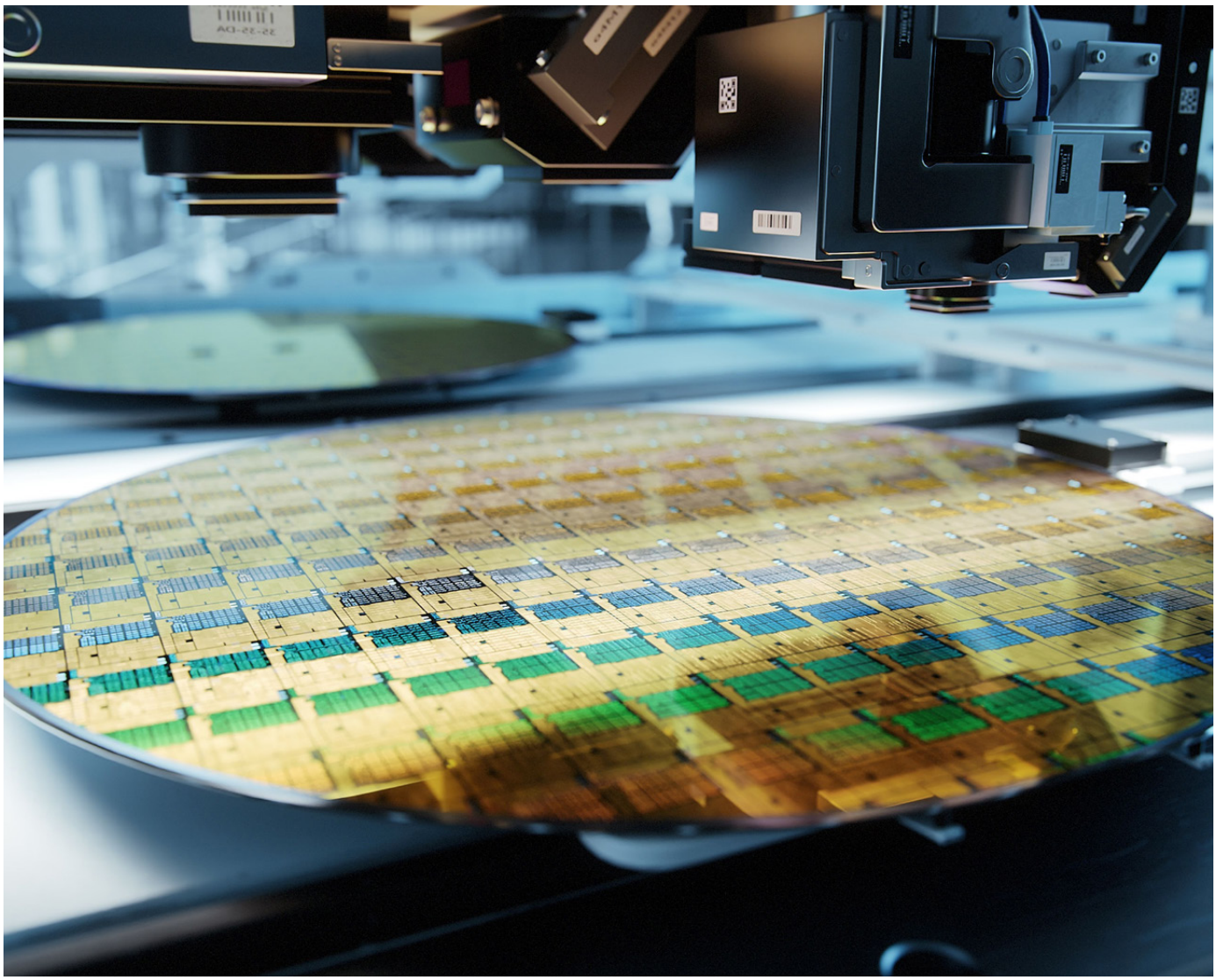
Molecular filtration for semiconductor cleanrooms



