

Detecting What Matters: Advanced Trace-Impurity Analysis for Semiconductor Materials

Are you struggling to detect trace metals, moisture, oxygen, organics, or other critical impurities at ppb and sub-ppb levels?

If You Cannot Measure It, How Can You Control It?

As semiconductor processes and device structures become more demanding, contamination control requires a deeper understanding of the materials entering the fab and reaching the process tool. Trace impurities can originate from process gases and precursors, purification systems, packaging, or gas-delivery components. For fabs and foundries, simply confirming that a material meets a purity specification may not tell the whole story. The more important questions are:

- What impurities are present?
- At what concentrations?
- Where are they coming from?
- Can they be measured at levels relevant to the process?

Nippon Sanso Matheson's Advanced Technology Center (ATC) in Longmont, Colorado supports advanced R&D in high-purity gases, gas-handling equipment, micro-contamination, and purification technologies. Its in-house analytical, evaluation, and testing capabilities help investigate gases, purifiers, and gas-system components across the material delivery chain.¹

If you cannot reliably measure the impurity, you cannot effectively understand or control it.

Why Advanced Semiconductor Materials Require Advanced Analytics

Semiconductor manufacturing uses a diverse range of gases and materials. Nippon Sanso Matheson offers semiconductor products including arsine, phosphine, diborane, silane, disilane, hydrogen selenide, BCl_3 , Cl_2 , HBr , dichlorosilane, SiCl_4 , halocarbons, hydrocarbons, and super-high-purity inert gases.²

Different materials present different analytical challenges. A technique used for moisture in an inert gas addresses a different measurement problem than trace metals in a reactive chemistry or organic contamination in a purge gas.

We have developed analytical capabilities to detect sub-ppm/ppb impurities and trace metals in reactive and inert chemistries including more than 45 elements listed as potential targets. We have developed advanced analytical techniques such as CRDS, ICP-MS, and APIMS which provide the measurement capability needed to understand impurities at increasingly stringent levels. We use these capabilities to (i) evaluate the effectiveness of our purification media and (ii) to accurately characterize trace impurities in ultra-high-purity gases intended for demanding semiconductor applications.³

There is no universal analytical technique for semiconductor-gas purity. The method must be matched to the molecule and the impurity.

Silane	SiH ₄	OMX™	Reactive agents on a polymeric support	H ₂ O, O ₂ , CO ₂ , CO	<100 ppt, LDL	DC only
Monomethylsilane	SiH ₃ CH ₃	OMX™	Reactive agents on a polymeric support	H ₂ O, O ₂ , CO ₂ , CO	<100 ppt, LDL	DC only
Arsine	AsH ₃	ASX-II™	High surface area inorganic medium	<75 ppb H ₂ O in AsH ₃ , LDL		Not available
		ASX-II XL	High surface area inorganic medium	<75 ppb H ₂ O in AsH ₃ , LDL		
Phosphine	PH ₃	PHX™	Reactive agents on an inorganic support	<33 ppb H ₂ O in PH ₃ , LDL		Not available
		PHX-II XL	High surface area inorganic medium	<75 ppb H ₂ O in PH ₃ , LDL		
Germane	GeH ₄	Desicore	High surface area inorganic medium	<5 ppb H ₂ O in GeH ₄ , LDL		Not available
1-10% Arsine 1-10% Germane 1-10% Phosphine	AsH ₃ GeH ₄ PH ₃	OMX™	Reactive agents on a polymeric supportmedium	H ₂ O, O ₂ , CO ₂	<1 ppb	Not available

Table 1. Ultra-trace analysis of organic and inorganic impurities in hydrides like Arsine, Phosphine, Germane and their respective mixtures.

What Are We Trying to Measure?

A semiconductor gas may contain multiple classes of unwanted impurities. The specific targets, appropriate analytical method, and meaningful detection limit depend on the gas matrix and application.

- **Moisture and Oxygen:** Trace H₂O and O₂ are common targets in ultra-high-purity gas and purification applications. Our technical literature documents ppt-range measurements for selected contaminants and purifier evaluations.⁴
- **Trace Metals:** We have developed capabilities for measuring impurities and metals in reactive, inert chemistries and new materials, with more than 45 elements listed as potential analytical targets.³
- **Organic Contaminants:** We have published development work involving removal of total organic contamination in inert gas with NANO-CHEM® INX-Plus™, including reported hydrocarbon performance in the ppq range.⁵
- **Gas-Specific Impurities:** Reactive gases, hydrides, corrosive gases, precursors, and new materials may require chemistry-specific sampling and analytical approaches.³

Advanced analytical science begins with the question: What impurity are we trying to understand?

