semiconductor INTERNATIONAL

Joe Nardini, Applied Materials Inc., Santa Clara, Calif.
William McHaney, Consultant
Gustavo Suarez, Purity Systems Inc., San Jose

Torque Elimination Fittings Add to Gas Handling Safety

Applied Materials' flagship 300 mm system and process development facility is the Dan Maydan Process Module Technology Center (PMTC, Sunnyvale, Calif.). This facility contains the equipment and processes needed for Applied Materials' customers to develop and pretest integrated multi-level metal copper interconnect process modules before delivery to their fabs. The design of this center required the company to look forward to envision the facility requirements for cutting-edge process development 10 years in the future. At the current rate of evolution in the semiconductor industry, this represents about six chip generations.

In preparation for these future requirements, Applied Materials formalized its gas handling "best known methods," installed a sophisticated process gas purification system, and standardized on a torque elimination-type of metal face seal fitting in its process gas lines (Fig. 1). This fitting technology has helped keep safety and contamination control at the highest levels, while providing the potential for cost reduction by decreasing system setup time and downtime.

The PMTC

The 166,000 ft² PMTC has 39,000 ft² of ISO Class 1 open cleanroom space, and has capacity to house more than 300 individual process and support tools — including more than 100 major systems — making it the largest process development center ever operated by an equipment supplier. Since the end of July, more than 10,000 300 mm wafers have been processed in this facility.

The PMTC's fab-like size and system capacity require a tremendous amount of process gas piping with thousands of fittings. Unlike customers' production wafer fabs, however, the PMTC requires great flexibility in piping, electrical and airflow to accommodate frequent and rapid equipment changes.

To prevent the facility from quickly becoming obsolete, it was vital to include new technology that could address the future issues of chip manufacturing. The forecast provided by the International Technology Roadmap for Semiconductors (ITRS)[1] predicts upcoming chip geometries and identifies technologies that will be required to achieve those targets. The ITRS specifies objectives in the areas of chemical, material and equipment management; workplace protection; and environment, safety and health (ESH). The PMTC facility and its systems are designed to con-

Safety is the primary focus for all gas handling facilities at the PMTC, which included the use of torque elimination fittings in process gas lines.

At a Glance

Applied Materials' process development facility has developed new gas handling strategies that have resulted in increased safety, enhanced yield and reduced cost of ownership.

form to these guidelines, incorporating a new type of gas delivery system fitting that reduces leakage and particle contamination, while at the same time increases safety and stability in the event of earthquakes.

Changing a 20-year tradition

Metal face seal fittings without torque suppression (Fig. 1a) have been used in the semiconductor industry since the 1980s. Some of the problems found from unrestrained torque in metal face seal fittings have been reduced by clamping and locking devices. However, recent vibration/shock[2] and particle studies[3] have pointed out a need for improvement. After a detailed evaluation of available technologies, we implemented a specification change to be carried out throughout the PMTC.

The transition to a new technology that eliminates the causes of torque effects requires performance data persuasive enough to justify the change in the specification, training the technicians, and enforcing a new standard with subcontractors unfamiliar with and often resistant to the new requirements. The return for the short-term learning curve during this transition is the long-term benefit to facility safety and operation.

Torque elimination fittings

In a study at Quanta Labs in Santa Clara, Calif., the integrity of fittings with and without torque elimination was compared under Mil Standard 810E.[4] After being subjected to the shock/vibration protocol of this procedure, the fittings without torque elimination loosened and then failed the original leak check specification of $1^{*}10^{-9}$ (atm cc/sec He).

Testing of a torque elimination fitting by Omnisafe[5] that does not cause reverse torque to be stored in the tubing during tightening found no loosening under shock/vibration testing.

This fitting may be tightened twice as securely without damage to the sealing surfaces (Fig. 2). The torque elimination fitting also does not loosen during thermal cycling or if an attached component is rotated.

These safety features significantly increase equipment safety and stability during an earthquake. Increased leak integrity also has additional benefits of reducing frequency and duration of maintenance events. Systems using corrosive materials realize extended service life with reduced introduction of moisture and oxygen.

The PMTC's focus on advanced process development requires careful attention to protocols that minimize contamination and

The torque eliminator prevented the sealing surface damage that causes particles, and consequently no particles in the 1.0-0.1 µm size range were detected when the metal face seal fitting was tightened.

improve yields. Studies showed that metal face seals without torque elimination produced particles in the 1.0-0.1 µm range during tightening.[3] However, the torque elimination fitting prevented the sealing surface damage that causes particles, and consequently no particles in this size range were detected when it was tightened. The wetted sealing surfaces of this new fitting comply more closely with SEMI standards for both Ra microfinish and electropolished corrosion resistance after tightening, which increases system purity and service life.