Leadership in Filtration

MANN+HUMMEL

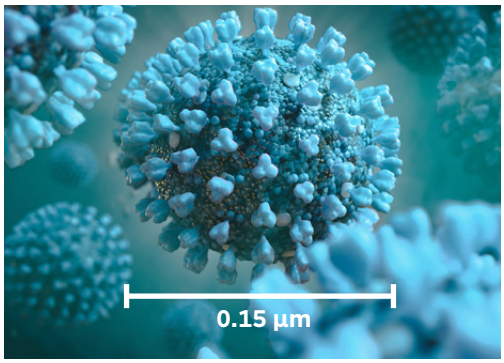
The dangers of molecular contamination

A SPECIALIST SUBJECT

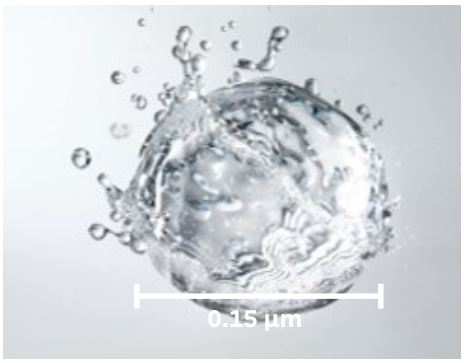
Whether the impurity is a particle or gas, airborne contaminants can have costly and wide-reaching impacts in semiconductor cleanrooms – compromising product quality, damaging machinery and equipment, reducing yield, and endangering the safety of workers.

But, while the impact may be the same, capturing gaseous contaminants is very different to particulate filtration. The particles that pose a threat in a cleanroom are typically microscopic in size. The gaseous contaminants are several trillion times smaller than that.

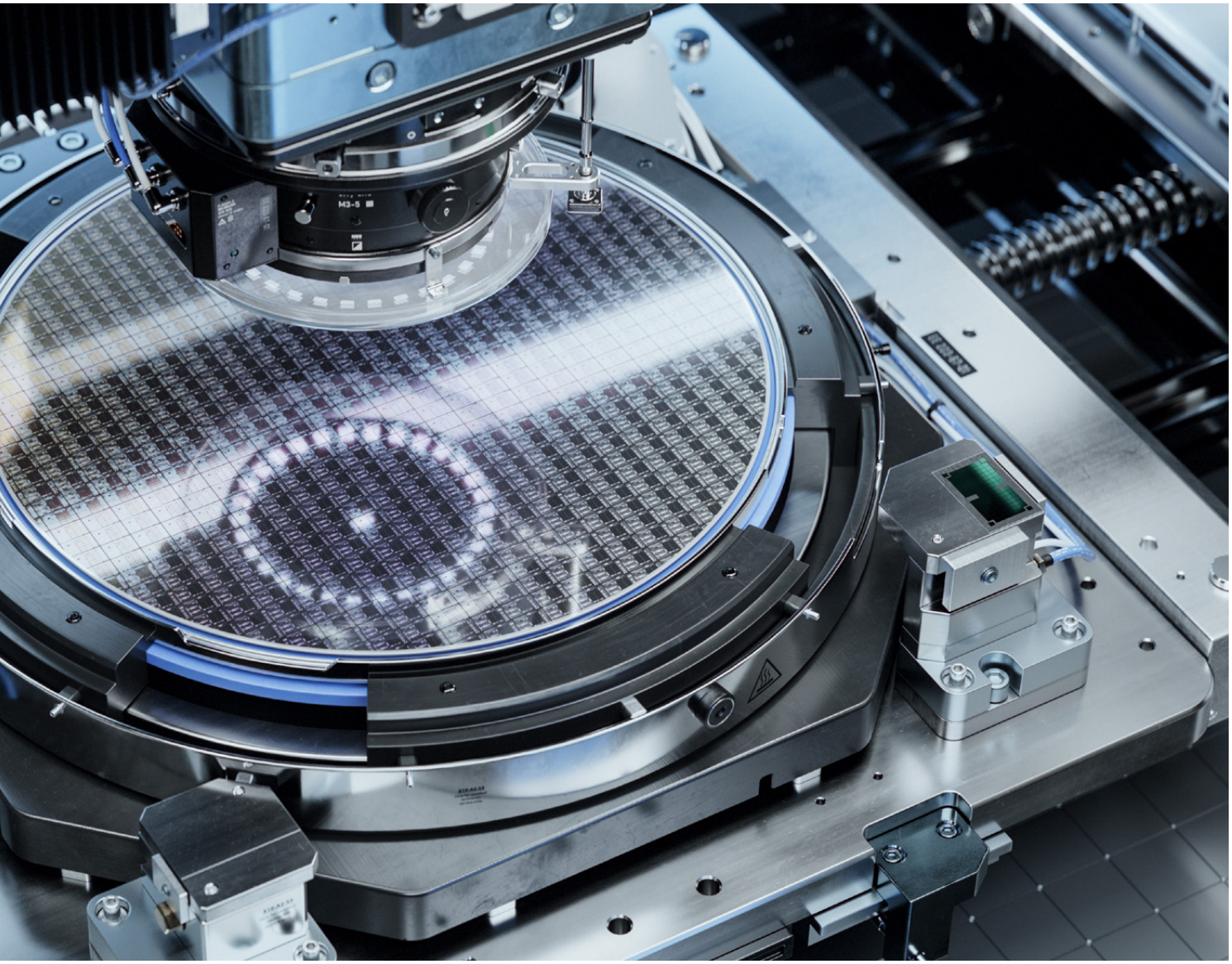
That's why it's crucial to work with a partner that understands the challenges and processes of molecular filtration completely.



