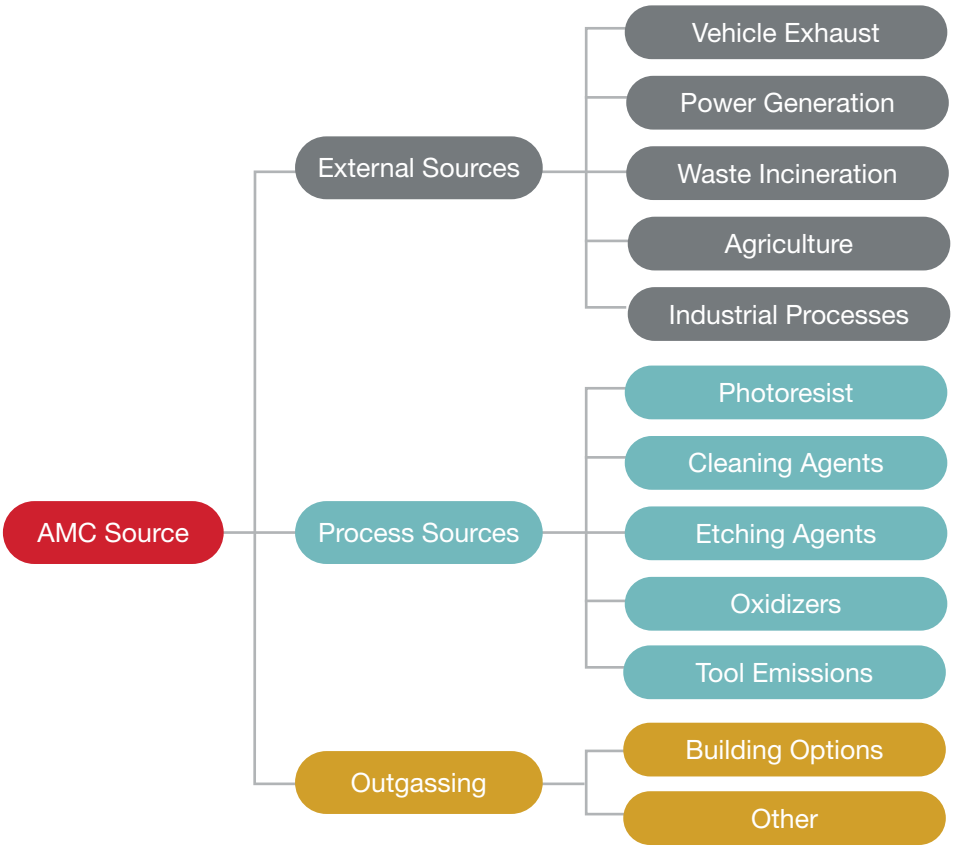
AMC Control Solutions

TESTING AND MONITORING SERVICES

Airborne Molecular Contamination Sources

The term Airborne Molecular Contamination (AMC) covers a wide range of chemical contaminants that can be present in cleanroom air. Outdoor air, manufacturing processes, fugitive emissions from process equipment, and chemical supply lines, cross-contamination between manufacturing areas, chemical storage areas, off-gassing from building and construction materials, accidental spills, and bioeffluents from cleanroom personnel can all contribute to the overall AMC load in the cleanroom. AMC can be detrimental to many processes and products and can also represent considerable health hazards to personnel. Subsequently an emerging focus area requiring innovative solutions is the preventive control of AMC.



As semiconductor-device geometry continues to decrease to 10 nm or smaller, the importance of chemical contamination has now become as important as particulate contamination. AMC can impact almost all aspects of submicron device fabrication, from overall fab operation to final device performance. New chemistries introduced to manufacturing processes have also been shown to cause unforeseen AMC-related effects. These materials can be new possible sources of AMCs, and effects on processes are not all understood yet.

There is a shift toward equipment makers and fabs worldwide creating AMC-free manufacturing environments including the use of air filters, purifiers, FOUPs, pods, compacts, AMC-controlled factory interfaces, cluster tools, purged reticle storage and stocker areas, and purged lithography tools. Airborne molecular contamination (AMC) control may be implemented either fab-wide or locally at certain critical processes, potentially also at different levels for different processes.

AAF can provide full-service testing capabilities in state-of-the-art laboratories for the monitoring, classification, and control of AMC as well as performance and life testing of gas-phase media and filters used for the control of AMC in semiconductor and microelectronics manufacturing applications. We can provide technical expertise in identifying and controlling AMC for improving process and product yields for semiconductor, disk drives, optoelectronics, and other contamination-sensitive industries.

