Prediction and Prevention of Failures in Semiconductor Bulk Gas Distribution Systems

Background

Semiconductor facilities consume vast quantities of high purity gases in the production of high end solid state devices. The purified nitrogen, argon, oxygen, helium and hydrogen gases used in various semiconductor manufacturing processes are collectively referred to as either bulk gases or house gases. House gases are typically distributed throughout a semiconductor manufacturing facility via gas distributions systems comprised of electropolished stainless steel tubing and other gas handling components designed for ultra high purity (UHP) applications.

To maintain the highest possible manufacturing yields from processes where bulk gases are consumed, highly sophisticated gas analyzers are used to verify bulk gas purity from the source. Each gas purity monitor is finely tuned to measure one or more potential contaminants, any of which can be present in the event of a system failure whether this is due to mechanical break down or human error.

Simply put, degradation of purity implies an increase in the presence of one or more impurities. Semiconductor process engineers specify the types of impurities that can negatively influence a specific process. In general, the most frequently specified impurities include moisture, oxygen, hydrogen, carbon monoxide, carbon dioxide, methane, and non-methane hydrocarbons (NMHC). Facility engineers are responsible for maintaining gas quality specifications from the gas source to each wafer processing tool. This responsibility can only be fully addressed by continuously monitoring house gases for all specified impurities.

Most mechanical break downs in gas distribution systems can be traced to equipment failure, leaks or outgassing (i.e. contamination from flow components like valves, fittings, regulators, etc.). For example, it is difficult to avoid introducing a small amount of moisture into a gas distribution system during piping installation. Once process gas flow begins, it typically requires one month or longer for this moisture to evaporate or outgas from the walls of the tubing. However, once a piping system is fully conditioned, moisture and oxygen analyzers are usually employed as a security against room air leaks into the piping.

Leaks can be a significant source of impurities in UHP gas distribution systems. However, other types of problems can occur that are not associated with leaks. To effectively detect these problems, no quality assurance strategy can compare with monitoring high purity gases for low molecular weight impurities such as hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2) and hydrocarbons. In dynamic systems, monitoring this ensemble of chemical contaminants provides the best indication of equipment degradation and component outgassing.

Protection at the Source

Gas purifiers are optimized to remove moisture and oxygen from semiconductor grade process gases. Unfortunately, the absorption capacity of any purifier is extremely low for the other low molecular weight impurities and these are generally the first impurities to break through purifiers. Thus, a strategic approach to QC/QA of purified gas includes detection of the early break through components, such as CO_2 or H_2. In other words, by the time moisture or oxygen break through is detected at the source, the other impurity concentrations have already reached a high level and it is probably too late prevent a process control crisis. This model serves as a diagnostic indication of the gas quality and as a way to prevent the eventual breakthrough of major components.

Hydrogen, carbon monoxide, carbon dioxide and methane are all known to influence semiconductor production yield and they are all the least manageable of all house gas impurities. A gas monitoring program which includes automated gas purity monitors based on ultra high purity gas chromatography systems coupled with highly sensitive RGD or FID detection technology can be specially configured to quickly and cost effectively manage gas distribution systems. Designed for continuous service, Trace Analytical™ UHP gas purity analyzers, from AMETEK Process Instruments, can deliver the piece of mind that comes with competent quality assurance programs.

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