Selecting the Right Gas Analyzer for Semiconductor and Industrial Manufacturing

Introduction

Residual gas analyzers (RGAs) are no longer just lab tools; they are essential to helping semiconductor fabs and industrial manufacturers run optimally. By monitoring and analyzing gas composition within vacuum systems, RGAs help ensure manufacturing quality and efficiency.

While today's RGAs focus on sensitivity, accuracy, and ease of use, not all are created equal. Selecting the right one depends on your application, goals, and requirements. This Technical Note serves as a guide to help users understand the basics and key differentiators of RGAs so the best instrument can be selected for each unique application.

How Does an RGA Work?

Residual gas analyzers measure the individual ion currents of gases in a mixture. In semiconductor manufacturing, an RGA can detect and quantify trace contaminants, such as water vapor or oxygen, that can compromise quality and affect output. By identifying contaminants early, RGAs can ensure the purity of the vacuum environment and quality of the final product.

An RGA system consists of three main components: a high-vacuum sensor that detects gases, electronics to control the device, and software that interprets and displays the data collected.

The Sensor

An RGA sensor comprises three critical parts:

1. **Ion Source**: The ion source contains a heated filament, made of either tungsten or yttria-coated iridium, which emits electrons that collide with gas molecules within the vacuum system, ionizing them and producing charged particles.
2. **Quadrupole Mass Filter**: The ions are then directed into the quadrupole mass filter, where they are sorted based on their mass-to-charge ratio, allowing only ions of specific ratios to pass through.
3. **Ion Detector**: The ions that pass through the quadrupole mass filter strike the ion detector. Upon impact, the ions are neutralized and generate a current that is proportional to the quantity of the gas component present, thereby identifying the specific gas.

This structured approach ensures precise and reliable analysis of gas compositions within vacuum systems, making the RGA an indispensable tool for various industrial applications.

The Electronics

The electronics modules are equipped with advanced electronics designed to enhance performance and reliability in demanding applications. Key features of the electronics include:

- **RF Stability**: The RF stability ensures consistent and accurate measurements by minimizing signal drift and noise, which is crucial for maintaining data integrity in environments with fluctuating conditions.
- **High-Precision Analog-to-Digital Converter**: INFICON RGAs utilize a high-precision analog-to-digital converter, translating analog signals into digital data with exceptional accuracy, essential for capturing detailed and reliable measurements for precise analysis of gas compositions.
- **Rapid Data Collection Speed**: The electronics are designed to support rapid data collection, enabling real-time monitoring and analysis, which is vital for applications requiring immediate feedback and adjustments, such as in semiconductor manufacturing and vacuum processes.
- **Versatile I/O Capabilities**: The electronics feature versatile input/output (I/O) capabilities, allowing seamless integration with various systems and devices, ensuring adaptability to different operational requirements and environments.

These advanced electronics are complemented by our intuitive system software, which simplifies integration and operation.

The Software

The RGA electronics module boasts a cutting-edge "smart sensor" design that efficiently processes the sensor's output for seamless integration with intuitive system software from INFICON and the user's external computer. This advanced software empowers users with real-time process monitoring, robust statistical process control, sensor automation, integration with equipment and factory systems, and streamlined maintenance procedures such as mass calibration, ensuring optimal performance and reliability.

As manufacturing continues to advance toward higher precision and complexity, real-time, high-resolution process insight is more critical than ever. Fault Detection and Classification (FDC) systems, enhanced by intelligent sensor integration, are redefining production efficiency and quality improvement. The FabGuard® FDC platform from INFICON—when combined with SmartFDC® AI/ML engines and SmartSensors™—exemplifies this evolution in modern process control.

Traditional tool-level data such as temperature, pressure, and recipe state are no longer alone sufficient to detect complex, subtle excursions that impact yield. FabGuard expands visibility by integrating hundreds of sensor types—including RGA, Optical Emission Spectroscopy (OES), Quartz Crystal Microbalances (QCM), and high-speed analog I/O devices—directly into its data acquisition framework. These sensors measure physical and chemical phenomena in real time, enabling accurate virtual metrology and fault detection directly related to wafer processing outcomes. SmartSensors extend this capability by incorporating intelligent signal processing and domain-specific models with sensor data regarding chamber chemistry and physics.

