Dopant gases: Developments in storage and delivery

By Rob Cockerill, published in gasworld magazine | 1 February 2018

The electronics industry is entering a new period of clarity and confidence, gasworld understands, as it converges with conviction on the technology roadmaps of its future.

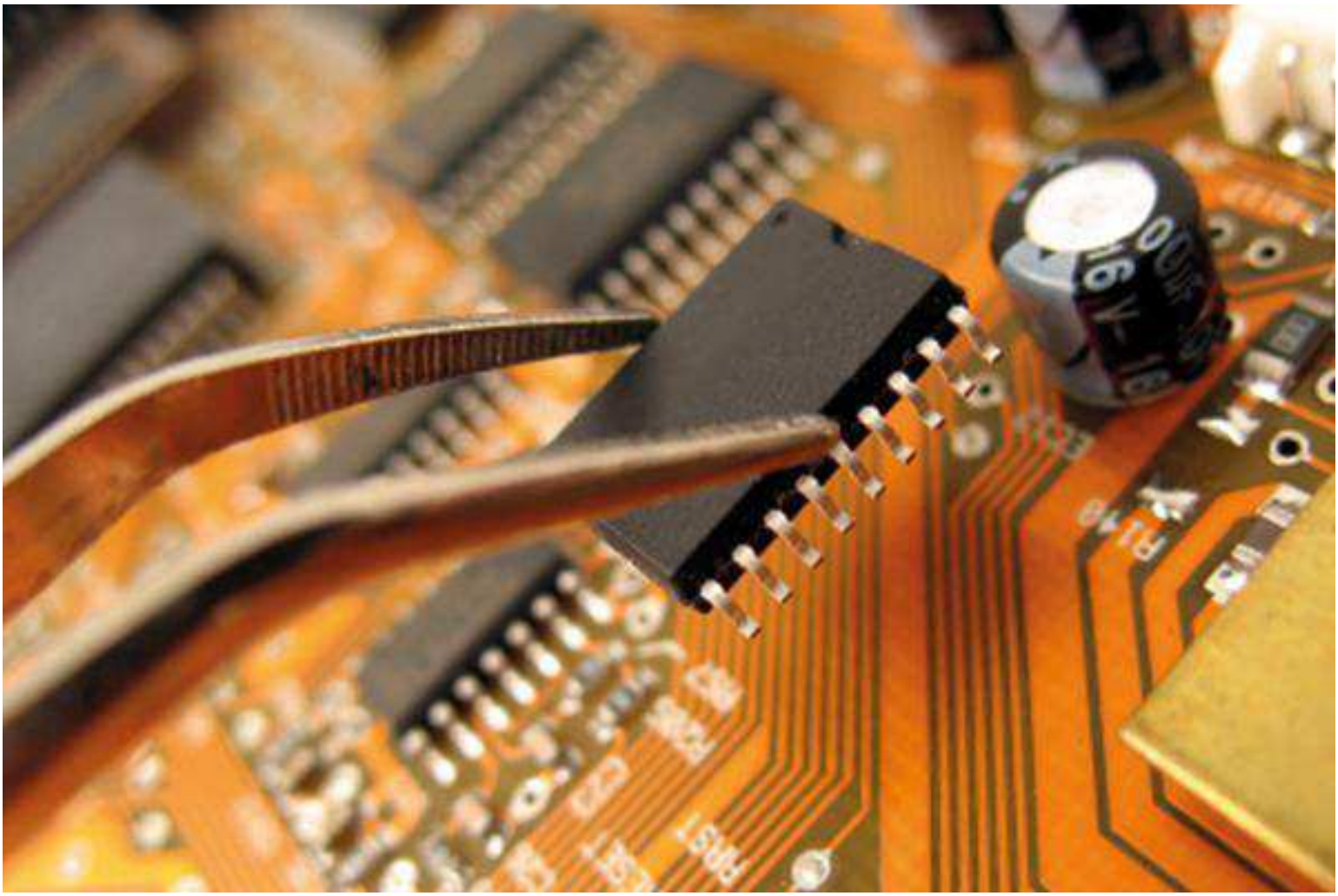
Like most other industries, however, the electronics sector is still under significant pressure to address increased process complexity, performance, and regulatory requirements.

