Ultra-Fast, Simultaneous Monitoring of Critical AMC Classes with ClearFab AMC Monitors

Carla Frege, Felipe Lopez-Hilfiker
TOFWERK, Switzerland

Sensitive and fast detection of airborne molecular contaminants (AMCs) present in semiconductor fabrication facilities is critical to the quality and efficiency of production. Fabs host hundreds of independent processes that can serve as contamination sources, including ventilation systems, leaks, device failures and human emissions. AMCs are comprised of a variety of chemical compound classes which are not comprehensively measured by conventional monitoring techniques. As nodes continue to advance to smaller dimensions, the presence of AMCs at trace concentrations (<10 pptV) have a greater influence on wafer defects, consequently resulting in yield loss.

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.

Using real-time chemical ionization time-of-flight mass spectrometry combined with proprietary fast polarity and reagent ion switching, ClearFab ABC Monitors support 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 ABC monitoring configuration's response and recovery time.

Using soft ionization, AMC constituents are measured with negligible fragmentation, enabling robust data quantification and straightforward mass spectra interpretation. 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

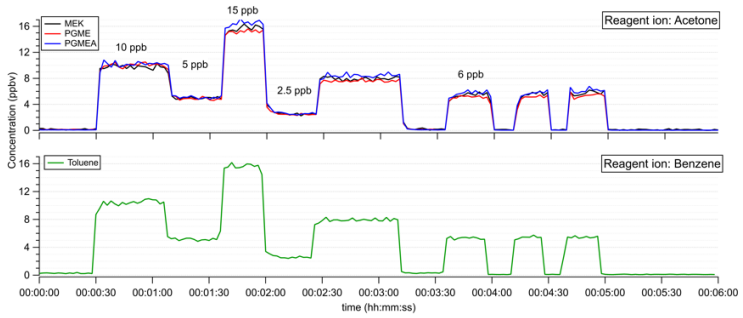

Figure 1. *Response and recovery time of a ClearFab AMC Monitor. Labels in the plot show target concentrations while the Y-axis shows the measured concentration of selected compounds. The upper plot shows the concentration of MEK, PGME and PGMEA measured with one chemical ionization chemistry, while the lower plot shows the simultaneous measurement of toluene with another chemical ionization channel chemistry.*

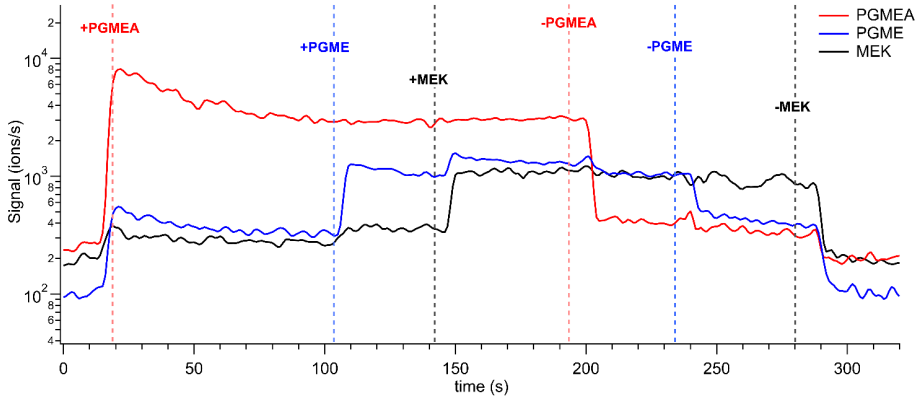

Figure 2. *Sequential measurement and removal of PGMEA, PGME and MEK demonstrating the detection of these challenging compounds without fragmentation.*

to distinguish with conventional AMC monitors. Figure 2 presents the sequential measurement and removal of these compounds to demonstrate the efficacy of the fragmentation-free detection provided by the monitor's soft ionization.

ClearFab AMC Monitors accurately detect single digit, part-per-trillion concentrations in real time, enabling greater contamination control and detection compared to conventional technologies. 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.

