# TOFWERK

# Solutions for Purity Assurance in Semiconductor Manufacturing

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## AMC Solutions

# COMPREHENSIVE AMC MONITORING
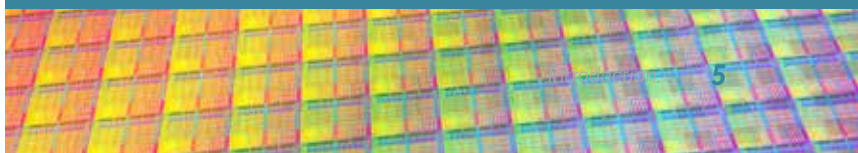# FOR CONTAMINATION-FREE MANUFACTURING

# TOFWERK
# AMC

## ENSURE A CONTAMINATION-FREE FAB

- Simultaneous detection of critical AMC categories
  - acids (corrosives)
  - bases
  - condensables
  - volatile organics

- Part-per-trillion limits of detection

- Customizable AMC database

- Negligible to no fragmentation measurements for simple identification

- Mobile, point-of-interest, or multi-port utility

As manufacturing practices advance, air borne molecular contaminants have a greater impact on production yield. A larger variety of AMCs now require monitoring, with greater speed and sensitivity than what is provided by conventional monitoring solutions.
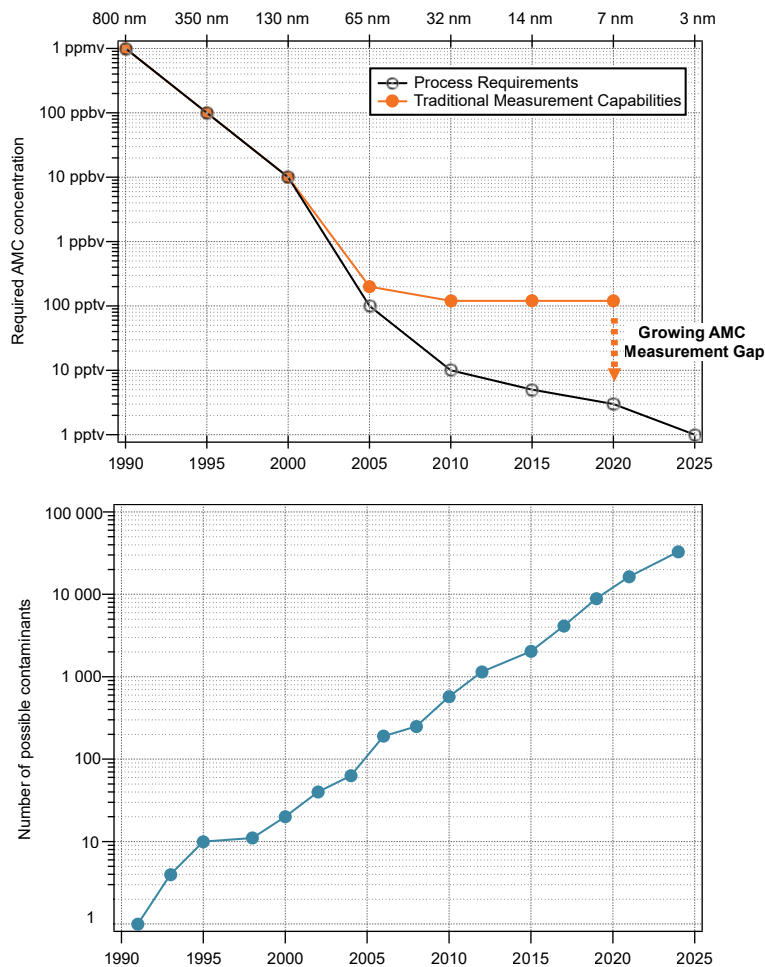


Sources: Black line: entegris.com
Blue line: The International Roadmap for Devices and Systems: 2017

# Comprehensive coverage
# for the most critical AMC categories

| Acids | Bases/Amines | Condensables | Volatiles | Unclassified |
|---|---|---|---|---|
| HF | Ammonia | Toluene | Acetone | water |
| HCl | DMA | Benzene | IPA | |
| HBr | NMP | PFAS | Fluorinated Refrigerants | |
| Sulfuric acid | Morpholine | TEOS | EEP | |
| Acetic acid | | HDMS | | |
| | | TEB | | |
| | | Phthalates | | |