"Error proofing" the maintenance of the gas distribution system includes making it easier to complete an assembly task correctly, and early detection of anomalies in the assembly before serious damage can occur. The torque elimination fittings prevented components from twisting out of alignment during tightening (Fig. 3), and prevented "cross-torque" that loosens adjacent fittings during tightening.

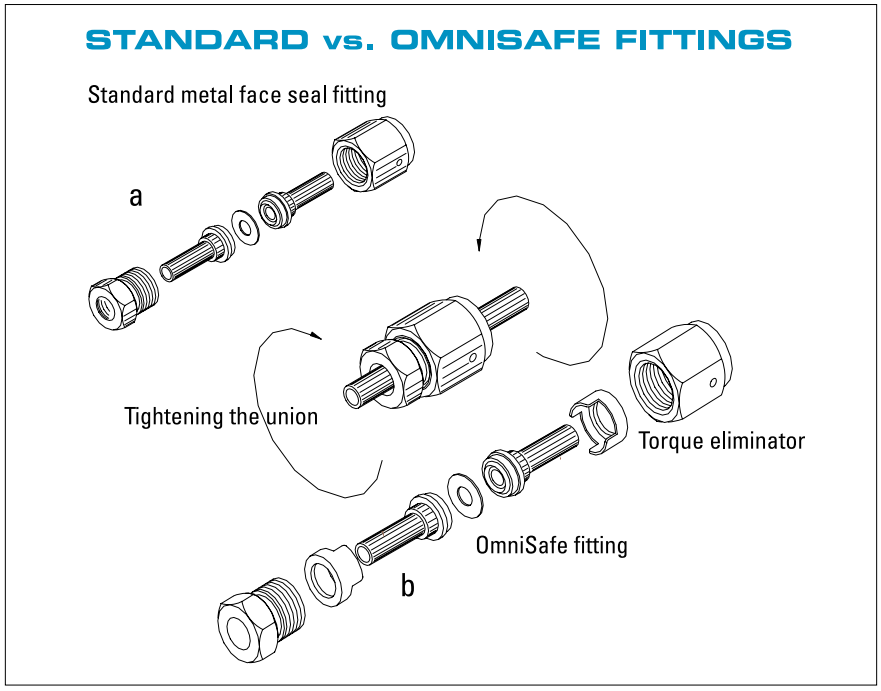
Keeping collateral effects to a minimum is especially important in an R&D environment where system modifications are common and frequent. As a result of preserving sealing surfaces during tightening, the new fittings continue to seal securely for hundreds of retightenings.

In terms of detection, we found that no false-positive helium leak test or seal damage occurs if the gasket is missing during fitting installation. This early detection may prevent a costly process leak during system operation.

Overall, the torque elimination fittings dramatically reduce the opportunity for and impact of human error, thereby decreasing the risk of unscheduled maintenance or exposure of fab personnel to hazardous materials.

Cost reduction

A significant portion of a process tool and gas delivery system's cost involves installation and warranty expenses. During setup of a gas system that incorporates metal face seal fittings without torque elimination, each fitting must be checked for loosening



1. Although tightened in the same manner (center), the OmniSafe fitting (a) includes torque elimination not found in a standard metal face seal fitting (b).

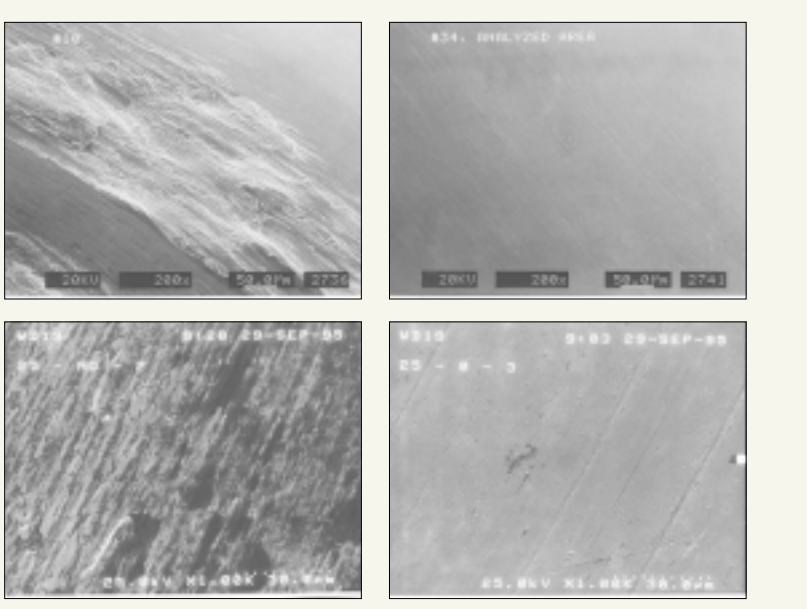
resulting from the shock and vibration of transportation. If detected, the gasket must be replaced and the fittings retightened.

