FEATURE

The Care and Handling of Seals

By Dalia Vernikovsky

This article is the second in a three-part series on high-technology sealing components used to create and safeguard ultraclean manufacturing environments.

There is tremendous financial pressure—and incentive – on today's billion-dollar semiconductor fabs to operate at full capacity without interruption. Of course, pauses in production are still inevitable for scheduled preventive maintenance as well as unpredictable downtimes when processes run out of spec. During any stoppage, it is crucial that fabs have a supply of spare parts available for quick replacements. But having an on-hand inventory of spares does not guarantee that the replacement parts will be used correctly and that fab operations will resume with the same high level of productivity. Nowhere is the correct handling and application of spare parts as vital—and as frequently misunderstood—as with high-purity sealing components.

Figure 1. Non-uniform stretching during installation can exert excessive stress on perfluoroelastomer O-rings, even on formed-to-shape seals such as this one.

Handling Issues

Most semiconductor-grade seals are made with one of two primary materials: FKM, which is well known by the trade name Viton®,[1] or perfluoroelastomers, which are also called FFKM. Of these two options, perfluoroelastomer (FFKM) O-rings are more advanced and generally provide more process-oriented sealing solutions in semiconductor applications.

However, FFKM seals including Perfrez®[2] are highly sensitive to handling, such as undue stretching during transportation and installation. The simple act of fitting an FFKM O-ring into its gland within a piece of semiconductor-manufacturing equipment can damage the seal if it is stretched as little as three percent to five percent (Figure 1). The carbon-fluorine loaded backbones that increase these O-rings' resistance to harsh processing gases and high temperatures make them ideal for chemical and thermal applications, but susceptible to mechanical stresses such as stretching and over-compression. Using too much force to fit a seal into its gland, especially if misaligned, can cause the base of the seal to crack (Figure 2), leading to early failure. Although the cracking may not be apparent upon visual inspection during installation, this type of damage will reduce the seal's integrity.

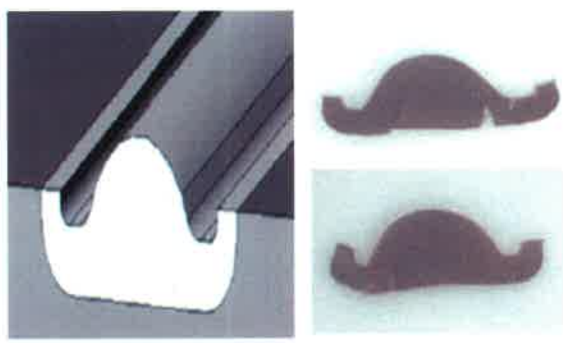

Figure 2. Misalignment and over-compression can cause cracks on the bottom of a seal.

Because of these sensitivities, FFKM seals must be fitted properly. If the housing of the equipment is in the shape of a rectangle, dovetail or other non-round figure, the only way to effectively achieve the right size and shape of seal is to use a mold. This will help to ensure that these specialty seals can be applied properly, providing users with the benefits of longer lifetimes and reduced contaminants. Regardless of composition, no seal should be installed with any type of grease. The seals' glands should be completely cleaned with IPA (isopropyl alcohol) or another compatible cleaning agent, but greases will introduce contaminants that may reduce the performance of the seals. Although most FFKM seals will not absorb grease, any substance applied to the surface of a seal will be outgassed or leached immediately upon use in production, contaminating the manufacturing process.

Process Considerations

Since the gases used to clean reaction chambers between process steps are known to degrade seals, some fab engineers may be tempted to use different gases for reaction chambers. NF_3 has been the semiconductor industry's standard cleaning gas for many years, and its corrosiveness is one of the reasons why durable FFKM seals have become a common choice for use in processing equipment. But switching to another cleaning gas would introduce new variables to the semiconductor manufacturing environment, which must be closely guarded against yield-diminishing factors. The wide variety of available seals puts a premium on selecting the right combination of gases and seals for optimal processing conditions and maximum seal life (Figure 3).

The most inhospitable areas for seals within reaction chambers are found in slit valves, sometimes called gate valves. Due to the dynamics of the valves and actuators that are part of gate valve and door assemblies, seals installed in this area are subjected to highly abrasive forces. For example, if the valves are not pneumatically actuated, which is the case in older models, or if their activation pressure is set high to assure tight gate closures, the wear on the seals will be greater. This can result in premature seal failures, shortened life cycles and particulate contamination. Because wafers come in direct contact with these seals, this area is very sensitive to physical and chemical contaminants. To maximize a chamber's useful life and extend the amount of time between preventive maintenance stops, the FFKM seals in slit or gate valves must be compatible with the process gases used in that toolset.

