Semiconductor Manufacturers Pursue Improved Gas Mixing Control and Reproducibility at Lower Manufacturing Cost

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Smarter Manufacturing for Silicon Epitaxy Applications Reduces Gas Consumable Costs by As Much as 60%

For decades, Semiconductor Manufacturers have been anticipating innovations in Gas Mixing equipment to keep pace with advances in Silicon Epitaxy Applications. However, due to a lack of technology advances, these manufacturers have relied on high-cost, minimally-precise methods of concentration control such as pre-mixed, low-concentration precursor gas cylinders from gas suppliers. Such low-concentration pre-mixed cylinders come at a much higher cost-per-gram of the precursor gas than their higher-concentration counterparts. Additionally, low-concentration, pre-mixed cylinders are unable to provide a highly stable cylinder-to-cylinder concentration, leading to poor tool-to-tool matching and the need for frequent requalification, usually after every cylinder change.

To address these challenges, Veeco, a leader in Gas Mixing technology, has introduced the Apex™ Gas Mixing System designed to address this manufacturing need and catalyze effective, low-cost point-of-use gas mixing. The Apex system generates precise binary gas mixtures on a single platform for use in semiconductor applications at 20nm and below. Apex improves concentration control versus existing methods, providing tighter process management, increased tool uptime and reduced manufacturing costs. It is optimized for advanced silicon epitaxy applications and other processes requiring low concentration and high precision for cost-sensitive gas mixtures. Apex provides a reliable flux of the binary gas at a highly precise concentration level.

This technology breakthrough allows manufacturers to deliver GeH₄ at a concentration of 1.0% in H₂, with a repeatability of <0.003% at up to 8 SLPM (see Figure 1). Similarly, the data in Figure 2 demonstrates how Apex maintains performance before and after a B₂H₆ cylinder change.

This level of precision allows semiconductor manufacturers to purchase lower-cost, higher concentration gases and dilute them at the point of use. With the reduction of cylinder changes and the ability to maintain a precise concentration level even after a cylinder change, Apex enables semiconductor manufacturers to greatly reduce – and in most cases eliminate – requalification at cylinder change.

Another method semiconductor suppliers have traditionally used to provide low-concentration binary gases to their process tools is the use of constant flow mixers. The primary disadvantage of constant flow mixers is the need for frequent – or even constant – scrubbing, leading to wasted materials and higher costs. Apex introduces
a solution by eliminating constant flow, which saves both production time and materials costs.

"The Apex Gas Mixing System addresses key challenges that face semiconductor manufacturers at the 20nm node and below," said Christopher Morath, Senior Director, Veeco Flow Technologies Group. "For example, the Apex system provides precise control of germane and diborane flux for doped silicon germanium films that have a critical impact on device performance with tight process control limits. Consequently, the Apex system allows manufacturers to improve real-time process control by up to

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**Figure 1. Apex GeH₄ concentration stability**

**Figure 2. Apex performance example-B₂H₆; 1% premix cylinder diluted to 50ppm by Apex**
a factor of ten as compared to pre-mixed gas cylinders. This will enable users to increase yield, throughput and profitability."

According to Mr. Morath, similar improvements in yield, repeatability and cost savings can be expected for other gases as well, including phosphine (PH₃) and even forming gases such as H₂/N₂, enabling the manufacturer to realize the improvements across multiple tools and processes.

Apex operates by mixing a higher-concentration precursor gas with a pure carrier gas, thus delivering a lower – yet very precise - concentration of precursor gas. Apex is able to achieve this level of precision by using Veeco’s production-proven Piezocon® Gas Concentration Sensors (see Figure #3). This makes Apex the only gas mixing system...
in the market to use Piezocon technology. The precursor and carrier gases flow to the Apex through dedicated MFCs. The gases are mixed and then the mixture is verified by the first Piezocon sensor operating in control mode. This Piezocon sensor sends concentration data to the Piezocon controller, which in turn sends correction factors to the MFCs, adjusting the mixture in real time to deliver a stable concentration. The mixed gas then flows into a storage tank to be available upon demand by the process tool. As a final check, the concentration of the mixed gas is verified by a second Piezocon sensor before flowing to the process tool.

Piezocon is a non-invasive, flow-through sensor for measuring the concentration of a mixture of two gases. The principal of operation is acoustic, and the basic measurement is the time delay between two received spread spectrum signals. Using the measured time delay in conjunction with the parameter data for the two gases, the Piezocon calculates the concentration of the precursor gas and sends this information to the Mass Flow Controllers (MFCs) to achieve real-time adjustment of the concentration. By using this real-time, PPM-level control, Apex allows semiconductor manufacturers to purchase lower-cost, higher-concentration gases, and then dilute them at the point of use to immediately cut gas purchase costs by as much as 60 percent (see Table 1). The total installed base for the Piezocon Gas Concentration Sensor is over 3,000 sensors worldwide in both silicon semiconductor and MOCVD applications.

The Apex Gas Mixing System is designed to easily integrate with existing wafer fab facilities and systems (see Tables 2-3), and is supported by a broad range of SEMI certifications. Apex’s stable output and precise control of gas concentration results in higher process tool up-time by eliminating the need to re-qualify after every gas cylinder change. These improvements reduce – and in some cases eliminate – system down-time due to routine cylinder changes. All of these features allow Apex to drive real-time control, high precision and reproducibility, and lower the cost of ownership for semiconductor manufacturers.

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