Building an Analytical Toolbox

Advanced semiconductor-material analysis is best approached as a toolbox rather than reliance on one instrument. We have developed advanced cavity ring-down spectroscopy (CRDS) and, across purification technical materials, references analytical methods including APIMS and ICP-MS for specific impurity and performance evaluations.^{3, 4}

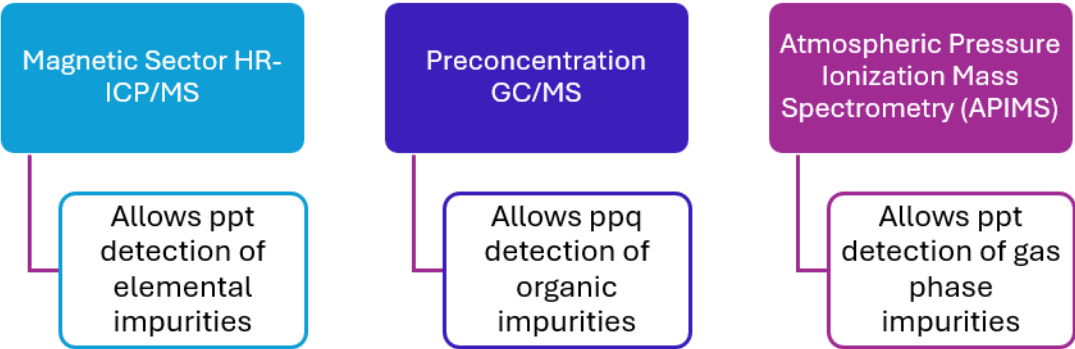


Figure 1: An analytical toolbox consisting of advanced analytical capabilities like ICPMS, APIMS and GCMS.

The differentiating capability is not simply access to a given analytical instruments. It is selecting a measurement approach appropriate for the impurity, matrix, concentration, and technical question being investigated.

MOISTURE / OXYGEN	Spectroscopic and gas-phase trace analysis
TRACE METALS	Elemental analysis and contamination characterization
ORGANICS	Ultra-trace hydrocarbon / organic analysis
REACTIVE CHEMISTRIES	Matrix-specific analytical method development

Trace Metals: When the Impurity Is an Element

Trace-metal measurements present a different analytical problem from gas-phase moisture or oxygen. The challenge can include identifying which metallic contaminants are present, differentiating meaningful contamination from analytical background, and understanding whether the source of the impurity is the original material or downstream handling.

We have developed purification technologies to remove critical impurities including metals together with analytical capabilities for measuring impurities and metals in reactive and inert chemistries.³

GASES PURIFIED	CHEMICAL FORMULA	PURIFICATION MEDIUM	PURIFICATION MEDIUM DESCRIPTION	IMPURITIES REMOVED	EFFICIENCY	END POINT DETECTION
Boron Trichloride Chlorine Trichlorosilane Dichlorosilane Hydrogen Bromide	BCl ₃ Cl ₂ SiHCl ₃ SiH ₂ Cl ₂ HBr	Metal-X™	High purity high surface area inorganic medium	H ₂ O <100 ppb, LDL Volatile Metals-Fe, Mo, Cr, Ti, Ni, Mn*		Not available
Hydrogen Chloride	HCl		High purity high surface area inorganic medium	H ₂ O <100 ppb, LDL Volatile Metals-Fe, Mo, Cr, Ti, Ni, Mn*		
Hydrogen Fluoride	HF	CleanCorr™	High surface area inorganic medium	H ₂ O <3 ppm, LDL B, Mg, Al, Zn, Zr, W, Fe <2 ppbw		Not available

Table 2: Halogenated corrosive gases purification by NANOCHEM® based proprietary purification medium and corresponding analytical techniques.

Detect → Quantify → Investigate the Source → Evaluate Purification → Verify Improvement

Analytical Science + Purification: Measure Before and After

Purification and analytical science are tightly linked. An effective purifier must be challenged and its inlet and outlet impurity concentrations measured with methods capable of resolving the performance being claimed.

