Entegris

Clean Gas Delivery Solutions

Reducing contamination and ensuring clean gas delivery through the full supply chain

Introduction

Semiconductor device yields have long been impacted by contamination. As process nodes continue to shrink below 5 nm, designs become more complex, process windows are narrowed, and sensitivity to contamination increases at all nodes. To address the requirements, gas purity must increase throughout the full supply chain to eliminate the chance of process excursions and improve device performance and reliability.

Three recent industry changes drive the need for holistic contamination control solutions:

MATERIALS EXPANSION CHALLENGES TIME-TO-YIELD AND DAILY YIELD NORMS

The introduction of new materials into the supply chain for semiconductor manufacturing can eventually make it easier to yield, but in the short term takes a significant amount of time and resources to optimize the process. By collaborating early in the materials introduction lifecycle, contamination control solutions can be designed to optimize the material and process, not simply accommodate it after-the fact. This approach can reduce the time to yield.

PROCESS COMPLEXITIES CHALLENGE DEVICE PERFORMANCE STANDARDS

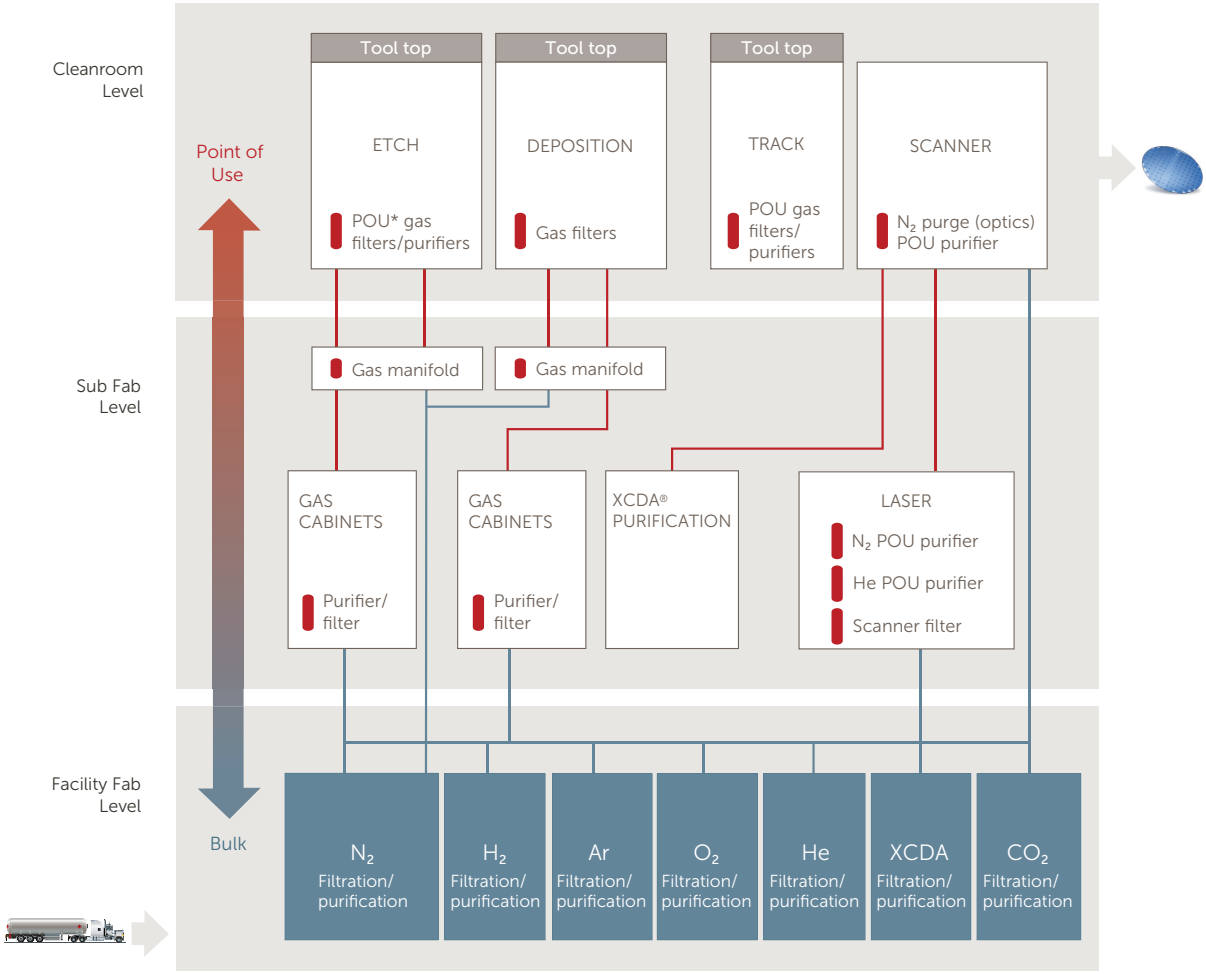
As process windows narrow and new materials are continually introduced, complexity increases. Being aware of the increase in complexity, and having the ability to anticipate it in advance, can aid in the design of contamination-control solutions that can maintain and improve device performance, while meeting increasingly strict standards.