This table summarizes some common AMCs measured with TOFWERK AMC Monitors; however, the monitors are capable of measuring many more.
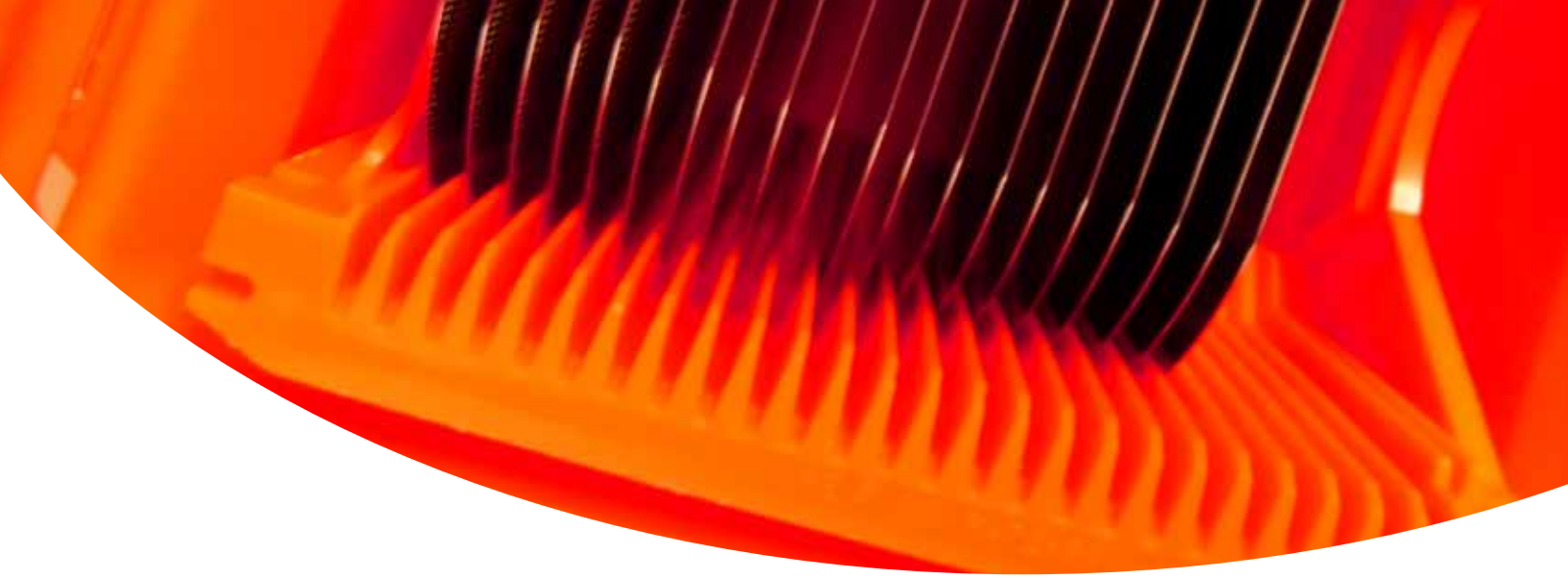
Fabs host hundreds of independent processes that produce AMC byproducts, including ventilation systems, leaks, device failures, and human emissions. Due to the complexity of these sources, AMCs are comprised of a diverse variety of chemical compounds which are not comprehensively measured by conventional monitoring techniques. Conventional solutions combine technologies to provide adequate coverage, often with poor time resolution.

TOFWERK AMC Monitors provide instantaneous and simultaneous measurements for each AMC category. Combining TOFWERK's chemical ionization time-of-flight mass spectrometry with fast reagent switching, and patented, ultra-fast polarity switching, assures that facilities are reliably monitored for contaminants with adequate coverage.

