PICARRO

AN035

Airborne Molecular Contamination Cleanroom Monitoring

The Picarro G2103 NH_3 and G2205 HF analyzers offer the power of CRDS for AMC cleanroom monitoring in a robust, compact, and transportable package.

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Semiconductor Manufacturing and Contamination

Figure 1. Picarro G2205 hydrogen fluoride analyzer

Measurement and control of contaminants is critical in a variety of industrial applications including power generation, petrochemical processing, and semiconductor manufacturing. In many cases, the measurement of critical contaminants at parts per billion (ppb) levels is required to achieve optimal process control or safeguard valuable work-in-process material.

The production of integrated circuits (IC) is a lengthy, multi-step process that exposes the evolving wafer to a variety of chemicals and their associated contaminants. IC performance is severely affected by parts per million (ppm) contamination levels of electrically active impurities, and it is very difficult to guarantee a contaminant-free process due to the number of fabrication steps involved. Furnace operations expose the wafer to contamination present in ambient gases, while etching and cleaning cycles contribute to further contamination.

Picarro trace gas analyzers provide both the sensitivity and speed needed for the most demanding trace contaminant monitoring applications. Delivering continuous measurements with parts per trillion (ppt) sensitivity, Picarro analyzers are ideal for semiconductor manufacturing applications, including airborne molecular contamination (AMC) cleanroom monitoring, stack emissions, and fence-line monitoring. Use Picarro trace gas analyzers to maximize product yield with simple, low maintenance, low cost of ownership operation.

Airborne Molecular Contamination (AMC) cleanroom monitoring

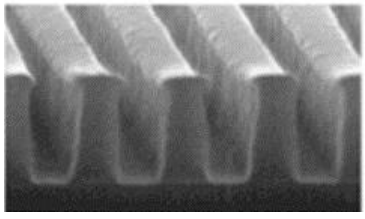

Figure 2. Photoresist "T-tops", which limit control of wafer feature size, can be caused by ammonia in cleanroom air.

Why be concerned with trace levels of AMC in semiconductor cleanroom environments? Product defects, and therefore reduced product yield, are a direct result of the presence of various AMCs and their effect on production at key stages of the semiconductor manufacturing process. Losses arise due to adverse effects including:

- Corrosion of metal features on the wafer
- Filter degradation, in some cases associated with particle shedding
- Haze on wafers and tool optics
- T-topping on developed resist profiles
- Changes in contact electrical properties

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It is therefore imperative that measures are taken to monitor and control AMC to optimize product yield.

Key AMCs

AMC results from the release of unwanted process chemicals and by-products from the semiconductor manufacturing process. The focus here will be on ammonia (NH_3) and hydrogen fluoride (HF), both of which have been highlighted in the most recent International Technology Roadmap for Semiconductors (ITRS) as critical AMCs requiring monitoring and control.

Control of NH_3 in the cleanroom is crucial to insure integrity of the photolithography process. NH_3 is emitted into wafer fab air by various semiconductor processes including chemical vapor deposition (CVD), wafer cleaning, coater tracks, and Chemical Mechanical Planarization (CMP), as well as from human operators.

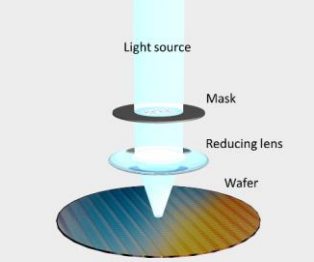

Figure 3. Photolithography process

At the photolithography step, ambient NH_3 can alter the photochemical properties of photoresist causing uncontrolled variation in printed wafer features. Chemical filters are in place in these areas to remove airborne contamination, but their lifetime and coverage do not offer complete protection. Constant monitoring of airborne NH_3 at ppb-levels and below is critical to protect wafers from NH_3 exposure.

HF is an extremely strong acid, and as such represents a significant hazard both to human health and the integrity of IC devices. While HF is used in controlled operations to etch the wafer surface, the presence of unwanted HF during other steps of the manufacturing process threatens to render semiconductor devices useless. In addition, HF is capable of reacting with borosilicate glass in high-efficiency particulate arrestance (HEPA) filters, releasing boron as an additional AMC. Boron is electrically active, causing unwanted p-doping of silicon-based processes.

