost effective

Low Concentration Calibration of an AirSentry II Ion Mobility Spectrometer



High Concentraion Calibration of an AirSentry II Ion Mobility Spectrometer

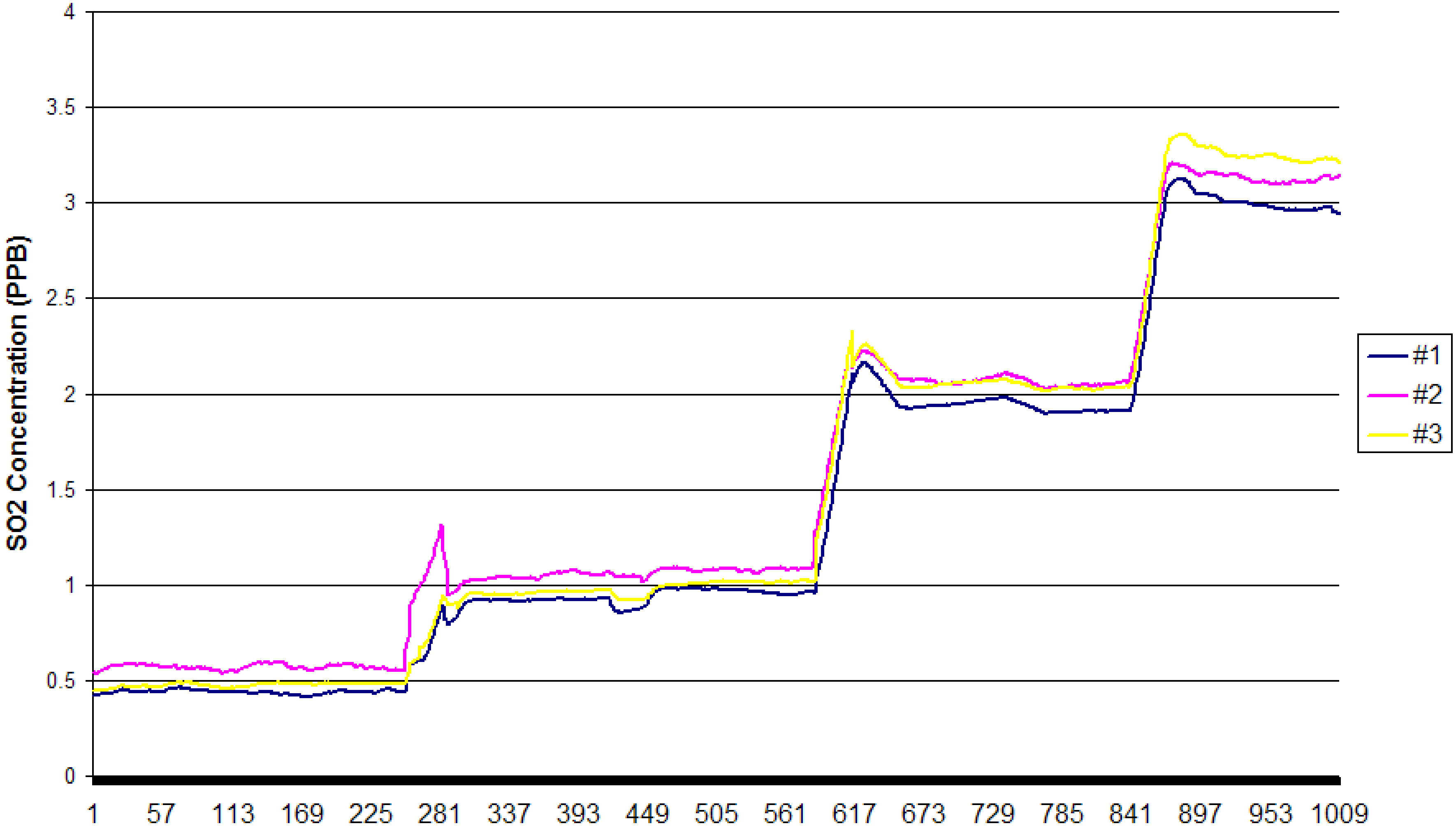


AMC Contaminants to Monitor

- 193nm Lithography
  - Amines & SO_2: In presence of 193nm exposure energy, ammonia and sulfur dioxide combine to form haze on exposure optics and reticles
  - Amines: Interact with resists in track creating t-topping defects
- Chemical filtration
  - Amines & Acids: Monitor for filter breakthrough, lifetime, and efficiency
- Purge gases
  - Amines & Acids: Monitor for contaminants in purge gases used to protect optics
- Reticle & wafer stockers
  - Amines & SO_2: Verify that AMC contamination is not accumulating or causing damage during storage
- Makeup-air handlers & process bays
  - Amines & Acids: Determine how much AMC contamination comes from external sources or exists in ambient cleanroom bays