**Conventional Technologies**
- Cavity Ring Down Spectroscopy (CRDS)
- Hybrid Detectors
- Quadrupole Mass Spectrometry

**TOFWERK AMC Monitoring Solutions**
- ABC Configuration
- VOC Configuration

> 10 nm Nodes          < 5 nm Nodes

Condensible Organics

Amines

Ammonia

Inorganic acids

Organic acids

1000          100          10          1

LOD (pptv)
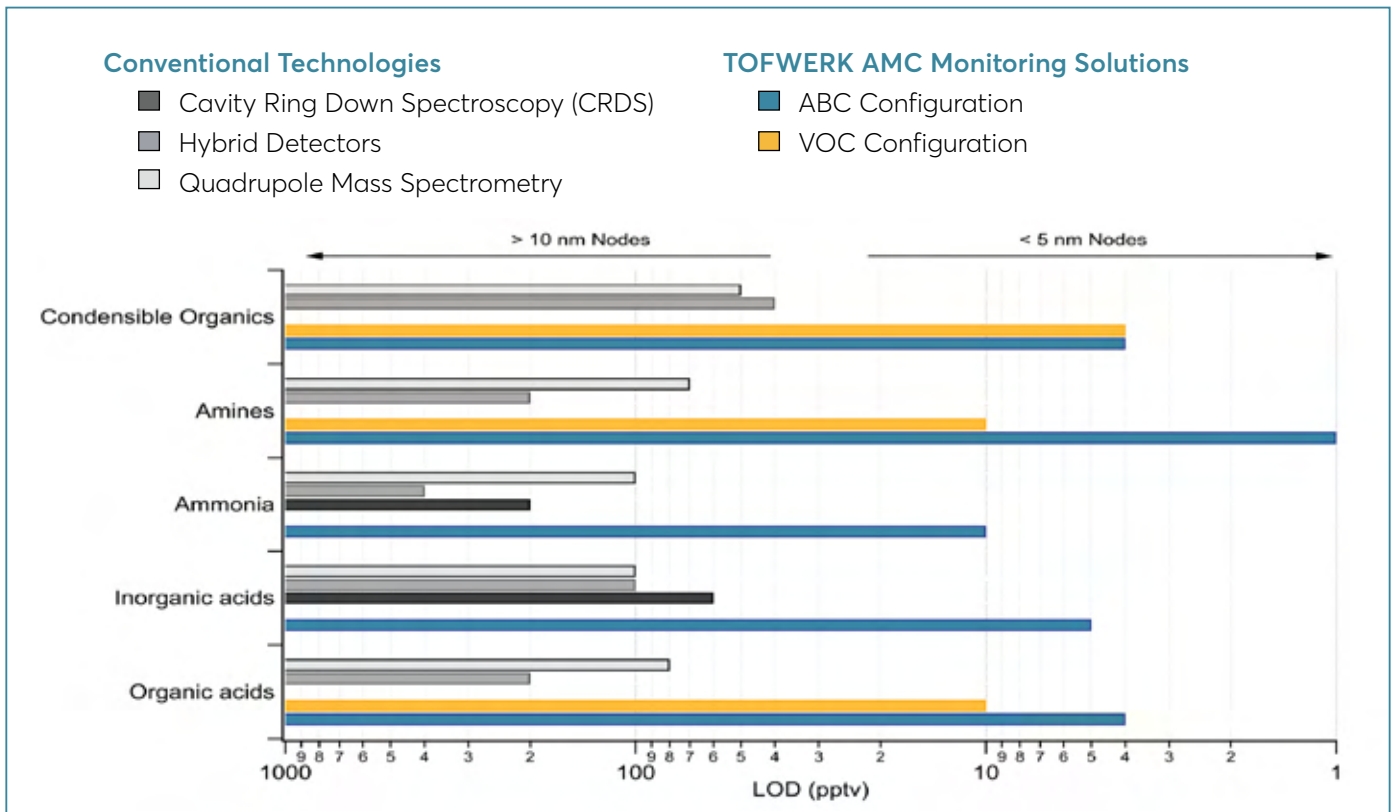
Failures produced at any point along integrated circuit manufacturing processes will result in yield loss. Such failures are associated to a variety of mechanisms or contamination. Sensitive, accurate, and broad detection of airborne molecular contaminants is critical for maximizing yield.

# Comprehensive Monitoring for FOUP Contamination

Using proprietary Fast Polarity Switching, TOFWERK AMC Monitors easily measure each AMC class simultaneously, allowing for robust and reliable detection free of ionization induced fragmentation.