CONTAMINANT SIGNATURES PRESENT UNIQUE CHALLENGES TO EACH PROCESS AREA

As complexity increases, so do the contaminants. At the intersection of new processes and materials, new contaminants will be created, with signatures that have yet to be discovered. These unique combinations of contaminants may be at levels that are undetectable or may not have been previously considered. By looking at your materials, equipment, and processes holistically, you provide the opportunity to identify potential contaminants before they are ever created, and further identify contamination-control solutions to address them.

Holistic Contamination-Control Solutions

When it comes to filtration and purification of air, bulk gas, or specialty gas, Entegris has the expertise, technology, and solutions to meet your needs. Whether you are trying to eliminate contamination in a chamber or on a wafer, outside the fab at the gas delivery pad, within the entire cleanroom, or only on top of a piece of equipment, Entegris has a long history of providing high-performance gas purification and filtration solutions to meet your needs.



*POU = point-of-use

Figure 1. Holistic view of contamination-control solutions.

Gas Purification

There are several drivers for innovation in gas purification:

- Ultrapure gas is required in advanced semiconductor manufacturing; "Ultra-high purity" grade gas is often not pure enough and/or delivers inconsistent outlet purity.
- Gas purification guarantees consistent gas purity.
- The list of desired contaminants removal is expanding, and desired outlet purity is getting more stringent.

Our innovative gas microcontamination control solutions effectively remove gaseous contaminants with high reliability, low cost of ownership, and high performance. Stand-alone gas purification systems offer in-situ regeneration with advanced control to meet your specifications. Our vast portfolio of gas purifiers and systems are designed to reduce gas quality variation while increasing lifetime and outlet purity. From bulk to specialty gas applications, you can rely on our wide array of reliable gas purification technologies to improve gas purity.

Table 1. Gas purifier technology comparison

	WHAT IT DOES	CAN BE COMBINED WITH
Heated getter	• Removes H_2O, CO, CO_2, H_2, CH_4, N_2 <0.1 ppb (process gas dependent)	Ambient adsorption
Heated catalyst	• Converts H_2, CH_4, and CO into H_2O and CO_2 in nitrogen, oxygen, and rare gases • Converts O_2 into H_2O in hydrogen streams	Ambient adsorption
Ambient temperature adsorption	• Removes H_2O, O_2, CO, CO_2, NMHCs <1 ppbV • Removes acids, organics, refractories <1 ppt in XCDA • Removes acids, organics, and refractories <5 ppt in bases • Removes acids, organics, and refractories <100 ppt for H_2O	—
Cryogenic temperature adsorption	• Removes H_2O, CO, CO_2, CH_4, N_2, Ar to <0.1 ppbV from hydrogen	—
Palladium separation	• Removes H_2O, O_2, CO, CO_2, N_2, He, Ar, and THC from hydrogen	—

Table 2. Comparison of purifier technologies under general conditions

This table provides general purification conditions. Purifiers based on the same technology but made by different manufacturers could have different specifications.

