BALAZS™ ANALYTICAL SERVICES

Cleanroom Air Monitoring

Contaminants found in your cleanroom air can adhere to wafer surfaces and negatively affect yields. Balazs analyzes five types of airborne molecular contaminants (AMC) in cleanroom air: trace metals, acids, bases, dopants and organic compounds. Results from any of these analyses can be used to correlate yield problems with contamination in air.

Trace Metals
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 16 elements by Inductively Coupled Mass Spectrometry (ICP-MS) are shown in Table 1.

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" and salicide defects. Some organic photoresist strippers are sources of amines. Monitoring chemicals in the air with the Cleanroom Air Sampler is critical to reducing contamination on your wafers. Acids and bases are analyzed by Ion Chromatography (IC). See Table 2 for selected detection limits.

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. Measurement of Boron, Phosphorus, Antimony and Arsenic in clean room air is available. Some organophosphate dopants can also be detected in air using our organic compounds in air analysis. Boron and Phosphorus on wafers can be determined by ICP-MS and organo-phosphates on wafers by TD-GC-MS.

AIR LIQUIDE ELECTRONICS

ORGANIC COMPOUNDS (MOLECULAR CONDENSABLES)

Organic compounds in cleanroom air may adversely affect many processes in the fab, including cleaning, etching, oxide growth, high temperature processes and film deposition. 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 minienvironments. Table 3 shows some compounds we commonly see in cleanroom air. The standard detection limit is 1 ng/L. Lower detection limits may be available depending on the types of compounds present in the air.

TABLE 1- DETECTION LIMITS FOR TRACE ELEMENTS IN AIR

Analyte	Method Detection Limit (ng/L in air)*
Aluminum (Al)	0.003
Boron (B)	0.008
Calcium (Ca)	0.100
Chromium (Cr)	0.001
Copper (Cu)	0.003
Iron (Fe)	0.020
Lead (Pb)	0.002
Magnesium (Mg)	0.001
Manganese (Mn)	0.001
Molybdenum (Mo)	0.002
Nickel (Ni)	0.002
Potassium (K)	0.100
Sodium (Na)	0.002
Tin (Sn)	0.001
Titanium (Ti)	0.002
Zinc (Zn)	0.002

*ng/L = ug/L^3

TABLE 2- DETECTION LIMITS FOR ACIDS IN AIR

Analyte	Method Detection Limit (ng/L in air)*
Ammonium (NH_4^+)	0.03
Bromide (Br^-)	0.03
Chloride (Cl^-)	0.02
Fluoride (F^-)	0.20
Nitrate (NO_3^-)	0.03
Nitrite (NO_2^-)	0.02
Phosphate (PO_4^{3-})	0.03
Sulfate (SO_4^{2-})	0.03

*ng/L = ug/L^3

TABLE 3- ORGANIC COMPOUNDS 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	Triethyl Phosphate
Phosphates	Tris(Chloropropyl)-Phosphate
Plasticizers	Dioctyl Phthalate
	Texanol Isobutyrate (TXIB)
	Dibutyl Phthalate
Siloxanes	Hexamethyldisiloxane
	Trimethylsilanol
	Poly (dimethylsiloxane)

SAMPLE COLLECTION AND ANALYSIS

For trace metals, acids, bases, and dopants, the Cleanroom Air Sampler is used. The Cleanroom Air Sampler is a modular unit manufactured using only cleanroom compatible materials.

The pump module creates a slight vacuum in the sampling module, ensuring a constant volumetric air flow through the scrubbing solutions. For the best recoveries, Balazs utilizes specific scrubbing solutions that are most effective in trapping the airborne contaminants of interest. The pump module and the sample module are connected in the cleanroom prior to sampling to avoid contamination. A precleaned tube is placed at a specific site to collect the contaminants and the unit is connected to an electrical outlet to begin sampling for 12-96 hours, depending on the analysis. Longer sampling time is used to achieve the lowest possible detection limit.

A blank (another sampling module that is treated in the same manner as the sample) accompanies the sample. This ensures that only contamination from the air is quantified, not contamination generated by sampling, shipping, or handling.

Once sample collection is complete, either the sampling module or the entire unit is returned to the lab and the sampling solutions are analyzed. The blank is analyzed in the same manner as the sample and is subtracted from the sample results. Results are typically reported in ng/L, however other units, such as ng/m3, ppbv or ppbm may also be requested. For organic compounds, special stainless steel sampling tubes containing distinct beds of proprietary adsorbent materials are provided by Balazs to trap organic compounds in cleanroom air. A battery-operated sampling pump is used to collect the air samples directly onto the adsorbent material, typically for 6-8 hours. A blank (a tube that has not been exposed to the air but has been treated in the same manner as the sample tube) accompanies the sample tube. Once sampling is completed, the tubes are returned to the lab for thermal desorption and analysis by Gas Chromatography - Mass Spectrometry (GC-MS). The analysis focuses on compounds with boiling points ranging from 100-400°C as these compounds are particularly problematic for wafers.