Below, Toluene and PGMEA are introduced in a FOUP and purged away using nitrogen. Trace acetic acid is then introduced and purged. Finally, two small pulses of Ammonia DMA and TMA are introduced – their removal is at a much faster rate because the reaction between the bases and nitric acid result in particle formation. This entire process is traced at remarkable speed, registering the data of each AMC category in milliseconds as shown in the lower figure.
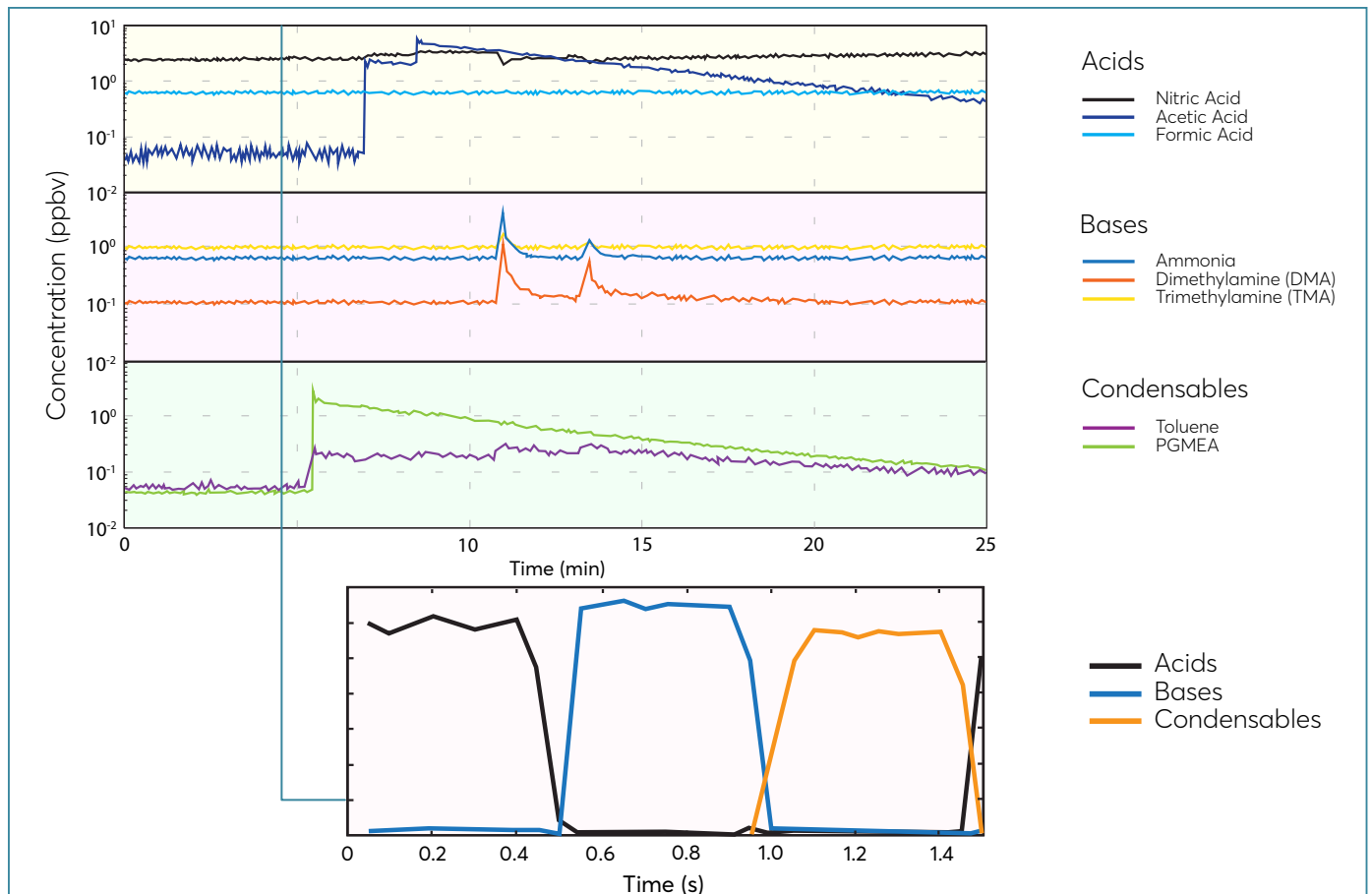


*Millisecond fast switching allows each compound class to be measured in real time, ensuring that transient signals are not missed.*

# TOFWERK AMC Monitoring

# Configurations and Specifications

## Limits of Detection

| | LOD ppt 1 min |
|---|---|
| Benzene | 6.1 |
| IPA | 9.6 |
| PGMEA | 13.1 |
| EA | 11.4 |
| PGME | 13 |
| Cyclopentane | 10 |
| HF | 10 |
| $HNO_3$ | 5 |
| HCOOH | 10 |
| $NH_3$ | 10 |
| DMA | 5 |
| PGMEA | 5 |
| Toluene | 5 |

*Representative LODs evaluated using 3 standard deviations with an integration time of 1 minute for selected AMC compounds.*

## System Specifications

| | |
|---|---|
| Library | Custom Defined |
| Concentration range | ppq-100 ppb |
| Resolution | >1000 M/ΔM |
| Limits of Detection | 1-50 pptv |
| Analysis Cycle | 40 kHz |
| Mode Switching | 5 Hz |
| Operating Temperature | 10-40 °C |
| Operating Humidity | <90% |
| Certification | CE |

TOFWERK AMC Monitors come with two electable configurations which can be utilized individually or jointly. Accessories are available for use in various fab applications.

## ABC Configuration

Ideal detection for Acids, Bases, Condensables, and some VOCs. Using TOFWERK's patented Fast Polarity Switching and Aim Reactor, each compound class is reported simultaneously, in millisecond timescale, with limited fragmentation.

## VOC Configuration

Comprehensive detection for Volatile Organic Compounds. The VOC configuration provides robust coverage for VOCs, leveraging proton-transfer-reaction (PTR) mass spectrometry.

## Accessories

### Mobility Cart

Transport monitors throughout facilities – suitable for all mobile applications including contamination incident investigations, temporary AMC monitoring for remote areas, and more.

### Multi-Valve

Connect to facility monitoring systems with multiple sampling inlets.

AMC classes vary significantly in physicochemical properties, uniquely interacting or reacting with surfaces or other compounds. Due to the complexity of AMC composition, modern monitoring systems must comprehensively measure a wide range of compounds spanning multiple chemical functionalities and a range of vapor pressures with sufficient speed and sensitivity.

