Plasma Process

In plasma process manufacturing, a remote plasma source generates a plasma gas. Note that this type of process is run in a vacuum environment. This gas is composed of ions, electrons, radicals and neutral particles. The flow of these particles must be carefully controlled for etching, deposition, or ashing/stripping processes. These processes often use oxygen, fluorine, and other exotic plasma gases, which are extremely aggressive to many materials. In addition, cleaning processes often use oxygen plasma. Precise control of the plasma gas in the chamber is critical so processes perform as expected, for all the individual chips, across the entire diameter of the wafer.
In the plasma process, which typically operate under a high vacuum, FFKM seals can be critical for maintaining system integrity and providing a long seal life. The term “long seal life” is relative. However these seals must perform at high temperatures, up to 250°C, and still maintain low offgassing and low particle generation to prevent contaminating the manufacturing process. In some cases, under extremely aggressive conditions of plasma gases and high temperatures, 6-8 weeks may be considered a long service life for an elastomer seal.

**Perfluoroelastomer Seal Requirements in the Plasma Process**

Depending on the elastomer seal location, different performance requirements may be needed. Close to the plasma source and leading up to the wafer, numerous ions are present in the plasma gas, making this a “physically” aggressive environment to the elastomer surface. When the ions directly bombard the elastomer surface, they can physically erode the polymer. In these locations, some type of filled elastomer is preferred. Unfilled elastomer seals may degrade too quickly, resulting in a leak. Unfortunately the use of a “standard” filler, such as carbon black, is not suggested. When a carbon black filled elastomer is eroded away, carbon black particles are released and can land on the wafer and cause short circuits in the electrical pathways of chips. In recent years, the development and use of polymeric fillers has provided increased protection to the elastomer polymer backbone while eroding away cleanly and not causing chip contamination. For example, DuPont™ Kalrez® 9100 o-rings utilize a polymeric filler for improved resistance to plasma gases and extremely low contamination.

Other particles in the plasma gas are also present in the plasma stream. However these particles, for example radicals, are considered less aggressive and are sometimes referred to as “chemical” plasma. These particles can still erode the elastomer surface, but at a slower rate than ions. Elastomer seals that are further from the plasma source, not directly in line with the ions generated by the plasma source, or the chamber area below the wafer will mainly see this type of exposure. Seals in this area still need to be “clean”, however non-filled or lightly filled elastomers may be used here because surface erosion is lower. Finally, for the exhaust piping, elastomer cleanliness is of less concern since any elastomer particles generated should be swept out of the system with the exhaust gas.

In the plasma process, especially deposition, material will eventually build up on the
chamber walls. The chamber then requires a cleaning process, typically an aggressive plasma gas to strip away the deposits. These gases may include oxygen plasma, which can be extremely harsh on elastomers by attacking the elastomer surface.

**Plasma Process Applications**

Elastomers can be used in a variety of sealing applications. These applications include: chamber lid seals, window seals, centering rings for flanges, exhaust valves, door seals, valve seals, and as cushioning for wafer transport. These applications have different requirements, so understanding the exact needs for each type of application can maximize service life and yield optimal elastomer performance.

**Door Seals**

These seals can also pose problems a number of problems for elastomers. Door seals usually offer one of two options regarding the seal. In the first case, the door contains a groove, into which an elastomer seal (usually an o-ring) is inserted into a dovetail groove. In the second case, the elastomer seal (cross section can vary) is permanently bonded to the door. Each case is reviewed separately below. Note that many of the concerns regarding door seals are similar to those for other types of seals such as gate or pendulum valves.

Door seals that contain a groove into which a circular cross section elastomer seal is inserted allow for easy replacement of the seal when required due to leakage or particle generation. The seals itself is often an o-ring. Unfortunately the action of the door, when opening or closing, often causes the o-ring to move or roll slightly, which can result in particle generation. In addition, if there is any sticking between the o-ring and the metal against which it seals, the o-ring may partially pull out of the groove when the door opens. This can result in pinching and damage to the o-ring seal the next time the door closes.

