Preventing Wafer Contamination

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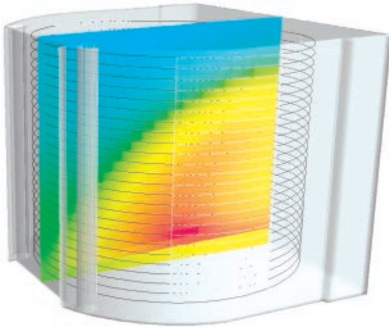
The front-opening unified pod (FOUP) is a 300mm wafer handling and contamination control device, used in the semiconductor manufacturing industry. The pods are used to transport wafers between processes, and care must be taken when using the pods to avoid wafer contamination. For example, the presence of humidity in the enclosed environment of the pods can cause a variety of phenomena, such as native oxide growth, corrosion, and film cracking. The presence of emitted organic compounds can lead to degradation of the electrical properties of integrated circuits fabricated from the wafer material. Simple intuitive purging with an inert gas such as nitrogen, a technique used to keep the pods free of contamination, does not always maintain wafer cleanliness compatible with high yields. At Alcatel, rigorous numerical simulation with CFD has been used to show how pod purging can be improved.

The potential inefficiency of purging a FOUP with an inlet and outlet located on the bottom of the pod – the classical purge configuration – has been examined using FLUENT. The FOUP was initially filled with ambient air with 40% relative humidity, a typical value for a wafer fabrication cleanroom. A transient analysis was done as a steady flow of nitrogen was introduced through the inlet. The calculation was continued until the air mass fraction reached 1% (with 0.4% relative humidity). To test the effect of the nitrogen gas flow rate, a range of inlet velocities was considered.

For each case studied, the time required to reach the above conditions was recorded and compared to a computed value for the ideal purge time, defined as the ratio of the FOUP volume to the volumetric flow rate. For the base case, using a 2L/min gas flow rate, results showed that classical purging requires a factor of three more time than ideal purging to reach the same condition. While classical and ideal purging begin with comparable discharge rates for air, the classical method drops off considerably after the initial 25% of air is removed from the device. The FLUENT results also showed that with a fully loaded FOUP, air flow between the wafers was significantly less than that along the wafer edges. This was attributed to the fact that the classical inlet position directs nitrogen upwards toward the base of the bottom wafer, where it is diverted to flow around the entire stack. Furthermore, the narrow spacing between wafers discourages circulation, and the slightly denser humid air causes the nitrogen to rise above, rather than mix with the air.

To improve the purging performance, a number of modifications were tested. A plenum purging system was introduced that injects purge gas from the sides of the FOUP. Different purge gases were tested, such as argon and dry air, and the temperature of the purging gas was altered to promote natural convection between the wafers. These and other modifications have reduced the purge time to a point that is closer to the ideal case. ■



The original humid air mass fraction after about 5 minutes of purging has taken place

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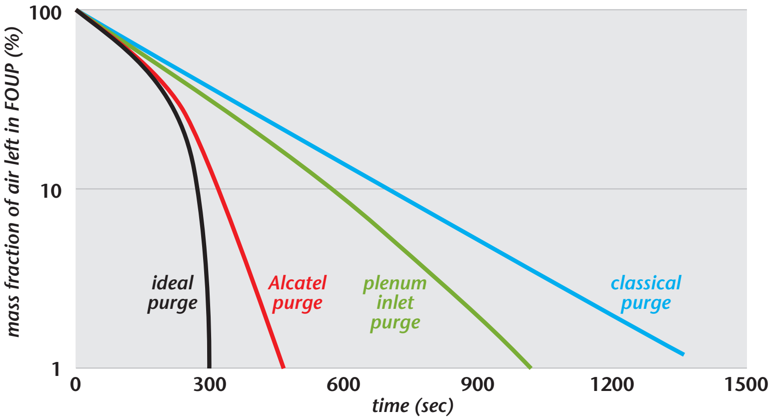

Comparison of different FOUP nitrogen purge times

Mass fraction of the residual gas using plenum injector purging after a) 1.5 minutes, b) 5 minutes, and c) 22 minutes