# App Note
## Simultaneous Detection
## of Acids, Bases, Condensables, and VOCs

Using real-time chemical ionization time-of-flight mass spectrometry with proprietary Fast Polarity and Reagent Ion Switching, the TOFWERK ABC Monitor supports up to six chemical ionization chemistries. This allows for the detection of multiple AMC classes with a cycle time less than 2 seconds. Figure 1 demonstrates the AMC monitor's response and recovery time when configured for acids, bases, and condensables.
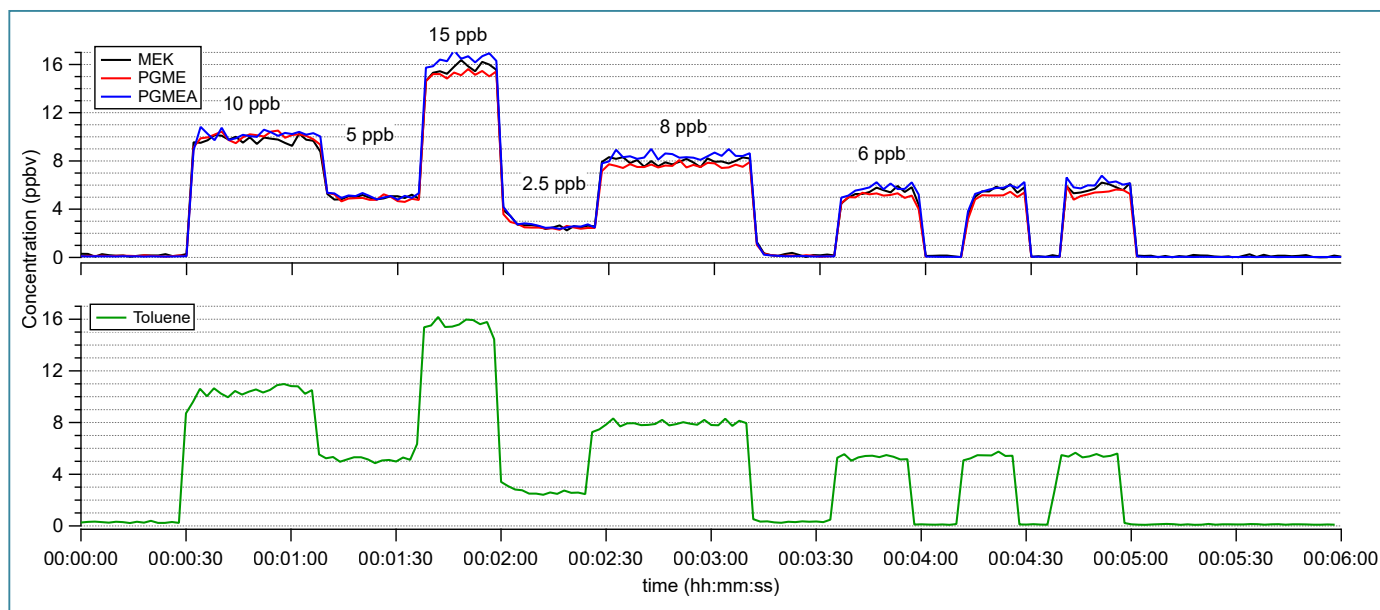


**Figure 1. The** *TOFWERK AMC Monitor's response and recovery time (ABC configuration). Labels in the plot show target concentrations while the Y-axis shows the measured concentration. The upper plot shows the concentration of MEK, PGME and PGMEA measured with one chemical ionization chemistry, while the lower plot shows the simultaneous measurement of toluene with another chemical ionization chemistry.*