- AirSentry II monitors all of these locations in real-time at the point of concern with ppt sensitivity

AirSentry II Acids
Low Level SO_2 Detection

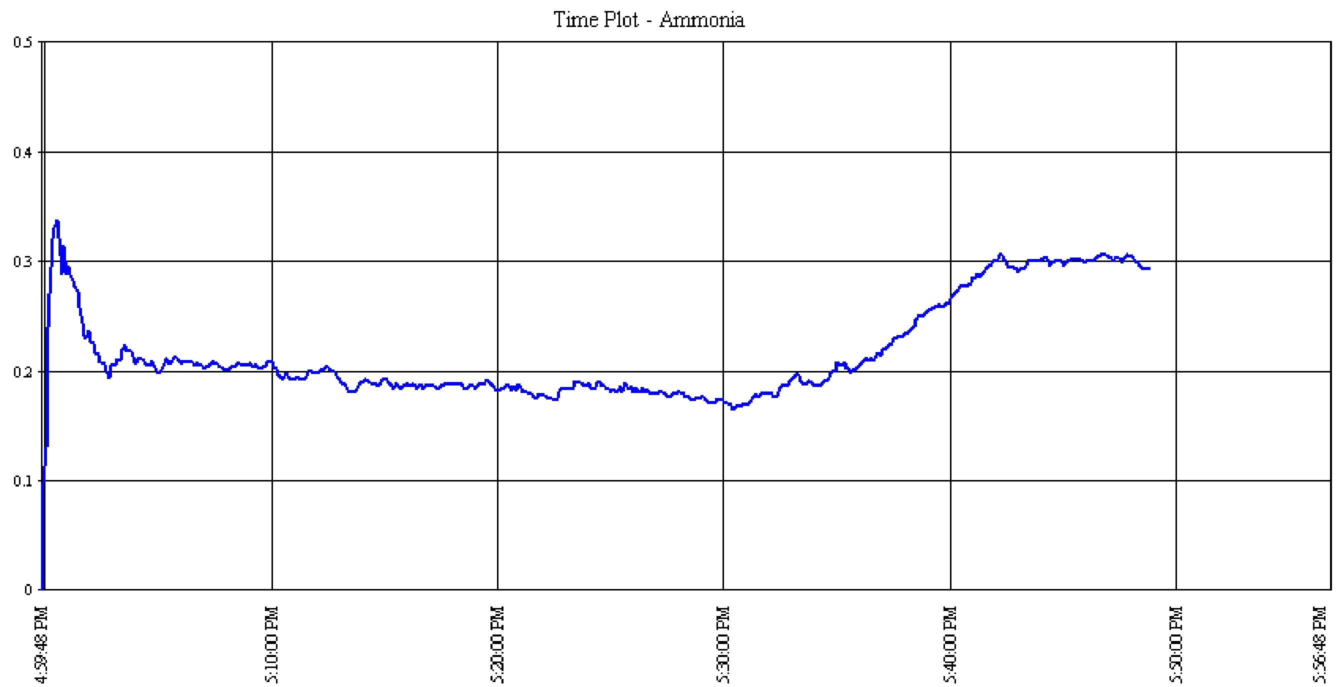


PARTICLE MEASURING SYSTEMS

AirSentry II Sensitivity to Change

Intentional Injection of 100 ppt Ammonia

PMSDEMO4



Item	Plot Data Type		Minimum	Maximum	Average	Std Dev
Ammonia	ppb	Avg	0.000	0.337	0.217	0.046

History Size: 100 samples (Statistics Generated For Plot Duration)
Plot filter: None
Alt plot filter: None
Filter join: Off
Flyer filter: None

<No User>

Part-Per-Trillion Monitoring Benefits
AirSentry II IMS Analyzer

Continuous	Samples without interruption
Cost	Low cost of entry
Sensitivity	< 70 part-per-trillion detection limit
Accuracy	NIST traceable calibration technique
Simplicity	Increased reliability, decreased service needs
Sample	Minimizes sample tubing
Size	Footprint allows placement in or near critical locations
Calibration	Single calibration source ensures matching

Conclusions

- Semiconductor manufacturing is driving AMC monitoring requirements to part-per-trillion (ppt) concentration levels
- Historical techniques such as manifold sampling and preconcentration do not provide sufficient data for effective process, equipment, or facility control of AMC concentrations
- Real-time ppt analyzers, such as Ion Mobility Spectrometers, deliver maximum AMC information per unit time per dollar invested.