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

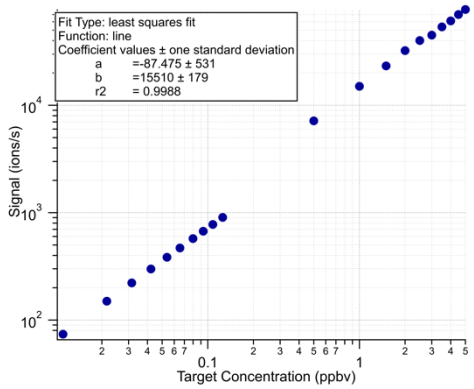

Figure 3. *Linear range of coverage for toluene.*

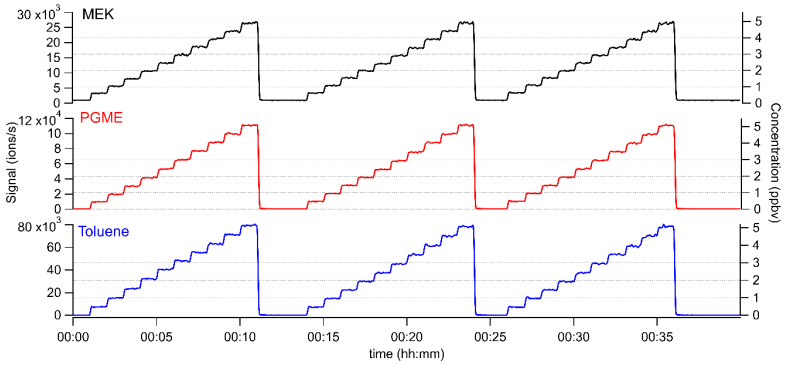

Figure 4. *To demonstrate reproducibility, accuracy, and time response, three sequences of increasing concentrations of MEK, PGME and Toluene are presented. The left axis shows the measured signal while the right axis shows the measured concentration. The compounds were measured after dilution from a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

Compound name	CAS	Molecule	2s LOD (ppbV)	1min 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 with a ClearFab AMC Monitor configured for the monitoring of acids (corrosives), bases, and condensables.*

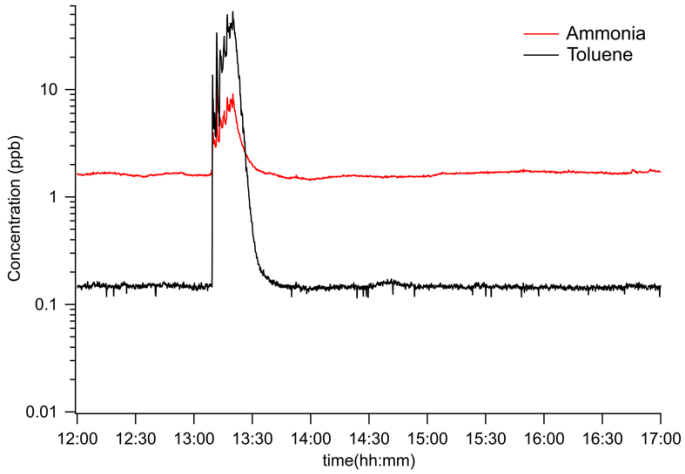

Figure 4. *Ammonia and toluene leak detected in an ISO 5 fine chemistry cleanroom.*

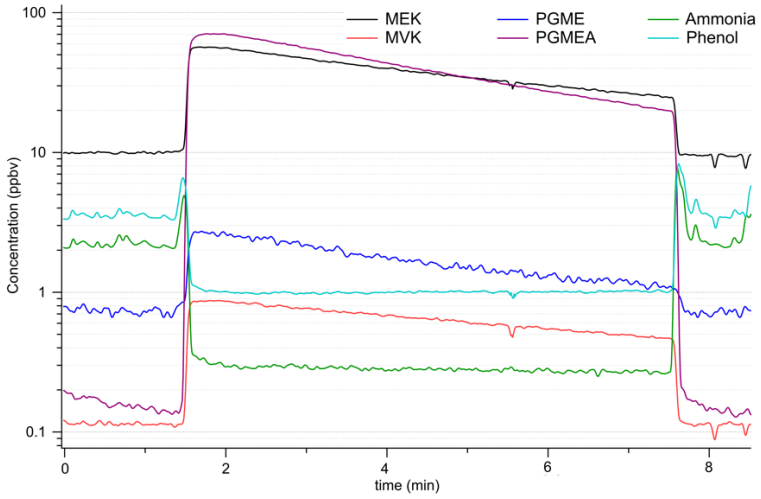

Figure 6. *Off-gassing of material in an ISO 5 microtechnology cleanroom. Material was purged with CDA and measured directly. Each time series shows simultaneous compound measurements with 3 different ionization chemistries for comprehensive AMC coverage.*

ClearFab AMC Monitors represent a significant advancement for contamination control and monitoring, providing simultaneous, fast, and sensitive detection of molecular classes that impact production quality and efficiency. With complete measurement cycles less than 2 seconds, and excellent time response, ClearFab AMC Monitors resolve contamination challenges experienced throughout semiconductor fabrication processes and environments.

Contact
sales@tofwerk.com

ClearFab