A single coronavirus is around 0.15 micrometers in diameter – around 600 times smaller than a human hair.



A drop of water 0.15 micrometers in diameter contains around 14,000,000,000,000 H_2O molecules.



MANN+HUMMEL is one of the world's leading manufacturers of activated carbon filter media and a cleanroom specialist for over 60 years.

LEADERSHIP IN FILTRATION

The air entering your cleanroom is an evolving, but continuous mass. While molecular filtration is a specialist subject, it must be part of a joined-up and integrated air delivery system that targets all contaminants.

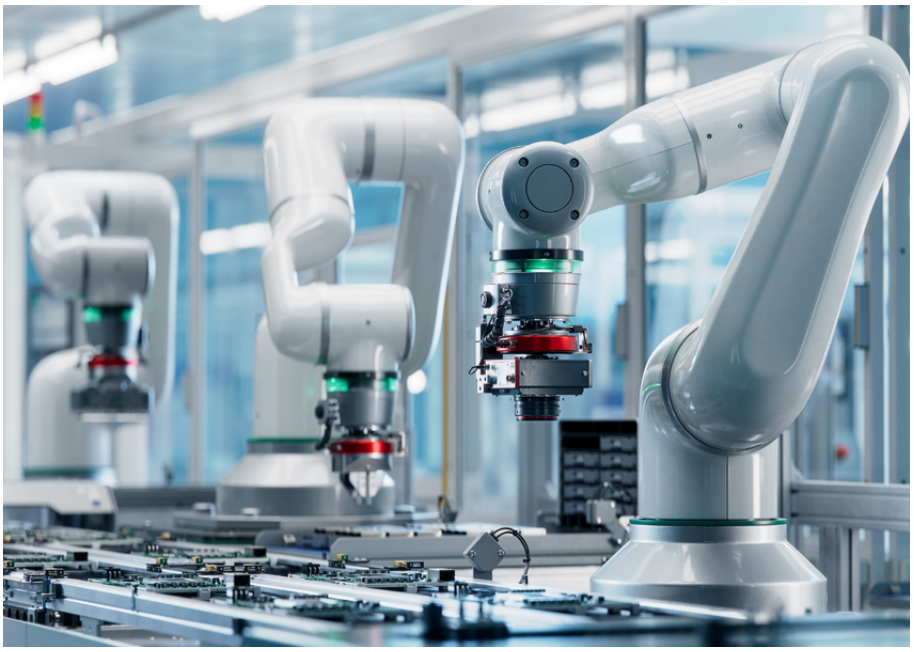
MANN+HUMMEL is a true filtration leader. We have the molecular know-how, but also the scale, experience and geographical reach to deliver an air filtration system that can help improve your outcomes and meet your performance goals.

Airborne molecular contamination (AMC)

WHAT IS AMC?

AMC appears in the form of gases, vapors or aerosols. The chemical nature can be organic, inorganic, or mixed. It plays an increasingly important role in cleanroom processes.

AMC can be detrimental to many processes, people, and products, causing corrosion, condensation, contamination of the final product, odors and health hazards.



AMC can easily find it's way to the surfaces of hardware, optical components, semiconductor devices, and more.