Technology	Inlet gas purity	Impurities removed	Impurities not removed	Flow range	Operating temperature	Pressure drop	Maintenance	Comment
Adsorber	5 nines	O_2, H_2O, CO, CO_2, HC>C_5, NO_X, S	N_2, CH_4, rare gases	0.1 – 120 m³/h	Room temperature	Low	Regeneration every 1 – 3 years	The better the inlet gas purity, the longer the lifetime Less expensive technology with limited performance
Regenerable adsorber	4.5 nines	O_2, H_2O, CO, CO_2, HC>C_5, NO_X, S	N_2, CH_4, rare gases	10 – 1,000 m³/h	Room temperature	Low	None	Suitable for very high flow rate Low running cost No N_2 removal
Getter	6 nines	O_2, H_2O, CO, CO_2, N_2, CH_4, NO_X, S	Rare gases	0.1 – 300 m³/h	300° – 600°C (572° – 1112°F)	Low	Getter column replacement every 3 – 8 years	Good when the gas is relatively clean Removes all impurities, N_2 included
Cryogenic	4 nines	O_2, H_2O, CO, CO_2, N_2, CH_4, NO_X, S	He	20 – 1,000 m³/h	-180°C (-292°F)	Low	None	Requires complex infrastructure to manage liquid N_2 High running cost Removes all impurities except He Competitive for high flow rates
Palladium membrane	3.5 nines	O_2, H_2O, CO, CO_2, N_2, CH_4, rare gases, NO_X, S	None	0.1 – 100 m³/h	400°C (752°F)	High	None	Removes all impurities, rare gases included Very compact Compatible with high inlet gas purity Sensitive to S contamination
Supported palladium membrane	3.5 nines	O_2, H_2O, CO, CO_2, N_2, CH_4, rare gases, NO_X, S	None	0.1 – 500 m³/h	400°C (752°F)	Medium-low	None	Removes all impurities, rare gases included Very compact Compatible with high inlet gas purity Sensitive to S contamination

Getter Purifiers

Getter purification technology is widely used for the purification of hydrogen based on zirconium alloys. The capacity of a getter column is much higher than the capacity of an adsorber column of the same volume.

HEATED GETTERS

GateKeeper® HGU heated getter purifiers are ideal solutions for point-of-use purification where CH_4 or N_2 removal is required. Getter technology allows irreversible chemical absorption of impurities to sub-ppb levels. Five different sizes are available for flow rates from 1 sccm to 150 slpm.

Heated Catalysts

When used in conjunction with ambient temperature adsorption technology, purifiers that utilize heated catalysts can remove H_2, CH_4, and CO in nitrogen, oxygen, and rare gas streams by converting them into CO_2 and H_2O and capturing it downstream. Heated catalysts can also be used to remove O_2 from hydrogen streams by converting it into H_2O.

HEATED CATALYSTS

MegaTorr® PS6 and PS9 gas purifiers efficiently remove numerous impurities with high reliability, low cost, and high performance. The PS6 design is optimized to provide sub-ppb performance in small footprints with flow rates up to 16,667 slpm and the PS9 design provides sub-ppb performance when higher flow is required, up to 200,000 slpm.

Adsorber Purifiers

Adsorber purifiers consist of a cylindrical column filled with high surface area materials that are suitable for the chemisorption and physisorption of impurities.

ADSORBERS

Our GateKeeper® GPU ambient in-line purifiers are designed to improve purity consistency, lifetime, and final purity. Leveraging our expertise in material science, we have developed a new generation of purification products that deliver unsurpassed value and performance. Our comprehensive portfolio is available with flow rates from 1 slpm to 2000 slpm.

Cryogenic Purifiers

In the cryogenic purification of hydrogen, stream is cooled down to cryogenic temperatures through a column filled with a high-surface media. All impurities, except helium, are trapped by the cryogenic column. A cryogenic purifier uses two columns in parallel so that one is in operation while the other is under regeneration.

CRYOGENIC PURIFIERS

MegaTorr® cryogenic hydrogen gas purifiers use an adsorption process to provide ultra-high purity hydrogen gas for semiconductor applications. Two adsorber vessels alternate between purify and regeneration modes, providing continuous purification. Our optimized design provides sub-ppb performance in small footprints with flow rates up to 16,667 slpm.

