APPLICATION NOTE

ELIMINATE PARTICLE CONTAMINATION CAUSED BY PUMP FAILURE

PROBLEM

Vacuum pump failures occasionally occur in semiconductor process equipment, especially in etch or deposition tools that must deal with abrasive and/or corrosive exhaust gases. These failures can arise from a variety of causes, including excessive backpressure in pump exhaust lines, voltage fluctuations in the electricity supply, or mechanical component failures within the pump itself. When a vacuum pump fails in these process tools, it produces turbulence and back-streaming in the foreline and process chamber. Under these conditions, particles may be dislodged from foreline walls, migrate into the process chamber, and be deposited on wafer surfaces. This creates irreparable defects in the devices undergoing fabrication, decreases yields, or requires the product to be scrapped. Most isolation valves employed in semiconductor process tools cannot close fast enough to prevent this contamination issue.

BACKGROUND

Many semiconductor processes require vacuum conditions; process pressures can typically range from high vacuum (≤10^{-6} Torr) to medium vacuum (1 to 1 x 10^{-3} Torr) with some processes even using pressures as high as rough vacuum (10 to a few 100s of Torr). Process chambers are normally evacuated using either a blower/mechanical pump system (in rough and medium vacuum applications) or a turbomolecular pump/mechanical pump arrangement (in high vacuum applications). The design of these vacuum pump systems has been refined over time to provide high reliability and long meantime between failure (MTBF). Occasionally, unexpected failures occur, especially in harsh environments such as etching tools. When a vacuum pump system fails while the process tool is in-process with substrates in the process chamber, the devices in fabrication can suffer irreparable contamination from back-streamed particulates. This represents a significant monetary loss, up to hundreds of thousands of dollars depending on the number of wafers in the load, the nature of the device being produced, and the degree of completion of the fabrication process when the vacuum system failed.

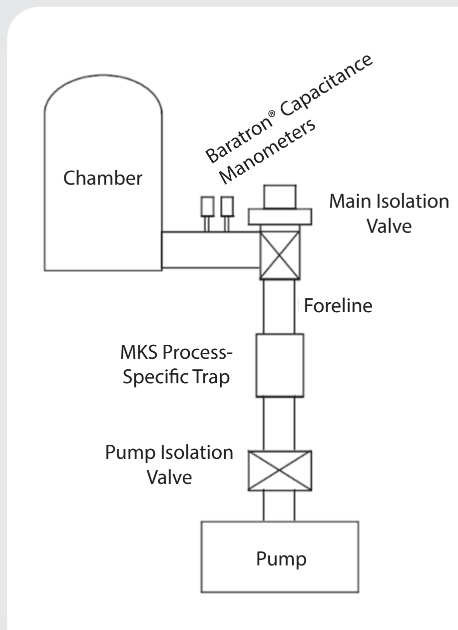

Figure 1 - Semiconductor process tool: system components.

Figure 1 shows a schematic of a semiconductor process tool that operates under vacuum conditions. The foreline in a typical process tool contains two isolation valves, one located directly upstream of the vacuum pump system (pump isolation valve) and one near the exit from the process chamber (main isolation valve). The pump isolation valve is routinely used to isolate the system from the vacuum pump during preventive maintenance while the main isolation valve isolates the chamber during certain process steps (i.e. substrate loading in a batch system) and during maintenance activities. In most fab environments, the pump isolation valve/vacuum pump assembly is remotely located in a subfloor. Except for times when maintenance is being performed, the foreline up to the main isolation valve is routinely maintained under vacuum and the pump isolation valve remains open. When the process chamber is pumped down to vacuum pressures, it is first "soft-pumped" (i.e. slowly evacuated, often using an ancillary system) to avoid gas turbulence in the chamber. The main isolation valve remains closed during this step. Once medium vacuum is achieved, the main isolation valve is opened, and the process recipe can proceed.

