

# Metal Contaminant Reductions from Gas Streams

*Authors: Rocky Gipson*

Semiconductor device yields have long been impacted by device contamination. As process nodes continue to shrink from 10 nm to 7 nm and soon to 5 nm — pushing CMOS to its very limits — the sensitivity to metal contamination during manufacturing processes has increased significantly. This article describes the primary causes of metal contamination in gas streams and ways to address the problem through the use of specially designed gas delivery systems.

## WHERE DOES METAL CONTAMINATION ORIGINATE?

Possible root causes of semiconductor device contamination in the front- and back-end-of-line processes include cross-contamination induced by chemicals, ultrapure water, and gases. The process environment, which includes the tools, network or gas/chemical distribution, and boxes for wafer handling and transportation, contribute to the problem.

Contaminants from the metallic components of process tools, plumbing and tubing play a role in metals contamination generation. Among the most common metallic contaminants are the transition metal constituents of 316L stainless steel — chromium (Cr), iron (Fe), manganese (Mn), molybdenum (Mo), and nickel (Ni) — as well as main group metals including sodium (Na), calcium (Ca), and aluminum (Al). Depending on the metal, it can degrade CMOS gate stacks, reduce carrier lifetime and more.

There are two main factors that contribute to metal impurities on a wafer due to the process environment itself:

1. Metal contamination inherent to the gas supply; and
2. Corrosion of metal surfaces induced by gases from the gas system itself due to the gases that are required by semiconductor manufacturing processes.

Not all processes requiring a gas supply use corrosive gases. Those that do, however, can impact the entire gas supply network. Dry etch processes, including ion beam etching, plasma etching, and reactive ion etching use corrosive gases that include arsenic pentafluoride, (AsF<sub>5</sub>), boron trichloride (BCl<sub>3</sub>), chlorine (Cl<sub>2</sub>), hydrogen chloride (HCl), silicon tetrafluoride (SiF<sub>4</sub>), and

phosphine (PH<sub>3</sub>), among others. Additional corrosives include dichlorosilane (SiH<sub>2</sub>Cl<sub>2</sub>, used in epitaxy) and chlorine trifluoride (ClF<sub>3</sub>), which is used for cleaning various semiconductor tool components.

In a high-volume manufacturing environment, it is general practice to employ a main gas cabinet in the sub-fab environment to store the bulk gas supply for multiple process tools. The gas is delivered to individual tools using a valve manifold box. Because plasma etch and epitaxial tools can require the same corrosive gases, both are typically supplied from the same bulk source. This scenario subjects the entire gas delivery system to corrosion and contributes to the contamination of the gas supply itself.

Historically, the tolerance for metal contaminants in gas supplies was 10<sup>10</sup> atoms/cm<sup>2</sup>. As devices reach smaller nodes and sensitivity to contaminants increases, the industry has tightened purity standards 100-fold to 10<sup>8</sup> atoms/cm<sup>2</sup> in an effort to reduce defect-causing contaminants found in process gases. One way to meet this new standard is by using gas purifiers designed to remove moisture, hydrocarbons, and volatile metals from corrosive gasses and gas distribution systems, thereby reducing the release of metal contaminants to acceptable levels and subsequently improving wafer yields.

## MITIGATING MOISTURE CONTAMINATION

High moisture levels in the corrosive gas stream are a significant contributor to corrosion. Mitigating moisture begins at the gas source and continues to the transportation and storage of the gas. If moisture can be reduced below a certain threshold (ca. 500 ppbV or greater), corrosion stops and volatile metals inherent to the gas supply can be removed.

Moisture contamination in gas supplies can reach hundreds of parts per billion (ppbV). By implementing a gas delivery system fitted with a mechanism that is designed to remove moisture from the supply, outlet concentration can be reduced to 15 ppbV or less.

## REMOVING CONTAMINANTS FROM THE GAS SUPPLY

In addition to mitigating moisture, capturing volatile metal particulates using special filters diminishes the occurrence of wafer contamination.

While gas delivery systems themselves feature similar components, the process gases and the contaminants inherent to them vary from gas to gas. As a result, different gases may require advanced construction materials to remove contaminants. One solution to address this is incorporation of nickel filters in the purifier cartridge instead of stainless steel (see Figure 1).

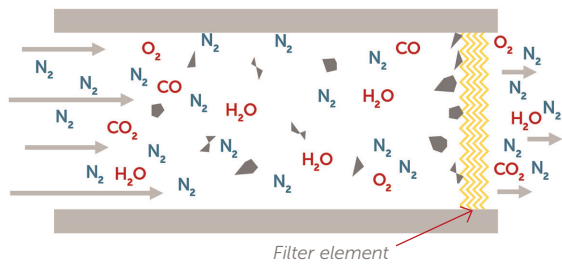


Figure 1. Filtration: A process or device that contains a porous element designed to prevent suspended solid particles from breaching the element barrier in a gas stream.

Nickel provides a much greater degree of corrosion resistance, as it is virtually unreactive towards many corrosive gases. For best results, purifiers are installed at the gas source and at the tool (see Figure 2).

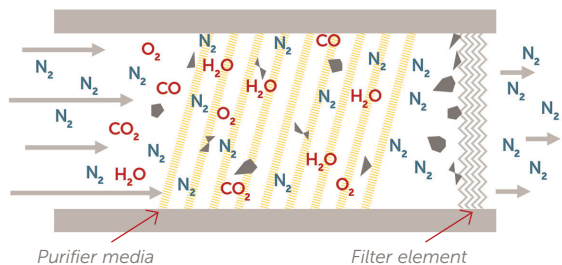


Figure 2. Purification: A process or device that contains media designed to "grab" molecular contaminants ( $O_2$ ,  $H_2O$ ,  $N_2$ ,  $CO$ ) as they pass through a gas stream using the principles of chemical adsorption.

## CONCLUSION

Minimizing moisture in a gas supply to 15 ppb or below, combined with reducing on-wafer volatile metal contaminants to  $<10^8$  atoms/cm<sup>2</sup> is the best strategy to improve final wafer yields, particularly in finer nodes. To achieve both these objectives, equipment such as Entegris' GateKeeper® GPU corrosive gas purifiers can be used. These point-of-use cartridges are constructed using proprietary adsorbents combined with advanced corrosion-resistant particle filtration and are engineered to remove volatile metal contaminants and moisture from corrosive gas streams. The GPU family's moisture efficiency performance is validated using state-of-the-art analytical instrumentation. The purifiers can be mounted at the point of use and at the gas supply in any physical orientation to provide end users with flexibility when designing gas delivery systems.



The GateKeeper GPU family of gas purifiers.

#### FOR MORE INFORMATION

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

#### TERMS AND CONDITIONS OF SALE

All purchases are subject to Entegris' Terms and Conditions of Sale. To view and print this information, visit [entegris.com](http://entegris.com) and select the Terms & Conditions link in the footer.



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

Entegris®, the Entegris Rings Design™, Pure Advantage™, and other product names are trademarks of Entegris, Inc. as listed on [entegris.com/trademarks](http://entegris.com/trademarks). All third-party product names, logos, and company names are trademarks or registered trademarks of their respective owners. Use of them does not imply any affiliation, sponsorship, or endorsement by the trademark owner.

©2017-2018 Entegris, Inc. | All rights reserved. | Printed in the USA | 4414-8579ENT-0318