Cleanroom Air Monitoring

Critical for Reducing AMC Related Defects

Airborne molecular contaminants (AMC) found in cleanroom air can react or adhere to wafer surfaces and become surface molecular contaminants (SMC) that can negatively affect yield. Escalation events in fabs have been traced directly to airborne contamination when the fab is operating at full production mode.

Balazs™ NanoAnalysis AMC and SMC monitoring programs analyze five types of molecular contaminants: acids (MA), bases (MB), organic compounds (MC), dopants (MD), and trace metals (MM). Our AMC and SMC programs are designed to provide baseline data via grab sampling for critical process areas in the fab. The results enable quicker recovery and allow for better correlation and understanding of AMC and SMC issues in the fab. Table 1 shows the recommended analyses for the process area. The analyses reflect the AMC/SMC issues most likely to arise in the area. It is recommended that these sampling events take place in the cleanrooms during standard operating hours when there are no excursions (baseline) and immediately after any defect or contamination escalation.

Table 1. Process area monitoring locations and recommended AMC/SMC tests

Process Areas	Anions by IC	NH_4^+ by IC	Organics in Air by TD GC-MS	Dopants by ICP-MS	Metals on Wafers by ICP-MS	Urea Test	SMOrg on Wafers
Pre-Diffusion/ Oxidation Furnaces	X			X	X		X
Lithography	X	X	X			X	
CVD	X	X	X	X	X		
PVD	X		X				
CMP	X	X	X		X		
ECP	X	X			X		X
Implant, Anneal			X	X	X		
MUA (incoming and post filter)	X	X	X	X	X	X	
Metrology Tools	X	X	X		X		X
FOUP Area/Stockers	X	X		X			X
Reticle Storage	X	X					X

www.balazs.com
Tel. +1 510 624 4000

Acids and Bases

Chemicals used in the fab are present in the air and can contaminate wafers, ultrapure water sinks, chemical baths, and other areas within the fab. Acids can corrode metal and equipment or lead to hazing problems for wafers, reticles and optics. Bases,especially ammonia, amines and amides, may cause DUV resist "T-topping" andsalicide defects. Some organic photoresist strippers are sources of amines. Monitoring chemicals in the air with a cleanroom air sampler is critical to reducing contamination on wafers. Acids and bases are analyzed using ion chromatography (IC). See Table 2 for selected detection limits for acids in air. Lower reporting limits are available for UHP gases and XCDA.

Table 2. Detection limit for NH_4^+ and acids in air

Ana-lyte	Reporting limit	
	µg/m³ in air	ppbv
NH_4^+	0.04	0.05
Br^-	0.04	0.05
Cl^-	0.02	0.05
F^-	0.01	0.20
NO_3^-	0.04	0.05
NO_2^-	0.02	0.05
PO_4^{3-}	0.04	0.05
SO_4^{2-}	0.04	0.05

ng/L=µg/m³

Organic Compounds (Molecular Condensable)

Organic compounds in cleanroom air may adversely affect many processes in the fab, including cleaning, etching, oxide growth, high temperature processes, film deposition and ionizer tips. Organophosphates in cleanroom air are known to counter dope silicon wafers. Identifying and monitoring sources of organics are becoming increasingly critical to yield enhancement. Balazs™ developed a method to trap and identify organic compounds, from C6 to C28. This method is useful for sampling air in makeup, recirculation, exhaust, and mini environments. Here are some compounds we commonly see in cleanroom air:

- Aldehydes: Benzaldehydes, Nonyl Aldehyde
- Amides: 1-Methyl-2-Pyrrolidinone (NMP), Dimethylacetamide (DMAC)
- Aromatics: Toluene, Xylene, Trimethylbenzene, Alkylbenzenes, Phenol, Cresols
- Chlorocarbons: Trichloroethane (TCA), Tetrachloroethylene (TCE), Carbon Tetrachloride
- Esters: Ethyl Lactate, Ethyl 3-Ethoxyproprionate, PGMEA, EGMEA
- Ketones: Methyl Propyl Ketone, Methyl Isobutyl Ketone, Methyl Ethyl Ketone
- Organo Phosphates: Triethyl Phosphate, Tris(Chloropropyl) Phosphate
- Plasticizers: Dioctyl Phthalate, Texanol Isobutyrate (TXIB), Dibutyl Phthalate
- Siloxanes: Hexamethyldisiloxane, Trimethylsilanol, Cyclic and Linear Siloxanes

The standard detection limit is 1 ng/L. Lower detection limits may be available depending on the types of compounds present in the air.

Dopants

Dopant-sensitive processes such as diffusion, epitaxy, polysilicon deposition or gate oxidation should be monitored for airborne dopants that may adhere to the wafer surface, causing unwanted doping. The most common ULPA filters are made using borosilicate glass filter media, which when exposed to ppb or higher levels of HF in the cleanroom air, react to allow boron to pass through the ULPA filter and adhere to silicon wafer surfaces. When heated, the boron can diffuse into the wafer surface and affect the electrical properties, such as resistivity, threshold voltages or leakage currents. Balazs™ can measure Boron, Phosphorus, Antimony and Arsenic in clean room air and some organophosphate dopants can also be detected. Boron and Phosphorus on wafers can be determined by ICP-MS and organo-phosphates on wafers by TD GC-MS.

Trace Metal

Sources of trace metals in cleanrooms include CVD chemicals, reactor by-products, CMP processes, equipment, construction materials, people, and outside air. Metals can impact diffusion and gate oxidation processes and may result in threshold voltage shifts, lifetime degradation, leakage currents and other problems. Cleanroom air analysis is useful for both identifying these sources and for routine monitoring of the cleanroom. Detection limits for the elements by Inductively Coupled Mass Spectrometry (ICP-MS) are shown in Table 3. Witness wafers can also be used.

Element	B	Na	Mg	Al	K	Ca	Ti	Cr	Mn	Fe	Ni	Cu	Zn	Mo	Sn	Pb
Method Detection Limit (ng/L in air = µg/m³)	0.008	0.002	0.001	0.003	0.1	0.1	0.002	0.001	0.001	0.02	0.002	0.003	0.002	0.002	0.001	0.002