Integrating RGA sensor data with equipment and process data further enhances the power of FabGuard's process control. High-bandwidth RGA sensors obtain direct measurements of chamber chemistry and process dynamics. This provides synchronized, event-driven data streams for FabGuard's process control to leverage for:

- Real-time and run-by-run SPC and control
- Predictive maintenance (e.g., chamber clean endpoint monitoring)
- Yield-impacting excursion prevention (e.g., vacuum integrity issues, pressure drift)

As fabs pursue zero-defect manufacturing and adaptive, autonomous process control, sensor-driven FDC platforms like FabGuard with SmartFDC and SmartSensors form the foundation of the next-generation smart factory.

Why Use an RGA?

RGAs are indispensable tools in modern vacuum applications, offering a range of functionalities that enhance process control, quality assurance, and system integrity. Here are some key applications where RGAs excel:

- **Leak Detection**: The RGA performs chamber leak checks by continuously monitoring helium or other tracer gases. The software provides both audible and visual alerts when helium levels exceed a defined threshold.
- **Process Characterization and Background Monitoring**: The RGA characterizes the background environment of a process chamber. Once baseline levels are established, it monitors deviations, ensuring process consistency.
- **Process Monitoring**: The RGA offers real-time monitoring of processes and instantly reports any anomalies or deviations. Integration software can relay this information back to the system for immediate corrective action.
- **Contamination Control**: The RGA identifies unexpected and unwanted substances within the system. Utilizing a comprehensive library of known spectra, the software helps pinpoint and identify contaminants from various sources.
- **Process Control**: RGA data can be leveraged for process control. Setpoint relays, programmed to activate at specific partial pressures, can control valves while analog outputs can be integrated into Programmable Logic Controllers (PLCs) for automated adjustments.

Important Factors in RGA Selection

Before recommending or specifying an RGA, it's important to consider several key factors to ensure the best application.

Mass Range

The mass range determines which gases an RGA can detect. Sensors are specified by atomic mass unit (AMU), which defines the spectrum of ion masses that the RGA can detect and analyze. Semiconductor manufacturing may require detection of gases such as hydrogen (2 amu), helium (4 amu), water vapor (18 amu), nitrogen (28 amu), oxygen (32 amu), and argon (40 amu). An RGA with a mass range of 1–100 amu would be suitable for detecting these gases.

For accurate and comprehensive gas analysis, ensure the RGA covers the necessary mass range for the specific application.

Gas	AMU #	Gas	AMU #	Gas	AMU #
Hydrogen - H_2	2	Air	28	Carbon Dioxide - CO_2	44
Helium - He	4	Carbon Monoxide - CO	28	Propane - C_3H_8	44
Methane - CH_4	16	Ethane - C_2H_6	30	Butane - C_4H_{10}	58
Ammonia - NH_3	17	Silane - SiH_4	32	Nitrogen Trifluoride - NF_3	71
Water - H_2O	18	Oxygen - O_2	32	Pentane - C_5H_{12}	72
Neon - Ne	20	Hydrochloric Acid - HCl	36	Xenon - Xe	132
Hydrofluoric Acid - HF	20	Argon - Ar	40		
Nitrogen - N_2	28	Mechanical Pump Oil	43		

Sensitivity and Detection Limits

Sensitivity refers to the RGA's ability to detect small changes in gas concentrations within the vacuum system. High sensitivity is crucial for applications where trace contaminants can impact process or product quality. Detection limits indicate the lowest concentration of a gas that the RGA can detect with confidence.

Consider the specific gases and their expected concentration ranges for the application. Semiconductor manufacturing may require parts-per-billion (ppb) sensitivity, while other applications might need parts-per-million (ppm) sensitivity. The choice between a Faraday Cup (FC) and an Electron Multiplier (EM) detector depends on the sensitivity required. The FC is adequate for many applications, while the EM offers enhanced sensitivity for detecting trace gases at very low concentrations.

Operating Pressure Range

Standard RGA sensors typically operate at pressures lower than 10^{-4} Torr to ensure accurate and reliable gas analysis, as higher pressures can interfere with the ionization, ion filtering, and detection processes. High-pressure RGAs use advanced technologies to operate up to 2×10^{-2} Torr, making them ideal for applications with challenging vacuum conditions or the need for real-time monitoring at higher pressures.