Our NANOCHEM® purifiers undergo live-gas testing to ensure they meet or exceed performance specifications in the specific process gas for which they are marketed.⁶

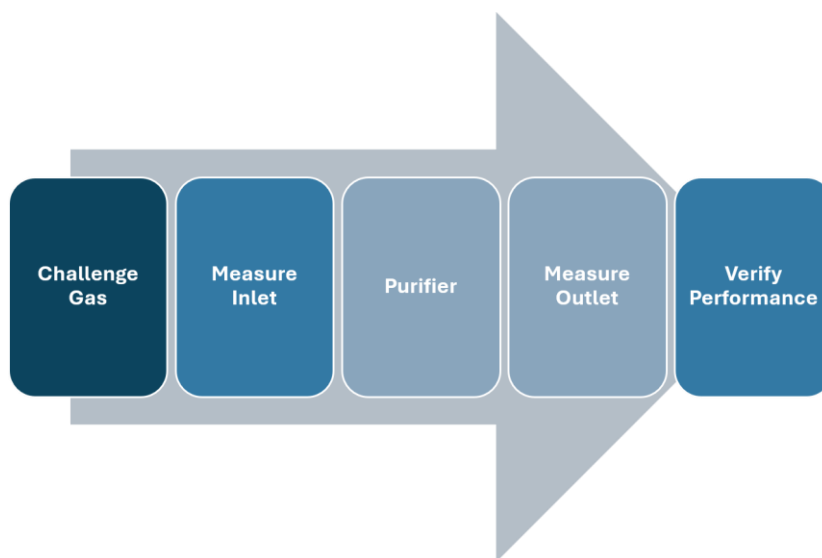


Figure 2. Purifier validation links analytical measurements directly to purification performance.

From ppb to ppt and ppq: Detection Capability Matters

At very low concentrations, analytical capability becomes closely linked to experimental design, sample handling, cleanliness, background contamination, matrix effects, and the detection limits of the selected method. We have published development work at the Longmont ATC involving hydrocarbon removal by NANOCHEM® INX-Plus™ to less than 426 ppq in inert gases.⁵

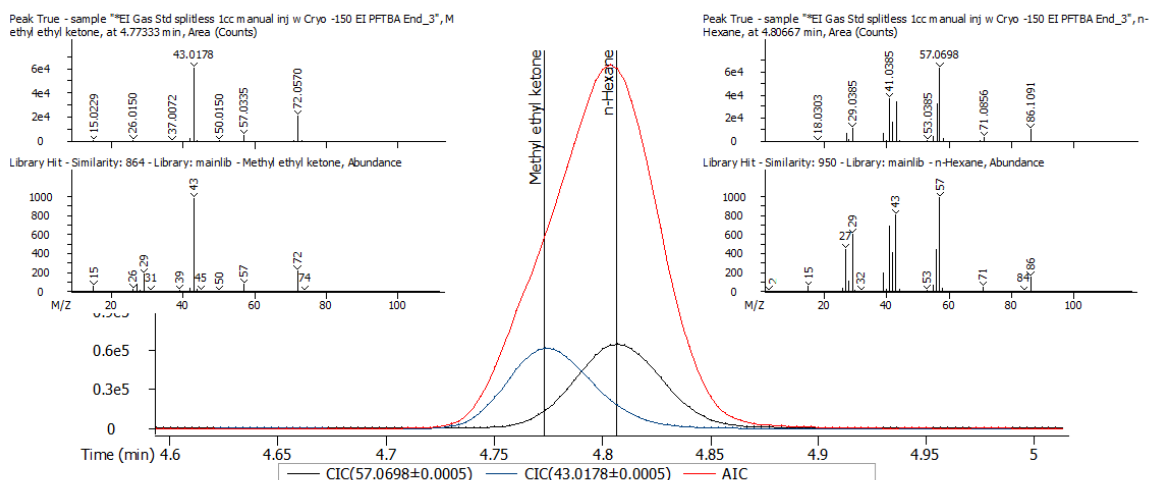


Figure 3: Application of state-of-the-art analytical techniques capable of resolving complex mixtures like methyl-ethyl ketone and n-Hexane using high resolution GCMS.

Analytics Is More Than Product Certification

For semiconductor customers, analytical capability can provide value beyond a Certificate of Analysis. An unexpected contamination signal can raise questions about the incoming material, packaging, delivery system, system components, purification performance, and concentration changes over time.



Figure 4: Application of state-of-the-art analytical techniques capable of detecting contaminants at ppt and ppb levels to support product development, quality assurance, and contamination investigations.