Palladium Separation

Our advanced palladium gas purifiers offer two to three times higher capacity than other models, with lower cost of ownership and improved durability for high-volume manufacturing processes.

PALLADIUM HYDROGEN PURIFIERS

Palladium hydrogen purifiers produce the purest hydrogen on the planet. Only hydrogen is able to pass through the palladium membrane, while all other impurities travel out the bleed line. This patented micro-channel palladium membrane technology removes all impurities to below part-per-billion (ppb) levels. Our PD Series H_2 gas purifiers efficiently remove H_2O, O_2, CO, CO_2, H_2, THC, N_2, He, and Ar at flow rates of up to 2,170 slpm.

Regeneration Services

Entegris provides an easy way to recycle your gas purifiers. Recycling can save you money and lower your cost of ownership. And recycling is not only environmentally friendly, it also extends your purifier warranty.

REGENERATION SERVICES

To help keep contamination from reaching your process, we offer easy access to our gas purifier regeneration services. Regeneration is the process of removing impurities from a saturated gas purifier. The regeneration process eliminates all contamination, and the lifetime after regeneration is identical to a new gas purifier. Regenerating your purifier can save you between 30% and 70% of the cost of a new purifier, contributing to lower cost of ownership.

Gas Filtration

Entegris offers an extensive selection of ultrapure gas filtration products to enable ultra-high purity gas processes. Our gas filter portfolio includes in-line and surface-mount, PTFE, nickel, stainless steel, and alloy-22 product families that provide contamination control by removing particles greater than 0.003 µm in ultrapure gas applications. We also offer gas diffusers for rapid venting to atmosphere.

Table 2. Gas filter membrane material comparison

GAS FILTER PROPERTIES	PTFE	NICKEL	STAINLESS STEEL 316L	HASTELLOY® A-22
Particle retention	+	=	–	=
Pressure/heat resistance	–	=	=	=
Pressure drop	+	=	=	=
Chemical compatibility	+	–	=	=
Corrosion resistance	=	=	–	=

Key: + *Best* = *Equal* – *Worst*

In-line Gas Filters

Entegris in-line gas filters improve process efficiencies and lower cost of ownership by enabling higher process gas throughput while reducing the overall gas box footprint.

IN-LINE STAINLESS STEEL GAS FILTERS

All-metal, Wafergard® in-line stainless steel gas filters are ideal for use in high-pressure and high-temperature applications such as diffusion, annealing, and epitaxy. The compact size and flexible choice of fittings provides ultimate design efficiency and minimizes engineering costs. Designed for flow rates ranging from 30 slpm to 500 slpm, they are easy to install without requiring design changes.

In-line Gas Filters (continued)

IN-LINE PTFE GAS FILTERS

Entegris offers various polymer membrane gas filters for ultrapure particle removal in lower temperature applications. We offer in-line PTFE gas filters that are compatible with all semiconductor high-purity process gases, as well as inert gases, and clean dry air (CDA). Choose from a variety of Wafergard and Linegard™ gas filter configurations with flow rates from 30 slpm to 1500 slpm to meet your specific application needs.

IN-LINE NICKEL GAS FILTERS

Entegris offers the cleanest and most efficient ultrapure, in-line nickel gas filters for high-pressure, high-temperature applications. The nickel membrane offers superior corrosion resistance and excellent compatibility in inert and reactive gas applications. Our portfolio includes flow rates from 30 slpm up to 6000 slpm to meet your bulk gas application needs.

IN-LINE ALLOY-22 GAS FILTERS

Wafergard IV alloy-22 filters (commonly referred to by the brand name HASTELLOY C-22® alloy) are the cleanest, most efficient, all-metal filters available for corrosive and ultrapure environments. The alloy-22 membrane offers the most inert and reactive gas compatibility in our Wafergard product line. Ideal for filtering carbon monoxide, hydrogen bromide, chlorine, and other corrosive gases.

Surface-mount Gas Filters

Entegris surface-mount gas filters have a compact, space-saving design with high flow rate characteristics that are ideal for use with process and purge gases.

SURFACE-MOUNT GAS FILTERS

Available with stainless steel or nickel filter elements, Wafergard surface-mount gas filters provide ultimate process protection, superior corrosion-resistance, and excellent compatibility with inert, hydride, and reactive gases. The surface-mount design consumes less space on gas panels and reduces parts inventories and variations.