If your system's operating pressure exceeds the standard threshold, a pressure-reduction method will be necessary to maintain the RGA sensor within an optimal vacuum range. A common approach is to use a pressure-reducing inlet, which employs a conductance-limiting technique. This method draws a sample through an orifice to the sensor, ensuring accurate measurements even at higher pressures.

Precision Redefined: INFICON Transpector® RGAs

The INFICON family of Transpector residual gas analyzers is engineered to meet the diverse needs of a wide range of industries. Whether for semiconductor manufacturing, vacuum coating, or research and development, INFICON RGAs deliver unparalleled performance and reliability for all your critical applications.

Transpector MPH/MPS | Open Ion Source – Standard & Long-Life Twister

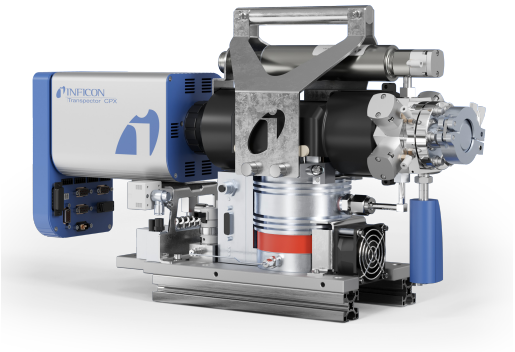
Experience unparalleled sensitivity with the INFICON Open Ion Source (OIS), available in multiple direct-immersion sensors. Engineered for high-vacuum environments, the OIS delivers exceptional performance with higher sensitivity. Designed for reliability, the standard OIS features dual filaments, ensuring continuous operation even if one filament fails—it's like having a "spare tire" for a system. For even greater efficiency, the Long-Life Twister OIS offers an extended filament lifetime, significantly increasing the time between maintenance cycles and maximizing uptime.

Transpector XPR3+ | High Pressure – (XPR)

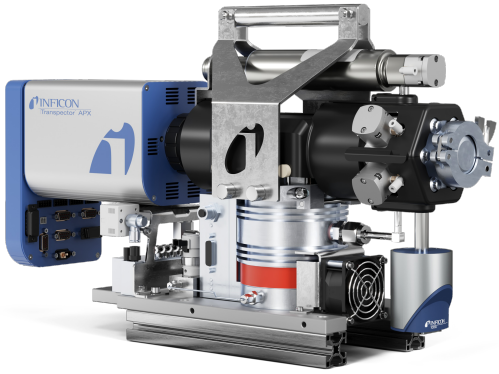
For applications requiring higher operating pressures, INFICON offers a high-pressure RGA, a direct-immersion sensor capable of operating at pressures up to 20 mTorr. Engineered for contamination resistance, this RGA features a dual ion source designed to withstand the challenges of sputtering pressure range applications.

Transpector CPX | Closed Ion Source

The INFICON Closed Ion Source (CIS) is available in multiple differentially pumped RGAs, designed for durability in higher pressure applications. When used with a pressure-reducing inlet, the CIS allows sampling from atmosphere to high vacuum while limiting interference from the pressure reduction system. Although it offers lower sensitivity, the CIS provides versatility and reliable performance when paired with a differentially pumped system, making it suitable for a wide range of applications.



Transpector APX | Harsh Chemistry



For harsh chemistry applications, INFICON offers a differentially pumped RGA, expertly designed to withstand corrosive environments while maintaining industry-leading precision. Featuring proprietary xParts coating, these robust sensors are perfect for demanding semiconductor processes such as ALD, CVD, PECVD, PVD, and etch.

Why the Right RGA Matters

Residual gas analyzers have evolved from specialized lab instruments into indispensable tools for semiconductor and industrial manufacturing. By providing precise, real-time insights into chamber chemistry, they enable fabs and manufacturers to safeguard quality, optimize processes, and maintain system integrity.

Selecting the right RGA ultimately comes down to understanding the operating environment, sensitivity requirements, and long-term goals. With solutions ranging from high-vacuum sensitivity to high-pressure durability, the INFICON Transpector family of RGAs delivers reliable performance across the full spectrum of applications. When paired with advanced platforms like FabGuard, RGAs don’t just monitor processes, they empower the next generation of smart, adaptive manufacturing.

Explore INFICON RGA Solutions

Contact INFICON today to learn more about how our solutions can improve your factory operations.

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