The industrial and specialty gases industry is rising to the challenge in terms of product supply, but work is also underway to evolve the technology that stores and delivers these products and improve yield. More specifically, technology is available for the high performance delivery of dopant gases used in the final stages of semiconductor manufacture, in the ion implant processes.

Ion implantation is the low-temperature process by which ions of one element are accelerated into a solid target, in this instance the semiconductor wafer, and thereby change the physical, chemical, or electrical properties of that target. Semiconductor doping with boron, phosphorus or arsenic is a key application of ion implantation, with each dopant atom creating a 'charge carrier' in the semiconductor after annealing. This essentially determines the type and conductivity of a semiconductor for a given application.

The properties of a semiconductor rely on the movement of electrons and their abundance as well as areas where electrons are absent but could occur (holes). Doping greatly increases the number of electrons within the crystal. In addition to the doping done at the time the monocrystal is grown, partial doping of specific areas and specific layers may be employed to alter electrical properties. A doping material can be diffused into the crystal lattice with the aid of gases like nitrogen and argon. These dopant mixtures fill the spaces between the silicon compounds. Ion implantation prevents existing dopants to diffuse. It is possible to mask certain areas of the wafer to treat only very specific areas, a process that can be repeated multiple times to yield the desired electrical property. To create the fine patterns of an integrated circuit, a photographic process is applied.

What NuMat Technologies and Versum Materials are now bringing to this process and the latter's global customer base in specialty gases is a new product line called ION-X®, based on Metal Organic Frameworks (MOFs) which can selectively absorb, store and safely deliver ultra high purity (UHP) gases at sub-atmospheric pressures. MOFs are a breakthrough material class with vast surface areas, highly tunable porosities, and near-infinite combinatorial possibilities. Critically, they can be programmed to uniquely interact with target molecules in ways that incumbent material technologies cannot, providing a differentiated platform for downstream product and process innovation, according to NuMat.



The company is a recognised pioneer in the design of MOFs and announced a global, commercial agreement with Versum Materials, Inc. in July (2017) to offer the new line of ION-X® products for the safe storage and delivery of dopant gases such as arsine, phosphine and boron trifluoride. NuMat says that its material-enabled application platform will support cost-advantaged production, improved yields, and increased safety throughout the fab – a key consideration during times of pressure to enhance industry performance.

ION-X® offers performance advantages over traditional carbon-based absorbent technology used in the ion implant processes for the manufacture of semiconductor devices, including increased machine utilisation, improved desorption and flow characteristics, and its ability to be 100% Plug and Play in existing equipment.

Versum Materials, Inc. is a leading global materials supplier to the semiconductor industry, having completed its birth as a spin-off of Air Products' former Electronics Materials Division in October 2016. The company has since gone on to break ground on a new multi-million-dollar R&D laboratory project at its chemical manufacturing site in Pennsylvania (May 2017), a new facility that will house a state-of-the-art R&D laboratory for new materials used in the manufacture of semiconductors. Scientists in the facility expect to synthesise and purify new molecules up to parts-per-trillion (ppt) impurity levels using the latest technologies available in the industry.

Commenting on the company's global commercial agreement with NuMat, Jim Minicucci – General Manager for Versum's Process Materials, Asia – said, "NuMat and Versum are combining their respective leadership positions, with NuMat manufacturing the proprietary MOFs and Versum harnessing its world-class global footprint to manufacture, commercialise, and distribute the ION-X® product globally. Building on our long-history in specialty gases, we plan to design and construct a new ION-X® dopant gas fill plant at our production site in Sihwa, South Korea."

Reflecting on the significance of the technology for the industry, Ed Shober – Senior Vice-President of Materials at Versum Materials – added, "We are excited about working together with NuMat Technologies to deliver ION-X® products to our global customer base. ION-X® represents a new and differentiated growth opportunity, is complementary to our Process Materials business, and further aligns with our core competencies as a leading specialty gas manufacturer and supplier."