In the rapidly changing semiconductor industry, advancements from one technology node to the next smaller one come quickly. Issues such as shrinking contamination tolerances, new processing materials and the advent of new fabrication schemes and IC architectures can each affect which sealing solution is the best for a given application. Selecting the optimal seal becomes even more difficult when you consider that it requires an understanding of not only FKM and FFKM properties, but also the fillers, their curatives and base polymers that go into making a semiconductor-grade seal.

For example, there are many types of supporting materials that can be used with FFKM O-rings. The available fillers include barium sulphate, titanium dioxide and silica/silicates. Useful curatives can be peroxide, triazine or bisphenol, each of which determines which cross-linking agent is best; options include bromides and TAIC (Triallyl Isocyanurate). Various blends of these materials can provide more strength or other mechanical or chemical properties. Selecting the right recipe is best done by a knowledgeable sealing expert who is familiar with the seal's intended use to avoid misapplications and unwanted chemical reactions.

NF_3 Plasma Test Results—Weight Loss

Seal type	Filler	30 minutes	60 minutes
		Weight loss (%)	Weight loss (%)
Material A	$BaSO_4$	1.14%	1.90%
Material B	Carbon Black	1.54%	1.99%
Material C	Carbon Black	0.95%	1.19%
Material D	Nano-PTFE	3.19%	6.94%
Material E	Nano-PTFE	3.33%	6.88%
Material F	$SiO_2 + TiO_2$	4.73%	9.67%
Material G	$SiO_2 + TiO_2$	5.03%	9.03%
Material H	SiO_2	4.67%	8.69%

Figure 3. Repeated exposure to NF_3 cleaning gases can cause different degrees of weight loss in seals, depending on their composition.

A Call for Standards

Currently, the semiconductor industry has no international standards to define the myriad of characteristics that describe a sealing component. Without standards, the engineers, equipment operators and service technicians on the fab floor are left without the necessary guidelines for the proper care and handling of today's sensitive seals. Often the only reference sources are data sheets that come with the products. But these can be misleading because seals that look alike in some ways—such as having the same color or durometer value (a measure of elastomeric hardness)—can yield different performances (Figure 4).

These issues have led Applied Seals North America to reach out to the global semiconductor industry and promote greater education on the variety of sealing solutions available today. At the core of this mission is our pledge to work with the Semi-

	Seal #1	Seal #2	Seal #3	Seal #4
Color	Black	Black	White	White
Hardness, Shore A (ASTM D2240)	75	78	80	80
Tensile Strength, psi (ASTM D1414)	1,900	1,673	2,363	1,600
Elongation, % (ASTM D1414)	200	170	159	165
Modulus at 100%, psi (ASTM D1414)	825	1,014	1,087	1,050

Figure 4. Physical property comparisons are not necessarily indicators of seal performance.

conductor Equipment and Materials International (SEMI) trade association to push for the development of a SEMI Standard for O-rings. A task force has already been established. Participants from leading chip makers, equipment suppliers and seal manufacturers attended our first meeting in mid-January. Our objective is to begin defining parameters such as stress relaxation under temperature that may lead to a universally accepted means of measuring some true performance criteria for seals.

Summary

In the fast-paced world of semiconductor manufacturing, it's important to remember the old adage that you cannot judge a book by its cover. In the case of sealing components, quickly grabbing a look-alike seal from the spare parts inventory may not provide the best solution – and may even result in contamination and downtime problems.

It is vital that anyone involved in seal installation and replacement understands the different types of seals and why some require careful handling. Millions of dollars in productivity could be at stake. Developing industry standards will help to provide the critical know-how to avoid costly missteps and pave the way for next-generation sealing technology as the semiconductor industry continues moving forward.

Note: As part of its commitment to industry education, Applied Seals North America offers technical seminars and customer training – both in-house and at open technical forums at industry conferences such as the SEMICON West trade show in July – to stimulate discussion and share its experience regarding how the right sealing solutions can improve the efficiencies of everything from preventive maintenance cycles to fab-wide productivity.

The next article in this series will address the evolving role of seals as manufacturing technologies advance.

1. Viton is a registered trademark of DuPont Performance Elastomers L.L.C.
2. Perfrez is a registered trademark of Applied Seals Co., Ltd.

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