SOURCES OF AMC

AMC arises from an almost endless and often unexpected range of sources. Key sources include:

People	Outdoor air	Manufacturing processes	Accidental spillage	Solvents: cleaning, lithography
Outgassing of equipment and materials	Emissions from process equipment	Contamination across production areas	Storage areas for chemicals and materials	Wet cleaning, wet and dry-etching processes

What's the risk for semi-conductor cleanrooms?

SEMICONDUCTOR TRENDS

As semiconductor device geometry continues to decrease to 10 nm or smaller, components are miniaturized further and spaced together more tightly – and new materials are being adopted to facilitate this.

All of these changes increase both the risk and extent of damage that chemical contamination can cause in a semiconductor cleanroom.

On the manufacturing side, activities like the continuous improvement of hardware performance and sustainability initiatives, also make hardware more sensitive to attack by corrosive particles and gases.

As these trends continue, controlling molecular contamination is vital to ensure product quality and yield remain high, while also enabling new technologies to flourish.

PRODUCT QUALITY

Airborne molecular contamination can impact almost all aspects of submicron device fabrication – from overall fab operation to the performance of the final device.

Manufacturing errors
Contamination of lithography processes, often in the form of condensation on reticles and lenses, can cause image errors and performance reductions of optical systems.

Surface contamination can cause etch rate shifts, high contact resistance, shorts, spotting, electroplating defects, and delamination.

Contamination of the product
Molecular compounds can easily deposit on the surface of products leading to the failure of components – such as circuit boards, gold and nickel connections, processors, and drives.

Condensation of certain AMC substances on product surfaces can also cause direct damage to the final device. For example, the condensation of sulfur dioxide (airborne acid) and ammonia (airborne base) on silicon wafers, in combination with humidity, generates microscopically small crystals of ammonia sulfate (time-dependent haze).

DAMAGE TO MACHINERY AND EQUIPMENT

And it's not just product quality at stake. Molecular contamination can short circuits and create ghost signals in machinery and equipment. This not only means expensive repairs, but also downtime and the risk of electrical fires too.

Effective protection against airborne molecular contaminants is essential for both product yields and process safety.

SEMI F21-1016

SEMICONDUCTOR AMC CLASSIFICATION

SEMI F21-1016 classifies microelectronics clean environments in respect of their molecular contaminant levels. The classification provides a consistent way of establishing acceptable levels of various molecular contaminant groups.

Each category is designated by the letter 'M,' followed by the first letter of the category name A, B, C, D or M. The integer following the category designator indicates the maximum total gas phase concentration in parts per trillion (ppt 1 × 10-12).

For example, a category MA-10 has a maximum allowable total concentration of 10 parts per trillion for the category of interest.

SEMI F21-1016	CONCENTRATION IN PARTS PER TRILLION				
	1	10	100	1,000	10,000
Acids	MA-1	MA-10	MA-100	MA-1000	MA-10000
Bases	MB-1	MB-10	MB-100	MB-1000	MB-10000
Condensables	MC-1	MC-10	MC-100	MC-1000	MC-10000
Dopants	MD-1	MD-10	MD-100	MD-1000	MD-10000
Metals	MM-1	MM-10	MM-100	MM-1000	MM-10000

SEMI F21-1016 indicates the maximum allowable gas phase concentration of each material.

TYPICAL GASES (DERIVED FROM THE WORK OF THE GASES GLOBAL TECHNICAL COMMITTEE)

Acids	Bases	Condensables*	Dopants	Metals**	
▪ Hydrofluoric acid (HF) ▪ Sulfuric acid (H_2SO_4) ▪ Hydrochloric acid (HCl) ▪ Nitric acid (HNO_3) ▪ Phosphoric acid (H_3PO_4) ▪ Hydrobromic acid (HBr)	▪ Ammonia ▪ N-Methyl-2-pyrrolidone (NMP) ▪ Triethylamine (TEA) ▪ Trimethylamine (TMA) ▪ Tetramethylammonium-hydroxide (TMAH) ▪ Cyclohexylamine ▪ Diethylaminoethanol ▪ Methylamine ▪ Dimethylamine ▪ Morpholine	▪ Silicones (from sealants, O-rings, lubricants) ▪ Hydrocarbon ▪ Plasticizers ▪ (from floor tiles, vinyl materials, gloves)	▪ Boron (usually as boric acid) ▪ Phosphorous (usually as organophosphates) ▪ Arsenic (usually as arsenates)	▪ Al ▪ Cu ▪ W ▪ Li ▪ Na ▪ K ▪ Mn ▪ Mg ▪ Co ▪ Cr ▪ Pb ▪ Mo ▪ Ni	▪ Sn ▪ Zn ▪ V ▪ Ti ▪ Zr ▪ Hf ▪ Bi ▪ Nb ▪ Sr ▪ In ▪ Ge ▪ La