Our Longmont ATC has in-house characterization laboratories and testing facilities for assessing gases, purifiers, and gas-system components.¹

The source of a contamination problem does not necessarily respect boundaries between gas, container, purifier, component, and process tool.

Analytical Capability Across the Material Path

The analytical strategy can follow the same material path used to manage high-purity gas: from incoming material through purification, packaging, distribution, delivery components, and point of use.

Gas / Raw Material	Purification	Packaging	Distribution	Components	Point of Use	Process Tool
CHARACTERIZE → Identify and quantify impurities	MEASURE → Compare inlet vs. outlet purity	ASSESS → Evaluate material compatibility and contamination	MONITOR → Track impurities through the delivery system	EVALUATE → Identify contamination from valves, regulators and surfaces	VERIFY → Confirm gas quality where it matters	CORRELATE → Connect material quality to process observations

Figure 5: Analytical Approach for Identifying, Tracking, and Verifying Contamination Across the Semiconductor Gas-Delivery Chain

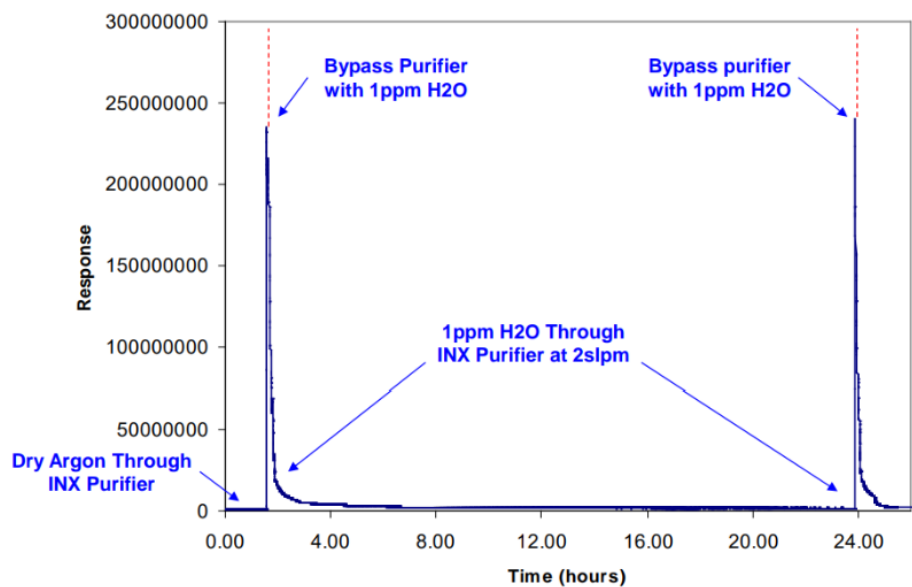


Figure 6. Analytical checkpoints can be applied across the gas and material path to support contamination-control investigations. Efficiency of the in-house developed NANOCHEM® purifier establishing moisture removal down to 100 PPT (or below). The plot shows excellent reproducibility of 1 ppm H₂O spiked Ar after 24 hrs.

Analytics Can Help Answer the “Why?”

Measurement tells us what is present. Technical problem-solving asks why it is present. Our Longmont based ATC has conducted work spanning pure gases, gas-handling equipment, micro-contamination studies, and purification technologies.¹

- **Detect:** What impurity is present?

- **Quantify:** At what concentration?
- **Localize:** Where is it being introduced?
- **Understand:** What mechanism could be responsible?
- **Mitigate:** Can purification, packaging, materials, or gas-handling changes address the source?
- **Verify:** Did the intervention reduce the impurity?

From Analytical Laboratory to Technology Partner

The value of semiconductor analytical capability is ultimately not the instrument. It is the solution to the problem that the instrument helps solve. NSM's deep technical know-how and global network connects expertise in purification, packaging, and analysis with materials and process development which encourages collaboration with strategic alliances, national laboratories, universities, and customers.³

What impurity are you trying to understand, and what is it doing to your process?

Can You Measure What Matters?

Advanced analytical capabilities provide the measurements needed to understand gas and materials purity, evaluate purification, investigate contamination sources, and support technology development. At Nippon Sanso Matheson, analytical science complements capabilities in semiconductor gases, purification, packaging, gas-handling equipment, and materials development.^{2, 3}



You cannot control what you cannot reliably measure.

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