AMC Classifications

SEMI Standard F-21-2016: *Classification of Airborne Molecular Contaminant Levels in Clean Environments*, classifies AMC in cleanrooms by their chemical properties providing a way to characterize the environment by groups of materials that could have similar effects on an exposed wafer. This allows for classification of cleanrooms with respect to their molecular (nonparticulate) contaminant levels. The classifications are defined as follows:

- **Molecular Acid (MA):** A corrosive material whose chemical reaction is that of an electron acceptor
- **Molecular Base (MB):** A corrosive material whose chemical reaction is that of an electron donor
- **Molecular Condensable (MC):** A chemical substance capable of condensation on a clean surface (excluding water)
- **Molecular Dopant (MD):** A chemical element that modifies the electrical properties of a semiconductive material
- **Molecular Metal (MM):** A trace metal that may exist either in elemental form such as Al, W, Mn, Pb, etc., or as a compound, such as $AlCl_3$, WF_6, etc.

AMC Types, Sources, and Effects

AMC Class	Contaminants	Sources	Effects
Molecular Acids	Fluoride, chloride, bromide, sulfates, phosphates, nitrogen/ oxygen compounds	Etch chambers, diffusion furnaces, CVD processes, wet benches using HCl, HF, BOE	Hazing of reticles / wafers, optics of exposure & metrology tools, corrosion of Al & Cu metal lines, inhibits CAR
Molecular Bases	Ammonia, amines, amides, trimethylamine, triethylamine, cyclohexylamine, dimethylamine, methylamine, ethanolamine, morpholine	**Ammonia sources:** CVD, HMDS, CMP, slur-ries, wafer cleaning processes, TiN/Si_3N_4 films deposition. **Amine sources:** photoresist strippers, poly-mers, epoxies, TMAH decomposition **Amide sources:** solvents such as NMP, dime-thyl acetamide, polyimides	Neutralizes photoacids in resists, reactions with acids can cause haz-ing, particle formation, nitrides on wafer surface
Molecular Condensables	Dibutyl phthalate, organophosphates, siloxanes, HMDS, PGMEA	Outside air, process chemicals, outgassing from filters, sealants, walls, adhesives, floors, wafer shippers, FOUPS, pods, gaskets, seal-ing tape, bagging materials, flame retard-ants	Hazing of exposure tool optics and masks from HMDS byproducts, delamination of PR and ARCs, un-wanted n-doping of wafer, interference with thin film metrology
Molecular Dopants	Boron, phosphorus, organophosphorus, arsenic, antinomy	Outside air, degradation of HEPA/ULPA filters, exhaust from RIE, EPI, CVD processes, flame retardants	Unwanted n- and p-doping of wafers
Molecular Metals	Organometallic compounds	Cross-contamination of wafers, plastic additives containing organo-tin/bismuth compounds, corroded ductwork	Particulates in air and on wafers

Analytical Classifications

- **Total organic compounds (TOC)** include condensable organics, non-condensable organics, and refractory compounds (e.g., siloxane, organophosphorus, organosulfur) and halogenated hydrocarbons
- **Molecular acids (MA)** as anions (F^-, Cl^-, NO_2^-, NO_3^-, PO_4^{3-} & SO_4^{2-})
- **Molecular bases (MB)** as ammonia (NH3)

Total Organic Compounds (TOC) (expressed as toluene equivalents)		Molecular Acids (MA)	Molecular Bases (MB)
Refractory Compounds Siloxane(1) D3 Siloxane(2) Tetramethylsilane (TMS) HMDS(3) Organosulfur Organophosphorus Halogenated hydrocarbons	TOC (TVOC) condensable organics(4) non-condensable organics(5)	F^-, Cl^-, NO_2^-, NO_3^-, PO_4^{3-}, SO_4^{2-}	NH_3

NOTES: (1) siloxane: silicon containing VOC [except: TMS, D3], (2) D3: hexamethylcyclotrisiloxane, (3) HMDS: hexamethyldisiloxane, (4) B.P >150°C, M.W >120, (5) B.P <150°C, M.W <120

Industry Guidelines

AAF participates on international committees working to develop and update standards and guidelines related to AMC and AMC control including the International Roadmap for Devices and Systems (IRDS), the Institute of Environmental Sciences and Technology (IEST), the International Organization for Standardization (ISO), and Semiconductor Equipment and Materials International (SEMI).