After the system is brought back to leak-tight condition, moisture and contamination must be pumped and purged from the system before it can be recertified, causing preventable time losses. The cost avoidance associated with torque elimination fittings that remain tight during transportation and avoid cross-torque can significantly reduce setup time and warranty cost.

Certification at PMTC

Purity Systems Inc. was the third-party QA/QC company at the PMTC. One of its responsibilities was final certification of the installed process gas delivery systems. Certification included helium leak detection and analytical testing of the specialty gas distribution systems. In the systems where Omnisafe torque elimination fittings were used, the certification process was expedited.

Normally, when testing a gas delivery system, leaks are commonly found in the mechanical connections. Because of the large number of systems tested in the PMTC project, we anticipated finding fitting leaks that would lead to additional service and test time. Because of the absence of leaks on the Omnisafe face seal connections, corrective action on those parts of the system was minimized. In addition, the analytical testing of the specialty gas systems in those areas went smoothly, with low contamination levels for O_2, moisture and particles. Uncoupling torque effects from the process of tightening a face seal fitting reduced redundant, non-value-added activity such as rechecking, realigning, and retightening of fittings by the certification team.



2 . Gland sealing surface after a single tightening, metal face seal fitting, without torque elimination (top left); gland sealing surface after a single tightening, metal face seal fitting, with torque elimination, side view (top right); gland sealing surface after 25 tightenings, metal face seal fitting, without torque elimination (bottom left); gland sealing surface after 25 tightenings, metal face seal fitting, with torque elimination (bottom right).

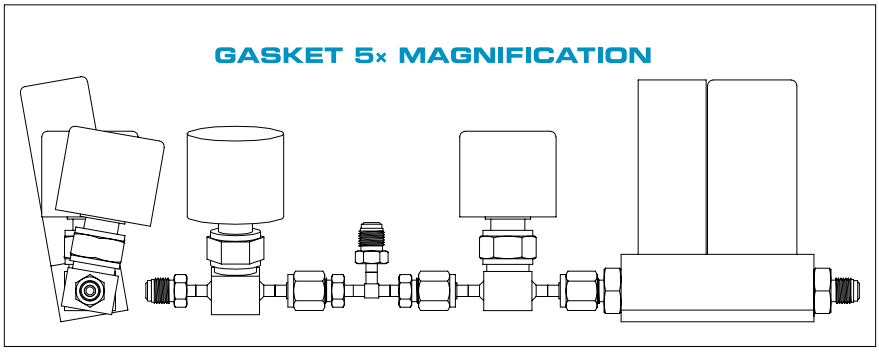
Conclusion

In the Applied Materials PMTC design project we combined "best known methods" from the past 20 years of fab maintenance[6] with our expectation of future needs to achieve a technological approach for gas delivery system fittings that will meet our needs for the next five years and beyond. This includes introducing a new torque elimination-type of metal face seal fitting technology that decreases contamination risk by reducing particles and increases the integrity of the sealing system against loosening from shock and vibration.

These efforts have resulted in an efficient and cost-effective strategy that provides increased safety, enhanced yield and reduced cost of ownership. •

References

1. International Technology Roadmap for Semiconductors, 2001 edition.
2. J.B. Tassano, E. Robinson, *Material Performance*, Vol. 38, No. 9, September 1999, p. 64.
3. D. Laureta, R. Sallot, E. Robinson, *Solid State Technology*, Vol. 40, No. 4, April 1997, p. 89.
4. Mil Standard 810E, Dept. of Defense, Military Standards, "Environmental Test Methods, Eng. Guidelines," (Washington D.C., U.S. Government Printing Office, July 14, 1989).
5. Omnisafe Co., San Jose, www.omnisafe.org.
6. Richard Pontius authored the Process Gas Systems Design and Installation Specifications, Richard_Pontius@amat.com.



3 . When the fitting without torque elimination is tightened, the components twist out of alignment. To prevent this problem, the components are normally attached to a back panel so they cannot rotate. However, now when the fittings are tightened, reverse torque or "wind-up" from the nuts rotating in opposite directions is stored in the tubing. Under shock and vibration, this stored torque will be released and cause the fitting to loosen and leak.

Joe Nardini is operations manager of Applied Materials' PMTC, which includes the Module Development Lab and Applications Labs. During its planning and construction, he was the technical manager responsible for the design and implementation of the entire PMTC facility.

William R. McHaney collaborated on the specification and implementation of the chemical and gas systems for the PMTC facility. He consults, gives lectures, and works with OmniSafe developing UHP gas system solutions for the semiconductor industry.

Gustavo Suarez is the microelectronics division manager and assistant director of operations for Purity Systems Inc. He oversaw the helium leak detection and analytical testing certification for the process piping at the Applied Materials PMTC facility in Building 85.