Using soft ionization, AMC constituents are measured with negligible fragmentation, enabling robust data and straight forward analysis. Due to fragmentation, compounds like propylene glycol methyl ether acetate (PGMEA, 108-65-6), propylene glycol methyl ether (PGME, 107-98-2), and methyl ethyl ketone (MEK, 78-93-3) are difficult to distinguish with conventional AMC monitors. Figure 2 presents the sequential measurement and removal of these compounds to demonstrate the efficacy of fragmentation free detection.
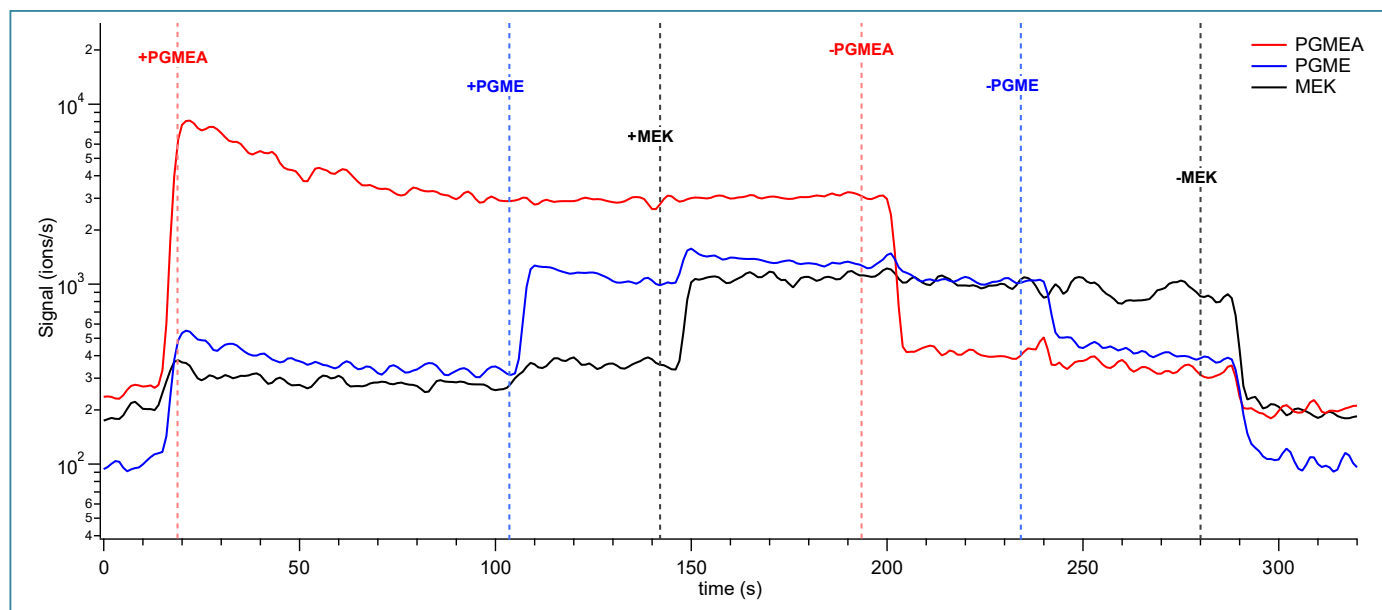


*Figure 2. Sequential measurement and removal of PGMEA, PGME and MEK.*

TOFWERK's AMC monitors reliably detect single digit, part-per-trillion concentrations in real time, enabling greater contamination control. Select limits of detection (LODs) provided by the ABC configuration are presented in Table 1 and coverage linearity is presented in Figures 3 and 4.

| Compound name | CAS | Molecule | 2 s LOD (ppbv) | 1 min LOD (ppbv) |
|---|---|---|---|---|
| Propylene glycol methyl ether acetate (PGMEA) | 108-65-6 | $C_6H_{12}O_3$ | 0.0065 | 0.0012 |
| Propylene glycol methyl ether (PGME) | 107-98-2 | $C_4H_{10}O_2$ | 0.052 | 0.0094 |
| Methyl Ethyl Ketone (MEK) | 78-93-3 | $C_4H_8O$ | 0.421 | 0.075 |
| Ethyl Acetate (EA) | 141-78-6 | $C_4H_8O_2$ | 0.104 | 0.019 |
| Cyclopentane | 287-92-3 | $C_5H_{10}$ | 0.132 | 0.023 |
| Acetone | 67-64-1 | $C_3H_6O$ | 0.002 | 0.0009 |
| Toluene | 108-88-3 | $C_7H_8$ | 0.012 | 0.003 |
| Ammonia | 7664-41-7 | $NH_3$ | 0.408 | 0.072 |
| Hydrogen fluoride | 7664-39-3 | $HF$ | 0.011 | 0.0002 |
| Hydrochloric acid | 132228-87-6 | $HCl$ | 0.526 | 0.095 |
| Nitric acid | 7697-37-2 | $HNO_3$ | 0.0072 | 0.0013 |
| Chlorine | 7782-50-5 | $Cl_2$ | 0.001 | 0.0002 |

