Witness Wafers Contamination Analysis

Providing Detection Sensitivities Below ITRS and SEMI Requirements

Contaminants from cleanroom air, gases, wafer processing and outgassing from materials can ad here to wafer surfaces and negatively affect yields. Balazs™ NanoAnalysis can use client-supplied monitor wafers or provide pre-cleaned witness wafers for collecting these contaminants, then perform analysis to below industry requirement including the International Technology Roadmap for Semiconductors (ITRS) and Semiconductor Equipment Materials International (SEMI) guidelines. Witness wafers and appropriate DOE (Design of Experiments) can be used for:

- Qualification: processes, factories, tools
- Baselining
- Trending
- Contamination levels monitoring
- Troubleshooting
- Failure analysis
- Process optimization

Figure 1. Witness wafers

Witness wafer exposure testing - combined with process wafers tests, outgassing, chemical bath and ultrapure water monitoring - can provide programs to identify levels and sources of :

- Airborne molecular contaminants (AMC) in cleanroom air
  - Acids and bases
  - Organics
  - Dopants
  - Individual metals
- Surface molecular contaminants (SMC) from tools & wafer processing
  - Metals, organics and dopants

Witness wafers are positioned for a defined period (24 hours or 1 week typically) or exposed to normal wafer handling to collect typical contaminants that adhere to the surface of the wafer. The wafers for each test method are packed using a unique process to avoid contact contamination often associated with shipping and handling (shipping blank wafers are provided). Analysis is then performed in Balazs™ cleanrooms with state-of-the-art instrumentation and validated methods.

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AIR LIQUIDE ELECTRONICS

Trace Metals

Balazs™ uses Vapor Phase Decomposition for metal collection from the wafers followed by Inductively Coupled Plasma Mass Spectrometry (VPD ICP-MS) for critical surface contamination measurement. This multi-element survey provides low detection limits (10^8 to 10^{10} atoms/cm^2) for not only heavier transition elements that affect wafers, but also for lighter elements such as Na, K, Al, Mg, Ca that can be mobile ions or affect gate oxide integrity. This test can be used to measure trace surface metal concentrations on silicon wafer surfaces and in dielectric thin films. When contaminants are found, similar extractive test methods can also be used to determine contaminant levels on parts or wafer handling equipment.

Figure 2. Automated VPD ICP-MS

Dopants

Adsorption of volatile contaminants such as volatile boron (B) and/or phosphorus (P) from cleanroom air may cause unintentional doping of wafers. 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. Unwanted doping may affect the electrical properties, such as resistivity, threshold voltages or leakage currents. Boron and phosphorus on wafers can be determined by Drop Scan Etch (DSE) ICP-MS and organo-phosphates on wafers by TD GC-MS. Balazs™ offers AMC testing of the air handling systems for dopants using air impingers if excessive dopants are found on the witness wafers.

Ionic Contaminants

Anions such as F^-, Cl^-, NO_2^-, NO_3^-, HPO_4^{2-}, Br^- and SO_4^{2-} may be present in the environment as AMC. If present in large amounts they can attack borosilicate ULPA filter media or air ducts causing the emission of particulate metals. Fluorine and chlorine can etch metallization or passivation layers and wafers to form pits. The cation NH_4^+, if present in the environment and adsorbed onto surfaces at a concentration greater than $1x10^{13}$ to $1x10^{15}$ atoms/cm^2, can form a haze on wafers, optics, flat panels and photomasks. Ultrapure water extraction followed by ion chromatography can detect ionic contamination on surface at the 10^{11} to 10^{12} ion/cm^2 detection range.

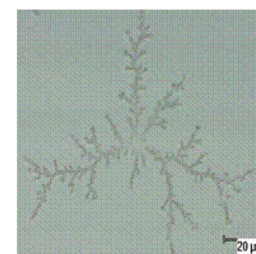

Figure 3. Ammonium sulfate haze

Organic Contaminants

Organic contaminants such as organophosphates, antioxidants, plasticizers, caprolactam, phthalates or siloxanes on wafers can cause unwanted doping, poor gate oxide reliability, delamination, contact resistance, copper electroplating failure, optical defects, wetting problems, time-dependent haze, silicon nitride nucleation delays, ellipsometry errors and many other thin film issues that could reduce yield. For optimum process control, organic contaminants on witness wafers may be identified by Thermal Desorption GC-MS (TD GC-MS) and matched to materials outgassing results to determine the root source of the organic contamination. One standard test method used by Balazs™ is the SEMI MF1982-1103 that provides a detection sensitivity to below 0.01 monolayer or 0.1 ng/cm^2.

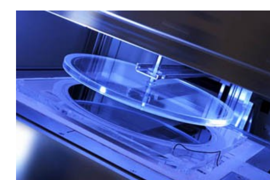

Figure 4. 300mm full wafer desorber

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Tests Available for Witness Wafer Analysis

Analyte	Technique	Sample Type	Sample Size	Results
Trace Elements	VPD-ICP	Bare, oxide, BPSG, SiN and other wafers	Up to 300mm	See note 1 and 2
Dopants	DSE-ICP-MS	Bare or witness wafers		B, P, As, Sb; others upon request
Ionics	IC	Bare or film		F^-, Cl^-, NO_2^-, NO_3^-, HPO_4^{2-}, Br^-, SO_4^{2-} NH_4^+
Organics	TD-GC-MS	Witness wafers		All semivolatile organic compounds that adhere to wafers and can be desorbed at 400°C

1. 16 elements: Al, Ca, Cr, Co, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, Ti, V and Zn.
2. 35 elements: Al, As, B, Ba, Be, Ca, Cd, Ce, Co, Cr, Cu, Fe, Ga, Ge, Hf, In, K, Li, Mg, Mn, Mo, Mn, Na, Ni, Pb, Sb, Sn, Sr, Ta, Ti, W, V, Y, Zn and Zr

Balazs™ NanoAnalysis operates ISO 17025 certified laboratories that identify, analyze and resolve contamination issues for high-tech industries around the world. The Microcontamination Experts™ at Balazs provide rapid and accurate analyses and expertise for water, air, chemicals, process gases, components, wafers, consumables and any other contamination sources.

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