While base pressures in an operational semiconductor process tool must be well into the medium vacuum regime, typically ≤1 mTorr, pressures in the chamber and foreline are significantly higher during process, lying between medium vacuum and rough vacuum. Gas flow in these pressure regimes has both molecular and viscous flow characteristics. This means that when sharp disruptions in the gas flow characteristics occur (i.e. a rapid change in volumetric flow or pumping capacity), gas turbulence occurs that can dislodge particles from the foreline walls. These particles can migrate back through the system to the process chamber and contaminate substrate surfaces. Thus, when a vacuum pump fails, the gas flow characteristics in the process chamber and foreline change rapidly, producing turbulence with the accompanying risk of particle contamination.

The problems associated with pump failure can be alleviated if the process chamber is isolated before particles have time to reach the chamber. Obviously, for this to happen, the main and pump isolation valves must close very rapidly. Therefore, the critical performance specification for these valves, at least with respect to contamination control, is the closing time (the time required to go from full valve open to full close). Extremely short closing times result in less chance of particle migration into the process chamber when a pump failure occurs. The choice of main and pump isolation valves is therefore of utmost importance.

Most users select an off-the-shelf valve for isolation duty. The design of such valves is a compromise that allows them to be used in a wide range of applications and therefore closing speed may not be a critical design parameter. Indeed, general-purpose valves are often designed with slow to moderate closing speeds to minimize the impact forces on the mechanical components of the valve and thereby increase the MTBF and cycle life of the valve. The best valve designs for isolation duty have typically been either gate valves or poppet-style valves. Gate valves provide the highest conductance and a desirable flow path, but they have operational limitations that result in slower closing times when compared with poppet-style valves. Poppet style isolation valves close more quickly and are generally cheaper than gate valves, however they have a less desirable flow path.

SOLUTION

The MKS Rapid Isolation Valve was developed as a solution for the specific event conditions described above. Its design builds upon the performance of MKS Jalapeno and High Flow Valves, with design modifications to the flow paths, integrated solenoids, and external pneumatic quick vents that ensure that the Rapid Isolation Valve has the fastest possible valve closing speed.

The Jalapeno valve performs well in pump isolation applications owing to its high conductance and high-performance heating options. Many customers are already using Jalapeno valves for pump isolation and Rapid Isolation versions are direct replacements. All Jalapeno valve specifications apply for Rapid Isolation Valves; the only change is that the cycle times are lower. Table 1 provides a comparison of the closing cycle times for the Rapid Isolation Valve vs. other valve types. Cycle life for the Rapid Isolation Valves is not rated due to the increase force on the valves during actuation. However, cycle life is not normally a critical factor for pump isolation valves since they are only actuated during pump service events or during a power failure or pump failure.

Size	Time to Close		
	Standard HPS Valve	Gate-Type Valve	Rapid Isolation Valve
NW 16	90 msec	500 msec	< 50 msec
NW 25	90 msec	600 msec	< 50 msec
NW 40	90 msec	800 msec	55 msec
NW 50	220 msec	1000 msec	80 msec
NW 80	1000 msec	2300 msec	170 msec
NW 100	2000 msec	3100 msec	180 msec
NW 160	3000 msec	4400 msec	600 msec

Table 1 - Closing times: Rapid Isolation Valve vs. Standard HPS and Gate-type valves.

CONCLUSION

The selection of the isolation valve in applications exhibiting harsh process conditions and an increased possibility for vacuum pump failure is critical for avoiding significant yield and monetary loss since isolation valve closing time can directly impact process particle contamination. While off-the-shelf standard products may offer lower upfront costs, such valves may not protect the product under process when a pump failure occurs. MKS Instruments' Rapid Isolation Valves offer significantly faster actuation speeds, high conductance, heating, and the reliability that customers expect from MKS Jalapeno and High Flow Valve products. The dramatic reduction in closing speed with MKS Rapid Isolation Valves protect the chamber from particulate back streaming, reducing tool downtime, and the need to scrap valuable product. For semiconductor fabs and other end users of semiconductor process tools, the investment in Rapid Isolation Valves can provide positive returns after just a single pump failure event.

Rapid Isolation Valve_02/23
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