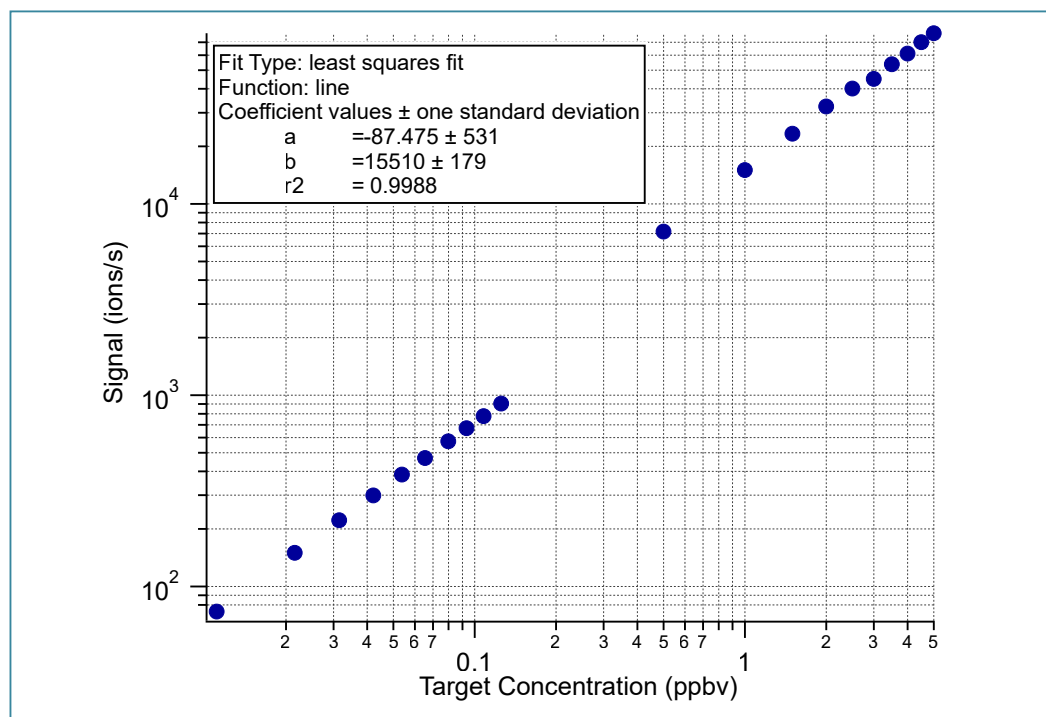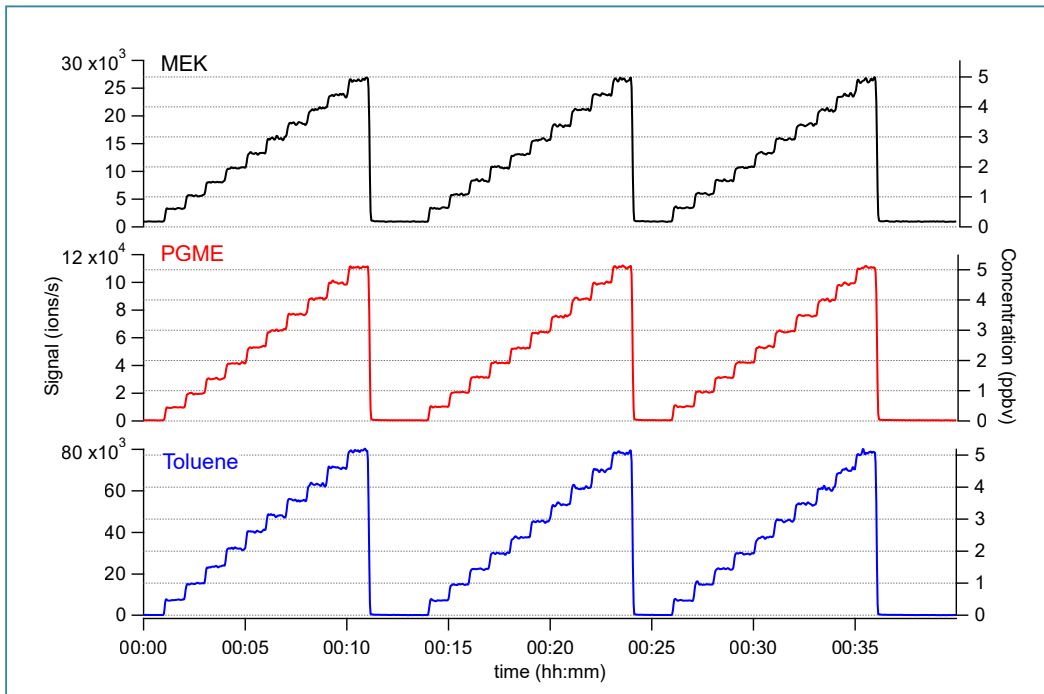**Table 1.** *Typical LODs for relevant semiconductor manufacturing compounds.*