*Condensables as defined by SEMI (boiling point >150 °C)

**Not in metallic form, but as volatile chemical compounds

Acids – MA

Molecular acids mainly comprise of hydrofluoric acid, hydrochloric acid, sulfuric acid and nitric acids. Acids in clean environment have detrimental effects in semiconductor manufacturing such as thin film defects, high contact resistance, corrosion of metallic films etc.

Bases – MB

Molecular bases mainly comprise of ammonia, amines and amides. Bases in clean environment have similar negative effects as molecular acids.

Condensables – MC

Molecular condensables include plasticizers, antioxidants, phosphates and silicones. Condensables can cause gate oxide integrity problems, delamination of thin films and hazing of optics and masks used in lithography tools.

Dopants – MD

Molecular dopants in cleanroom air are a result of reaction of acids with borosilicate glass used in HEPA and ULPA filters. They also originate from the flame retardants such as TEP (triethyl phosphate) used in filtration systems.

Metals – MM

Molecular metals comprise of elements such as Al, W, Mn etc. that may be byproducts of reaction chemistries utilized in semicon manufacturing. Increasing use of organometallic precursors in processes, such as atomic layer deposition (ALD), will likely contribute to increased presence of molecular metals in clean environments.

Your partner against molecular contamination

For more than 60 years, our filters have been in service in cleanrooms around the world – protecting people, processes and the wider environment from some of the most challenging contaminants known to man.

With every second that ticks by, another 26 filters roll off the MANN+HUMMEL production lines. And that is part of what makes us a world leader in filtration.

But it is our commitment to quality and innovation too. Of the 22,000 people we employ worldwide, over 1,000 work in our R&D department.

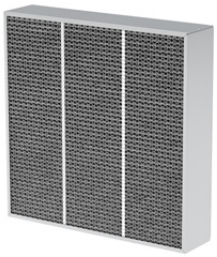
That means we are at the front when it comes to finding new ways to improve air quality or deliver it more efficiently – which can be seen in the more than 3,000 patents that we have registered.

And when it comes to delivering excellent service, we are always close at hand, with more than 80 locations across the world.

Solutions as individual as your requirements

MANN+HUMMEL‘s molecular air filter product range features a large variety of specialist physical and chemical activity options, and also standard, plug n‘ play formats. If you have a high flow rate, non-standard application that requires a special molecular filtration stage, please contact your local MANN+HUMMEL representative and we will be glad to help you.

Our Carboactiv range



Carboactiv Panel
Pleated molecular panel filters

Filter panels for cleanroom ceilings, fan filter units, mini-environments or process equipment. Panels features low outgassing and high cleanliness.

Carboactiv Cube
4V molecular compact filters

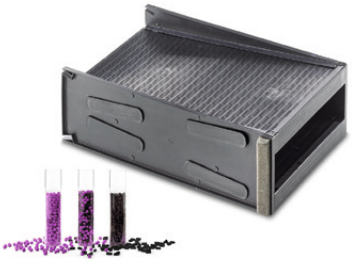
Offering particle and gas filtration in one filter, Carboactiv Cube provides high structural stability and can be installed in standard filter frames.

Carboactiv Honeycomb
Versatile filters with square channels

Our honeycombs are available in virtually any geometric shape, and provide exceptionally high adsorption capacities and low pressure losses.

Carboactiv Cartridge
Refillable steel or plastic cartridges

Used for the control of odors and corrosive gases in supply and exhaust air, our cartridges combine simple maintenance with excellent sealing.



Carboactiv Module
V-shaped plastic modules

Carboactiv Modules can be filled with a variety of activated carbons to provide extremely high adsorption capacities and long contact times.

Carboactiv Drum
High capacity drum scrubbers

Providing longer contact times to remove high AMC concentrations, Carboactiv Drum can be fitted with an integral fan and/or demister.