Gas Diffusers

Entegris gas diffusers are compatible with most system designs for easy installation or retrofit into load lock chambers, cooling chambers, transfer chambers, and process chambers.

GAS DIFFUSERS

Chambergard™ fast vent diffusers provide rapid venting to atmosphere without disturbing or adding particles in the chamber, increasing system throughput by minimizing load lock vent cycle times. They combine the flow characteristics of a diffuser with a high-efficiency filter to increase efficiency and throughput.

Clean Gas Delivery Through the Full Supply Chain

As a world leader in gas filtration and purification technology, Entegris is in a unique position to help you maintain a clean gas delivery environment with contamination-controlled solutions that will increase product yield and reduce contamination of process gases. Our end-to-end portfolio of gas solutions are less prone to variation and process excursions, and improve device performance and reliability while helping you maintain a clean environment through the full supply chain.

We help customers improve their device performance and reliability by providing solutions less prone to variation and process excursions.

Why Entegris?

As mega-trends such as artificial intelligence, smart cars, the Internet of things, and augmented reality evolve to meet the growing needs of speed, scale, and reliability, they put pressure on integrated device (IC) manufacturers to increase processor power efficiency and memory size. As device manufacturers strive to produce higher performing chips with more complexity and component integration at acceptable efficiencies and yields, they face significant challenges in terms of process control and economics.

With our broad portfolio of microcontamination control, advanced materials handling, specialty chemicals, and engineered materials, we are uniquely positioned to help customers face these challenges and meet these new worldwide consumer and business data demands at lower costs. Ongoing investments in technology, robust manufacturing, and supply-chain capabilities make us a proven, trusted partner. Our global infrastructure, technology portfolio, and operational excellence are unmatched by the competition. Investments in newer and purer materials enable us to provide the cleanest and most reliable polymer solutions to protect your overall process quality and efficiency.

Proven Quality and Performance

At Entegris, we have a relentless commitment to operational excellence. Our desire to be a relevant, trusted, technology partner drives us to identify complex problems critical to our customers, quickly develop a working solution, and move seamlessly from pilot to high-volume manufacture (HVM). In our pursuit to be the best performing operational platform in our market, we have aligned our quality systems to industry requirements and provide capabilities to meet/exceed customer expectations.

Motivated to supply consistent and predictable product performance to customers, reduce quality excursions, and minimize scrap, we have invested in advanced statistical process control (SPC) systems across all our manufacturing sites around the world. Integrated SPC provides immediate recognition of special variation causes enabling faster problem resolution, providing early quality alerts, and allowing easier decision-making to ensure process consistency and minimize product variation.

Customer requirements are demanding so we are always striving for practical, quantifiable, sustainable continuous improvement. By employing lean Six Sigma techniques and tools, we identify and remove the causes of process defects that enable us to improve quality. By minimizing variability in manufacturing and business processes, our DPPM (defective parts per million) performance has also dramatically improved.

Ensuring product performance standards are met, proven techniques such as ISO 9001 certified manufacturing sites, documentation control, and quality testing are utilized. Each manufacturing capability has been developed, tested, and improved to create pure, durable, consistent, and reliable products.

- Membrane development
- Media development
- Ultrapure cleaning
- Molding
- Extrusion
- Tool design/making
- Welding and flaring
- Overmolding
- Prototyping
- Machining

With nearly 2,000 issued U.S. and foreign patents, we have the expertise to develop process knowledge and products that enable innovation and efficiencies. Combining advanced engineering and design expertise with tools such as Finite Element Analysis (FEA), Computational Fluid Dynamics (CFD), and MoldFlow® analysis and modeling enables us to optimize product design and speed technological advancements. In addition to innovative design, we also use R&D and quality lab analysis and testing capabilities to develop dependable solutions.

QUALITY TESTING

- Vibration and shock
- Safety and industry standardization
- Trace metals
- Electrostatic charge

PERFORMANCE TESTING

- Particle testing
- Flow rate optimization
- Ion chromatography
- Failure analysis

We are dedicated to developing the purest products that assist in your goal for zero defects, and gain you the greatest operational efficiency.

