Gallagher recently published its *Failure Modes for Elastomers in the Semiconductor Industry* White Paper, now available for download on our site. This white paper discusses common issues that occur with elastomer seals in the semiconductor industry. The excerpt below is the second section of our new white paper, discussing Loss of Sealing Force, and Extrusion. To download the white paper in its entirety, visit our [Resources Page](#), or click on the image to the right.

## Failure Modes of Elastomers in the Semiconductor Industry

High performance elastomers are found in many applications in the semiconductor industry (see paper titled *Perfluoroelastomers in the Semiconductor Industry*). Though perfluoroelastomer (FFKM) seals are formulated to meet the highest performance requirements of integrated circuit (chip) manufacturers, even these elastomers can’t solve every sealing application nor will they last forever in service. Additionally, end users need to understand subtle performance differences between perfluoroelastomers in the same product line. For example, one product may be better at minimizing particle generation while another may be better for high temperature services.

To deal with elastomer sealing problems that occur in the semiconductor industry, root cause failure analysis is critical to solving issues and preventing them from reoccurring. This type of analysis should be carried out as a joint effort between the end user and the seal supplier/manufacturer. Although it is important to find the solution as quickly as
possible, the seal manufacturer cannot easily assist in root cause analysis without application details, including application temperatures, pressures, chemical environment and seal design. In addition, the seal manufacturer will need the failed part to properly conduct a root cause analysis.

The following sections detail common issues that occur with seals in the semiconductor industry. Examples are often given for o-rings, but are also applicable to other seal shapes.

Loss of Sealing Force

O-ring compression for perfluoroelastomer vacuum seals is typically in the range of 18-22%. The reason for this is the low differential sealing pressure and often high temperatures in the processes. If the initial o-ring compression is 22%, the relative compression on the o-ring, due to thermal expansion will be close to 30% at 300°C. At compression levels above approximately 30%, perfluoroelastomers may crack or split due to high internal stresses. Hence the initial elastomer compression must take into account the application conditions.

When an elastomer seal is initially installed, sealing force is at a maximum. In a compressed state, an o-ring will lose its sealing force with time; it will not return to its original shape when removed from a compressed state. This inability to completely recover to a round (or other original shape), is considered compression set. If the o-ring doesn’t recover at all to its original shape after compression, it is considered 100% compression set and the sealing force will be zero.

There are many factors that can accelerate loss of sealing force. Temperature cycling will decrease an o-ring’s sealing force due to the continual expansion and contraction of the o-ring. Cycling causes the polymer chains to relax and eventually sealing force becomes too low to maintain a seal. It may seem that one option is to simply increase the initial compression on the elastomer to a very high level. This will create a higher initial sealing force, but if the compression is too high, the elastomer may fail prematurely due to splitting.

Extrusion

Extrusion can be caused in three ways. First, the system pressure can be so high that it forces the elastomer too far into the sealing gap and therefore damages the elastomer. This may occur when the sealing pressure differential is 1000 psi or more. However, this is not the case in semiconductor equipment where the pressure differential is typically 1 atmosphere or less. Therefore when extrusion occurs in the semiconductor industry it is often the result of an elastomer expanding and overfilling the groove. The expansion may be due to thermal expansion (plasma or thermal processes) or chemical swell (wet process). When the elastomer volume completely fills the groove space, it then will squeeze out the sealing gap, even if that gap is extremely small.
A very common scenario occurs when a groove is designed for a fluoroelastomer, and the seal is replaced by a perfluoroelastomer due to an increase in process temperature. Since a perfluoroelastomer may have a coefficient of thermal expansion that is 50% greater than the fluoroelastomer, the groove is overfilled during operation and extrusion occurs. To solve this issue, the groove volume has to be increased or the elastomer volume decreased. This problem can be especially difficult to correct for o-rings in dovetail grooves. If the o-ring cross section is reduced to avoid overfilling the groove at temperature, the o-ring may not have sufficient compression to create a seal at room temperature. Attempting to design specialty elastomer shapes to fit in dovetail grooves and seal properly can be extremely difficult, or impossible. The best approach is to properly design grooves to handle all types of elastomers at the highest current or future process temperatures.

The following pictures show an o-ring that has extruded at the inner diameter and outer diameter of a standard rectangular groove. The extrusion gap was minimal (< 0.002"), but at a temperature of 302°F, thermal expansion resulted in elastomer overfill of the groove by 9%.

Figure 1 – Extruded O-Ring

Figure 2 – Close up of O-ring Section
About the Author

Russell Schnell spent more than 37 years as an engineer with DuPont, the last 26 years as a Senior Application Engineer with the Kalrez® perfluoroelastomer parts business. Recognized for his expertise in elastomer applications, seal design and failure analysis, he provided technical support for a wide range of industries including: chemical processing, aerospace, oil and gas, pharmaceutical and semi-con. He created and conducted hundreds of training seminars and workshops in this field and was solely responsible for the development of the Kalrez® Application Guide software tool.

Russ received a Bachelor of Science in Chemical Engineering from Columbia University in New York and MBA from the University of Delaware.