HF and NH_3 Monitoring

Cavity ring-down spectroscopy (CRDS) offers significant advantages compared with incumbent techniques, such as ion mobility spectrometry (IMS), which have traditionally been used to monitor both NH_3 and HF in cleanroom environments.

Analytical instruments that measure NH_3 and HF at ppb levels can have long-term drift in the baseline measurement, or require frequent re-calibration, due to the “sticky” nature of NH_3 and reactivity of HF. These gases are easily adsorbed to a variety of materials, including stainless steel, the typical material used for the construction of gas handling components and tubing. The measured concentration is dependent on the subsequent desorption, which can occur arbitrarily since it is dependent on humidity and temperature.

To account for these effects, the following innovations have been included in the Picarro trace gas analyzers:

- Gas handling and cavity surface materials selected to minimize adsorption.
- Precise internal temperature stability to milli-Kelvin levels.
- Scanning and analysis of multiple absorption peaks to compensate for spectral baseline drift.
- Simultaneous measurement of, and compensation for, moisture content.

As a result of these innovations, Picarro trace gas analyzers have best-in-class response times as seen in figure 4 below.

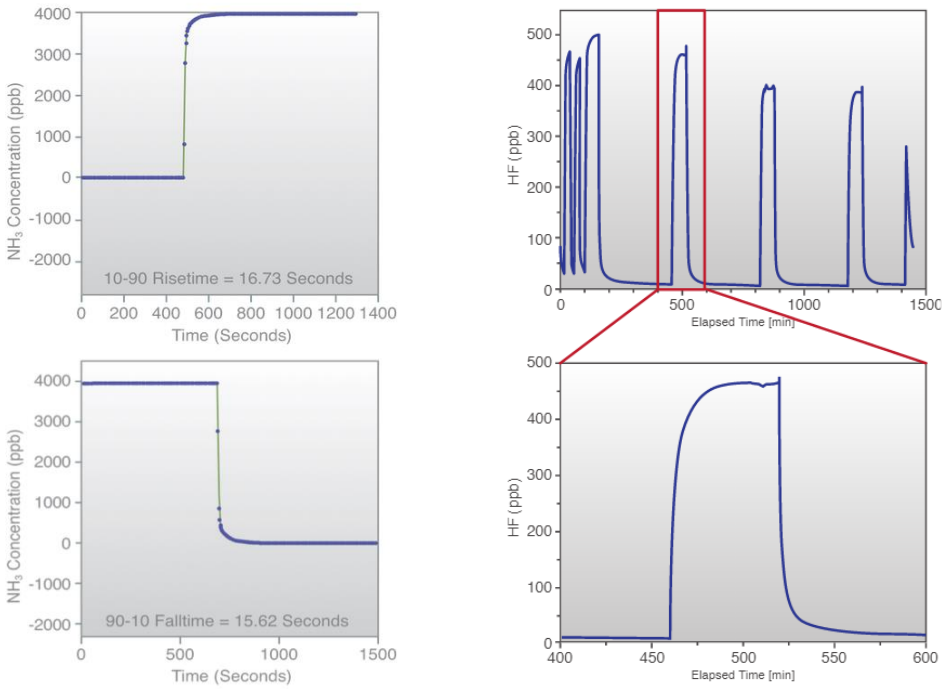

Figure 4. Response time of the Picarro G2103 for NH_3 concentration measurements (*left*) and the Picarro G2205 of HF concentration measurements (*right*). Picarro guarantees a response time of less than 30 seconds for 10-to-90% and 90-to-10% for 0 to 3 ppm NH_3, and less than 10 minutes for 10-to-90% and 90-to-10% for 0 to 0.3 ppm HF.

Both the Picarro G2103 NH_3 and G2205 HF analyzers offer the power of CRDS for AMC cleanroom monitoring in a robust, compact, and transportable package. Designed for long-term stability and low maintenance, they are ideal for continuous operation in semiconductor manufacturing facilities. Enclosed in a standard 19 inch rack-mounted enclosure, these analyzers undergo a rigorous set of factory tests, including three-axis drop, vibration, temperature cycling, and a one-week burn-in. Visit www.picarro.com for further details.