Sales and Applications Support

Entegris continually invests in expanding analytical and technology center capability globally. Our global direct sales team, sales channel partners, local applications engineers, and world-class customer service give you the support and expertise to solve your most difficult problems. This intimacy allows us to better understand your needs through direct feedback and roadmap sharing. By aligning our materials science, engineering, and R&D initiatives, we can develop indispensable contamination-control and high-performance solutions to solve your roadmap challenges.

eCommerce

Entegris has deployed an online purchasing and transaction management system that provides full eCommerce capabilities for our customers. For us, eCommerce is more than just a shopping cart, but rather a robust technology platform designed to deepen customer engagement and deliver value at every touchpoint. Driven by our customers' desire for lower costs, improved accuracy, and overall increased satisfaction, we have implemented state-of-the-art tools and full integration with our back-end systems to allow automated access to information, accelerated and easier transactions, and a convenient means to collaborate and do business.

Logistics Expertise

To support your logistics requirements, we manage the infrastructure and service provider partnerships, offering broad capabilities to ensure your supply chain door to door. Providing import processing, insurance, and transportation, we bring expertise in air, ocean, LTL, intermodal, small package, and hazardous shipments. You will receive in-house, regional logistic support in the U.S., Germany, Israel, South Korea, Japan, Taiwan, Malaysia, Singapore, and China. And our top-ranked freight partners provide import processing services and transportation to all the remaining locations around the globe.

Our global infrastructure with local R&D, manufacturing, and support focuses on specific customer needs throughout the world.

Corporate Social Responsibility

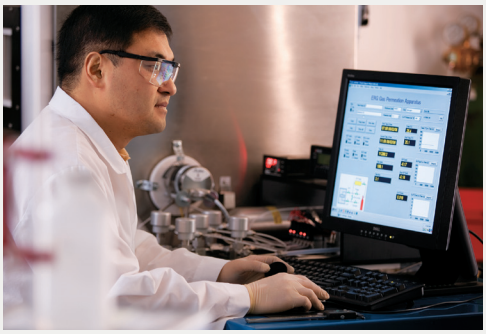
Entegris has a strong commitment to Corporate Social Responsibility and seeks to create value responsibly. We balance the demands of doing business with the need to protect the environment and its resources and to ensure the health and safety of our employees, customers, and the communities in which we work and live.

We are committed to applying these principles to product stewardship, environmental protection, employee health and safety, and plant security. In addition, we are committed to aligning our operations with the Electronic Industry Code of Conduct (EICC). Our new product development process is mindful of Department for Education (DfE) principles to ensure new designs meet customer and governmental material content restrictions, such as PFOA elimination, conflict minerals, and banned substances. We also work on developing strong relationships with our suppliers to ensure their commitment to EICC principles and product material content.

Experience You Can Count On

Contamination control is critical to your manufacturing processes and has a direct impact on production yields, product reliability, and operational efficiency. We focus on understanding your processes, sources of contamination, and on developing material-enabled solutions to ensure the cleanliness and integrity of those processes. We invest in identifying where impurities may be introduced, and take corrective actions to prevent them, which is a critical first step in contamination reduction efforts.

Trust us to support your vital applications and goal for zero defects by providing the highest purity, highest quality, and most robust products. Our reliable, cost-effective liquid filters and purifiers provide a line of defense to prevent defect-causing contaminants in current and new technology nodes.



Our ability to innovate new technologies is based on our deep knowledge of materials science and analytics.

LIMITED WARRANTY

Entegris' products are subject to the Entegris, Inc. General Limited Warranty. To view and print this information, visit entegris.com and select the Legal & Trademark Notices link in the footer. Entegris does not warranty any failure in the case of customers using unapproved foreign components.

FOR MORE INFORMATION

Please call your Regional Customer Service Center today to learn what Entegris can do for you. Visit entegris.com and select the Contact Us link to find the customer service center nearest you.

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Entegris

Corporate Headquarters
129 Concord Road
Billerica, MA 01821
USA

Customer Service
Tel +1 952 556 4181
Fax +1 952 556 8022
Toll Free 800 394 4083