**Figure 3.** *Linear range of coverage for toluene.*

**Figure 4.** *To demonstrate reproducibility, accuracy, and time response, three sequences of increasing concentrations of MEK, PGME and Toluene are presented. The left axis shows the measured signal while the right axis shows the measured concentration. The compounds were measured after dilution from a calibration cylinder with a total of 12 compounds, making an overall VOC concentration of ~1200 ppb.*
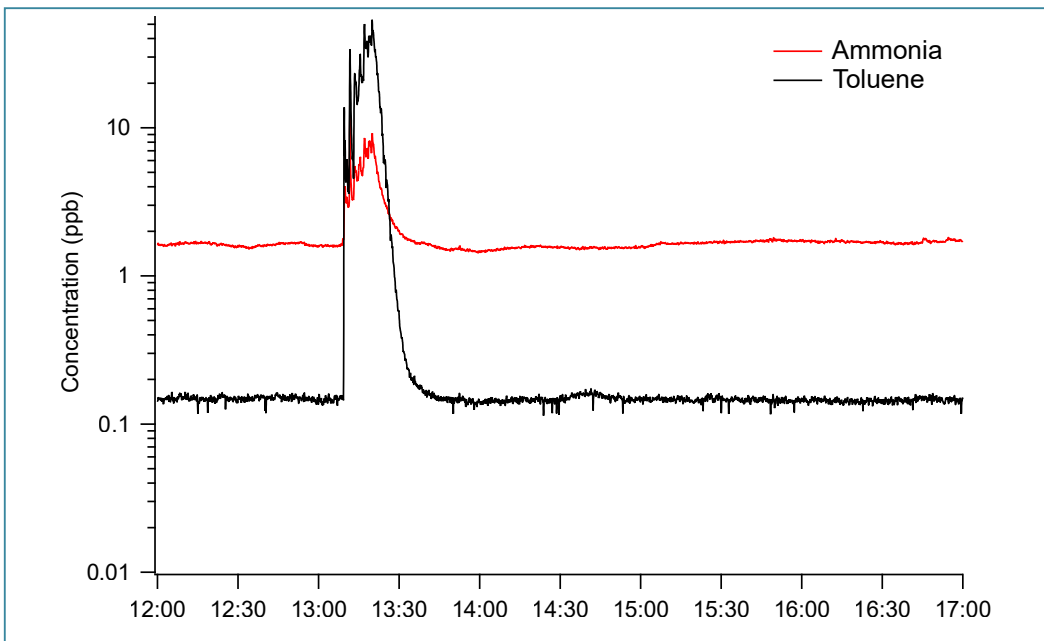


**Figure 5.** *Ammonia and toluene leak detected in an ISO 5 cleanroom.*

TOFWERK AMC Monitors accurately detect single-digit, part-per-trillion concentrations in real time, enabling greater contamination control and detection compared to conventional technologies. Select (LODs) are presented in Table 1 and coverage linearity is presented in Figures 3 and 4.

These AMC monitors have been evaluated for a variety of applications, including material off-gassing, cleanroom monitoring, leak detection, and FOUP quality control. Figure 5 presents a cleanroom event where a transient leak of toluene and ammonia was detected. Figure 6 presents off-gassing measurements for an ISO 5 microtechnology evaluation.
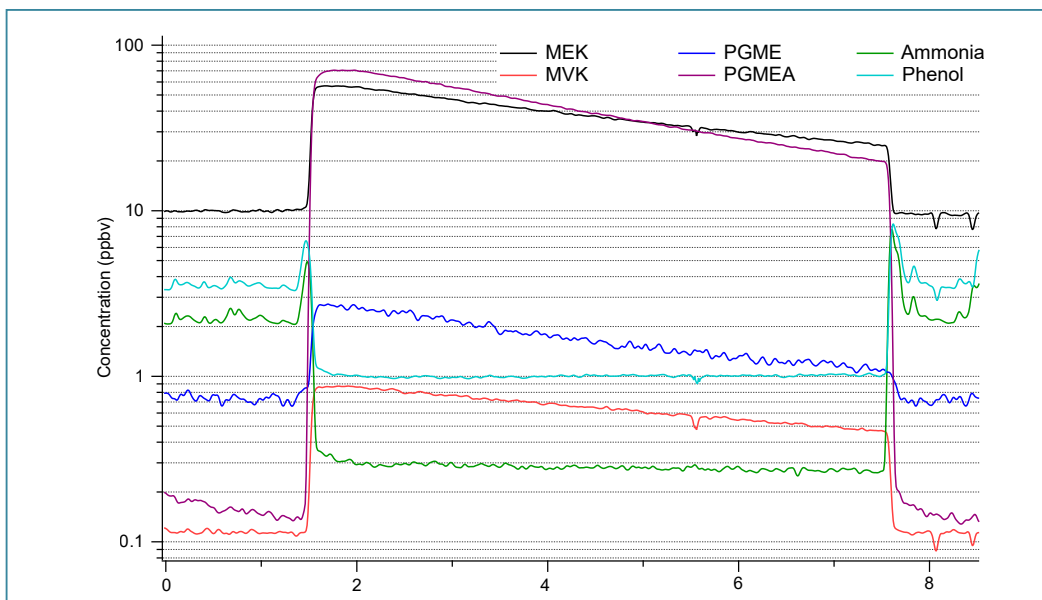


*Figure 6.* *Material off-gassing in an ISO 5 microtechnology cleanroom. Material was purged with CDA and measured directly with a TOFWERK AMC Monitor. Each time series shows simultaneous compound measurements with 3 different ionization chemistries.*

LEARN MORE

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