Finally, o-rings are not often the best choice for door seal grooves, which have a racetrack design. The use of o-rings can result in localized areas of high stretch when fitted around the groove corners. Excessive localized stretch can result in plasma cracking, if the seal is exposed to plasma gas. A custom seal, which is in a racetrack shape, like the groove, is a better choice. If this design is satisfactory for the application, this door seal is the lower cost option of the two listed.

Bonded door seals offer a number of advantages over the previously mentioned design. Bonded doors can have elastomer seals with custom cross sections to give the best sealing results for the application. Because it is bonded, the elastomer cannot roll when the door is opened or closed, which minimizes particle generation. The elastomer will not pull out of
the groove if there is sticking when the door opens. Lastly, the seal is molded to the door so there is no localized excessive stretch to cause part damage while in use. However, bonded door seals are more expensive than doors utilizing a groove and an o-ring for a seal. Further, when a bonded door fails to seal, it must be thrown away and a new door installed. The choice between these two options comes down to the application and performance requirements.

**Chamber Lid Seals**

Applications such as chamber lid seals often involve the use of large o-rings. The large surface contact area can result in sticking of the o-ring to the lid, making it very difficult to open. In general, perfluoroelastomers tend to be stickier than other elastomers, for example, fluoroelastomers (FKM). Filled elastomers tend to be less sticky than non-filled elastomers. If this is a problem, look for information on which products have lower stickiness. Alternatively, perfluoroelastomers tend to be less sticky at elevated temperatures. Hence if the chamber lid needs to be opened and is sticking at room temperature, raise the equipment temperature to 50°C, before opening the lid.

**Exhaust Valves**

These valves are located at the bottom of the chamber and exhaust the chamber. An example is a butterfly valve that is throttled to achieve the desired level of vacuum in the chamber. The constant movement (fluttering) of this type of valve can result in seal wear. Low seal friction and abrasion resistance is important for these types of services. Also, since these valves are located away from the wafer and exhaust gas away from the wafer, the seals do not have the same rigid particle generation requirements as those used in the chamber. A final consideration is that the area near the exhaust valves may be heated to minimize build-up of material from the process stream. This then becomes a high temperature area and will require the use of high temperature perfluoroelastomers in order to maximize service life.

**Flanges**

Elastomers can be used in flanges, e.g. KF flanges, for piping connections in the gas system. These flanges have a centering ring that contains an o-ring as a seal. Proper sizing of the o-ring is critical or else elastomer extrusion and seal failure will occur. Some AS size rings are often listed as options when the proper size o-ring is a metric size. The AS size o-ring “equivalent” is often larger than the metric size and will result in extrusion of the seal at elevated temperatures. Selection of the correct o-ring size
is especially important for perfluoroelastomers since they have a higher coefficient of thermal expansion compared to other elastomers.

**Wafer Transport**

As the wafers are moved from one chamber to another via a robotic arm, care must be taken that the wafers do not shift position or fly off the arm. Elastomer parts are often used to support, cushion and hold the wafer in place while it is moved. The elastomers must provide sufficient friction to eliminate movement of the wafer while the robotic arm quickly moves in a horizontal plane. However, there should not be any sticking when the arm sets the wafer into position, on a support, in a chamber for a subsequent operation. That is, the wafer must not stick to the elastomer supports when it is placed in the chamber. Any sticking may cause a shift in wafer positioning. Finally, the elastomer should not leave any residue on the wafer after release. These elastomer parts may be either custom parts, or o-rings, depending on the support design.

Another consideration is the wafer temperature. Often wafers may be 300°C or higher when picked up by the robotic arm and contacting the elastomer. Although the wafers cool relatively quickly, the elastomer will see this high temperature for a short period of time. This repeated high temperature exposure can cause the elastomer surface to change its frictional and sticking (stiction) characteristics. Hence the wafer may start to slip slightly on the elastomer pads of the robotic arm after a number of high temperature wafer transports. Care must be taken in the selection of an FFKM material, choosing one that has performance characteristics that resist change over time while in contact with high temperature wafers.
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.