Gas Purity Enhances Chips for Wireless Revolution

By Jeremiah R. Riddle, Tiger Optics, LLC

Most users of *iPhones*, *iPads,* and other wireless technology hardly imagine that gases are critical to the manufacture of the tiny chips that operate their devices. But, ultra-pure hydrogen chloride (HCl), hydrogen (H_2), and nitrogen (N_2) all play vital roles in the manufacture of super-fast, low-temperature, lower power consuming telecommunications chips. Underscore "pure" because the process of manufacturing tiny chips itself — a derivative of traditional epitaxy — actually invites contamination in an unexpected fashion.

Epitaxial (epi) processing is used in specific types of semiconductor production, including advanced CMOS applications for microprocessors and other types of digital communications. This type of chemical vapor deposition (CVD) offers great benefits for wafers using silicon (Si) and germanium (Ge) materials that are critical building blocks for wireless technology.

A predictable strain in the germanium lattice enhances the quality of the layers on a chip and therefore, the performance of the end-product. Facilitating a predicable strain dictates low thermal budgets in order to maintain doping profiles and prevent diffusion; hence, the emergence of so-called "Low Temperature Epitaxy."

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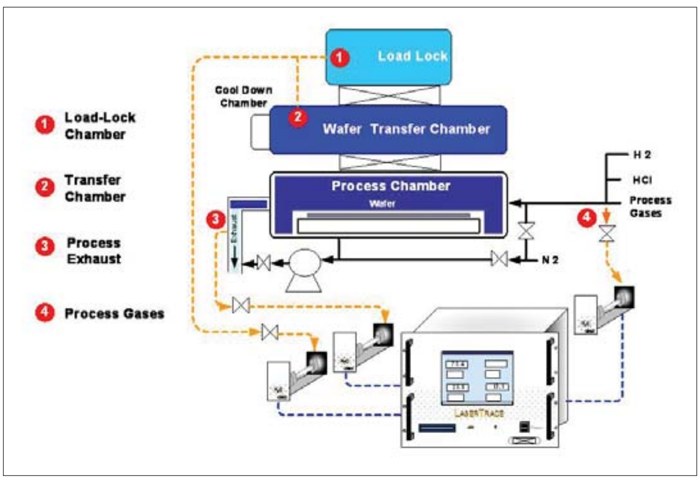
But, as the search for yield enhancement and cost-effectiveness in advanced epitaxial processing progresses, unintended consequences can and do occur. For example, at high temperatures, moisture (H_2O) and oxygen (O_2) bake-off and interfacial oxidation defects are unusual. But, with the shift to lower temperature epitaxial processes (below 800°C), process engineers learned that O_2 molecules still baked-off, but H_2O molecules remained. Depending on the partial pressure of the gas, this residual H_2O can deposit oxygen on the highly reactive wafer surface, leading to oxidation at the epi-substrate layer and in the epi layer.

That makes moisture molecules a prime source of oxidation defects. Moisture can be introduced into the process chamber from a variety of sources, including aging purifiers; wafer handling chambers (WHC) upon introduction of the wafer; the carrier and dopant gases; insufficient purging or baking; and leaks in the tool itself. The research consortium for international semiconductor manufacturing (IMEC) has studied moisture effects in low-temperature epi since 2005. Dr. Roger Loo, Senior Scientist Si, SiGe, and Ge epitaxy at IMEC in Leuven, Belgium, notes, "Normally, the wafer susceptor is coated with a protective Si layer just before loading. If the dichlorosilane (DCS) is of bad quality, this protective layer acts as a contamination source during further processing."

Moisture molecules are both extremely sticky and also ubiquitous, making them difficult to eliminate. Preventing moisture from entering the process is challenging as well. Some of the gases used (notably HCl and DCS) are hard to reliably purify to levels considered acceptable with current thermal budgets (< 10 parts-per-billion). Different temperature and pressure regimes can further reduce the allowable level of H_2O at the start of the epi process.

For these reasons effective process control must identify the amount of H_2O present in the process down to single-digit part-per-billion levels. This allows process engineers to validate measures taken to reduce moisture levels. It can warn of abnormal process conditions (gas-line leaks, purifier breakthroughs, faulty seals, leaks in gate valves, etc.) to avoid damaging wafers.



Multi-channel LaserTrace allows monitoring at multiple points in the EPI process pictured here. Image: Tiger Optics

Pinpointing the source of moisture in gas lines with instruments like Tiger Optics' LaserTrace is critical to low-temperature epi. Photo: Tiger Optics

Some identification and remediation steps include:

- Pinpointing the source of moisture in gas lines. Dr. Loo points out: "The cause of moisture levels can be in one of the many gas lines. For example, if a H_2 ring line is connected to several tools, one tool connection can have a small leak, impacting on the H_2-purity reaching all other tools." He recommends "moisture measurements on the central H_2-line and moisture measurements at the H_2 entrance at the tool."
- Checking the overall moisture level in the tool at the WHC and at the exhaust of the process chamber. If the tool is leak-tight, the user can perform a long high-temperature bake at low-pressure and high H_2 flow to condition the reactor.
- Verifying purifier efficacy by comparing oxygen incorporation in the epi layer with and without purifier.

These checks demand a gas analyzer that can provide the necessary data in a timely fashion. The analyzer must handle inert gases, like H_2 and corrosives, like HCl, and function well in a variety of temperature and pressure regimes. Speed of response is also a key requirement. To that end, Tiger Optics' trace gas analyzers are in wide use in the epitaxial process, at over 100 measurement points worldwide.

Tiger's "Continuous Wave Cavity Ring-Down" (CW-CRDS) spectrometers are based on an "absolute" measurement method: they are drift free, and require no external calibration sources. Engineered for ultra-high-purity gas applications, they provide real-time readings and very fast response. The CW-CRDS technique is neither temperature nor pressure sensitive (within fairly broad parameters), which allows its use at both the wafer handling chamber and the process chamber.

Tiger analyzers are used for process control and research on the chemical interactions that affect epitaxial processing. Meeting the on-going need to reduce thermal budgets and speed throughput, they provide deeper insights into the effects of changing conditions on yields. And that makes young texters around the world very happy.

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