Carboactiv Fill
Pelletized molecular filtration media

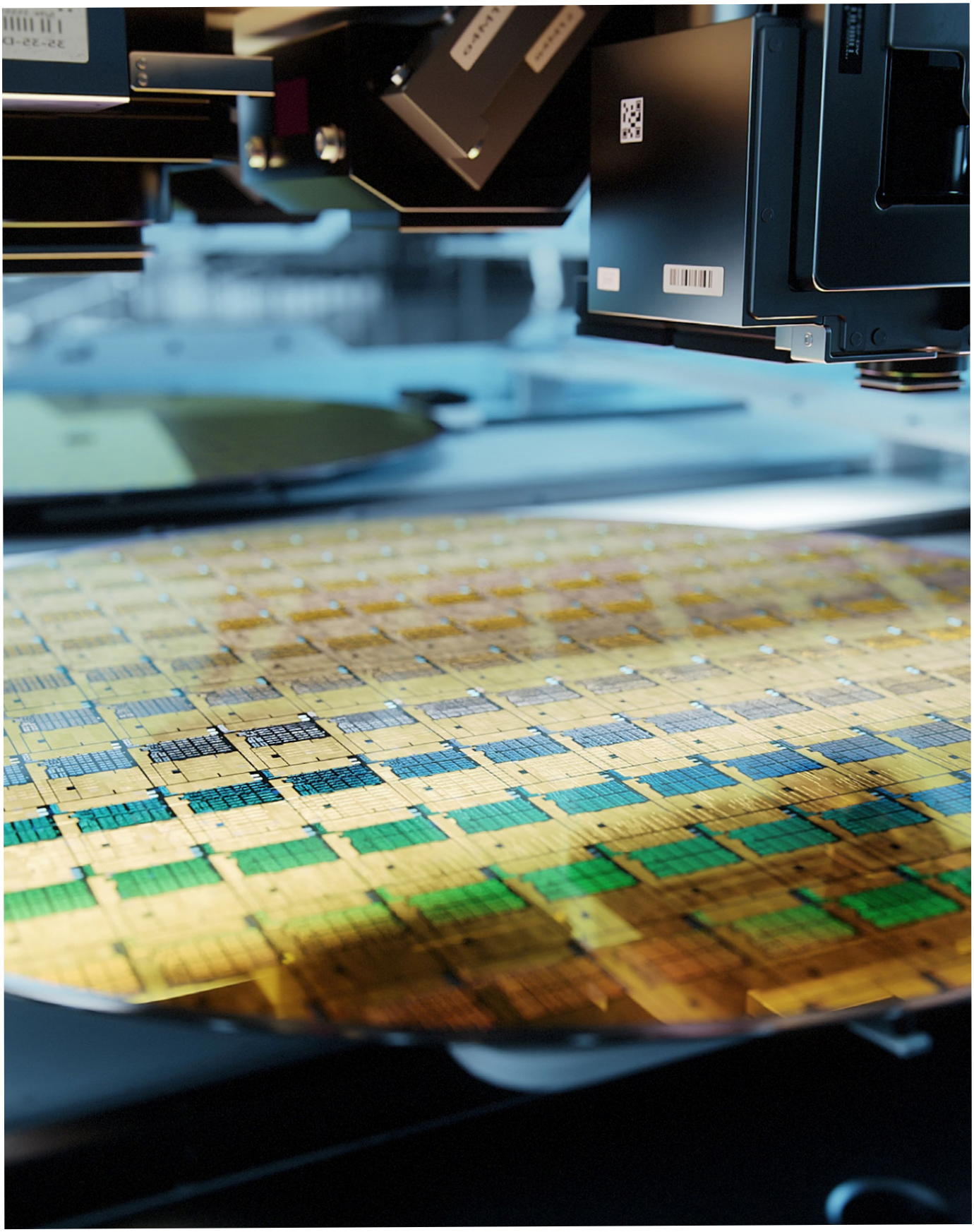
Various types of loose fill media to target specific gaseous molecular air contaminants, solvents, chemicals and biological odors.

Carboactiv Coupons
Copper and silver-based coupons

Used to identify and measure sources of corrosion in cleanrooms, coupons enable effective targeting of the most prevalent contaminants.

Filter analysis

Filter lifetime depends on gas concentration, type of gas, work duration and air flow. We can conduct a remaining lifetime analysis of installed filters for a defined interval in a representative environment, so you can schedule your filter changes for the right time.



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