- IRDS (International Roadmap for Devices and Systems): Factory Integration and Yield Enhancement chapters
- IEST-G-CC035: Design Considerations for Airborne Molecular Contamination Filtration Systems in Cleanrooms and Other Controlled Environments
- ISO 14644-8:2022: Cleanrooms and associated controlled environments, Part 8: Assessment of air cleanliness by chemical concentration (ACC)
- SEMI F21: Classification of Airborne Molecular Contaminant Levels in Clean Environments

AMC Analysis & Measurement Methods

Measurement Methods

Online Monitoring	Impinger Sampling
Method	Method
Cavity Ring-Down Spectroscopy (CRDS), Ion Mobility Spectrometry (IMS), Ultraviolet Fluorescence (UVF), Proton Transfer Reaction Mass Spectrometry (PTR-MS), Chemiluminescence Detection (CLD) **MA** HF, HCl, HBr, NOx, SO_2, H_3PO_4, HFc, HAc, HPr, Hlac, Hox **MB** NH_3, TMAH, TMA, NMP, Amines **MC** Condensable Organic Compound (b.p. > 150°C) Total Refractory compound (Si, P, S) **Total Organic Acids** **Total Organic and Inorganic Bases** **Total Organic Compounds and Inorganic Compounds that contain P, B, As, (dopants)**	Ion Chromatography (IC) **MA** HF, HCl, HBr, HNO_3, H_3PO_4, H_2SO_4,H_2SO_3, SO_2 **MB** Total Organic and Inorganic Bases

Online Monitoring	Impinger Sampling	SEM/EDS
Method	Method	Method
IC, Thermal Desorption coupled with Gas Chromatography/Mass Spectrometry (TD-GC/MS) **MA** HF, HCl, HBr, NOx, SO_2, H_3PO_4, HFc, HAc, HPr, Hlac, Hox **Total Organic Compounds (TOC)** > C6 **Total Organic and Inorganic bases**	TD-GC/MS **(TOC)** > C6 **Total Organic and Inorganic Bases** **TOC and Total Inorganic Compounds that contain P, B, As (dopants)**	Scanning Electron Microscope/Energy-Dispersive X-ray Spectroscopy (SEM-EDS) **Surface Analysis** **Elemental Analysis** B~U

State-of-the-Art Laboratory and Testing Facilities

Analytical / Test Equipment

- Gas Chromatography–Mass Spectrometry (GC-MS) – Perkin Elmer / Agilent automated thermal desorption GC-MS system.
- Ion Chromatography (IC) – Dionex ICS 2000, ICS-5000, ICS-6000
- Scanning Electron Microscopy and Energy Dispersive Spectroscopy (SEM-EDS) – Axia ChemiSEM HiVac
- Small-scale test rigs for accelerated life testing for adsorbent/chemisorbent media
- Full-scale gas-challenge test rigs for pressure drop, outgassing, removal efficiency and capacity testing: can accommodate filter sizes from 12"x12" (310x310 mm) up to 24"x24" (610x610 mm)

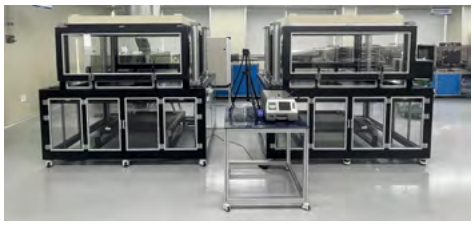
Gas Chromatography Analyzer: Automated Thermal Desorption - GC-MS station

Ion Chromatography Testing station

Scanning Electron Microscopy / Energy Dispersive Spectroscopy station

Accelerated media life test station and gas monitoring equipment

Full-scale filter test rig for pressure drop, removal efficiency, outgassing, and particle emission measurements



FFU Filter Testing station

Analyses Performed

- AMC monitoring in air (IC, GC-MS)
- Accelerated media / filter life testing (available challenge gases and typical test conditions shown below)

AMC	Flow Rate (L/min)	Inlet Conc. (ppm)	Test Column Size (mm)
NH_3	17	100	60Ø
O_3			
SO_2			
NO_2			
Toluene			
HCl			

- AMC removal efficiency – full-scale and small-scale
- Material outgassing
- Particle emissions
- Pressure drop testing
- Other analyses upon request

AAF INTERNATIONAL a member of DAIKIN group
9920 Corporate Campus Drive, Suite 2200, Louisville, KY 40223-5690
888.223.2003 Fax 888.223.6500 I aafintl.com

ISO Certified Firm GPF-1-212 04/24