High Purity Seals Rise to ALD Challenge

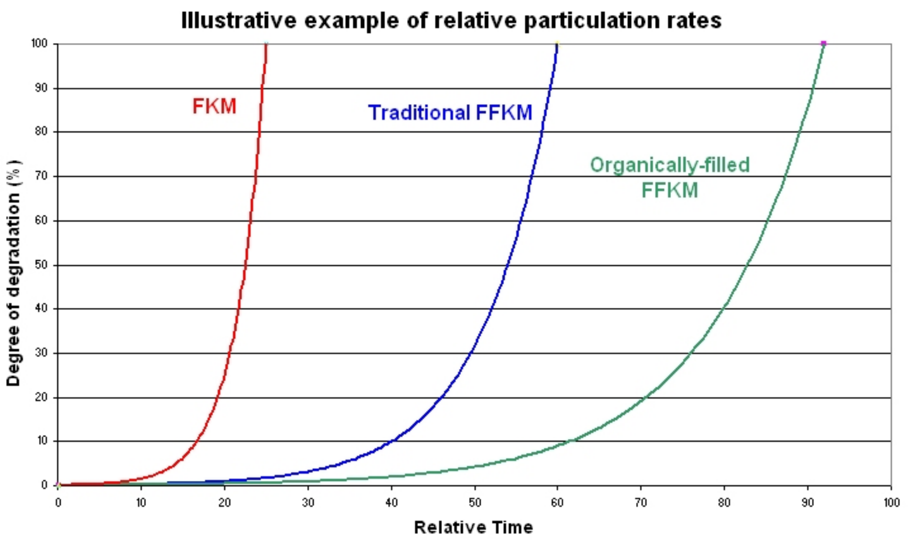
David Holt, Business Development Director, Perlast Ltd., reports on how perfluoroelastomer sealing technology is keeping pace with the purity demands of the latest semiconductor manufacturing process – Atomic Layer Deposition.

Semiconductor engineers will be familiar with the range of sealing materials available to them. In most cases, Fabs will use a perfluoroelastomer (FFKM) or a fluoroelastomer (FKM) material due to exposure to the combination of harsh chemicals and temperatures used in most semiconductor processes. Perfluoroelastomers are often preferred over fluoroelastomers due to their superior resistance to high temperatures and aggressive plasma gases, leading to lower etch rates. The perfluorinated elastomer has a fully fluorinated polymer backbone to give it outstanding chemical resistance at temperatures up to 325^{o}C (617^{o}F).

Over the past five years, Perlast Ltd has led the development of high purity, perfluoroelastomer sealing technologies for semiconductor manufacturing equipment used in HDP-CVD, PECVD, LPCVD and SACVD processes, PVD, etch, stripping and cleaning, RTP/batch process, lithography, and optical equipment. These rely on an organically filled perfluoroelastomer to deliver increased resistance to chlorinated / fluorinated gases, solvents and cleaning agents.

During semiconductor processing, the combination of aggressive gases, solvents and high temperatures degrades the perfluoroelastomer seal. An inorganically filled elastomer releases particulates which can contaminate the wafer. An organic filled perfluoroelastomer, on the other hand, significantly reduces the risk of particulation and thus offers far lower particle counts than inorganic filled perfluoroelastomer, thereby reducing particulation defects.

The graph below shows that a regular, inorganically-filled system such as traditional FKM and FFKM, on degradation, leave substantial residues, generally made up of mixed metal-oxide particles. Obviously, these particles are the cause of 'particulation', and subsequently, having to replace an O-ring before one would actually need to.

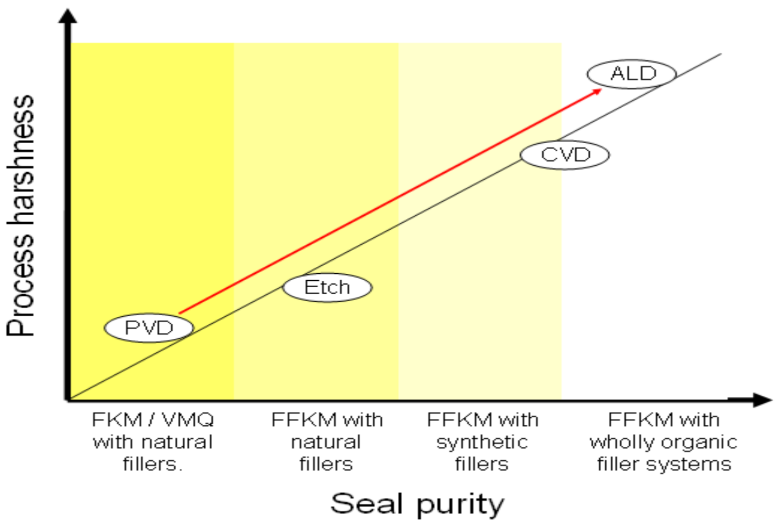


When moving to an organically filled seal, particles are reduced dramatically. This is because an organically filled O-ring uses semi-crystalline fully-fluorinated organic fillers, rather than inorganic fillers. The highest purity technology seals, using organic fillers, degrade to form only gaseous species. This marks a step-change improvement over the standard filled grades which have extractable particles well above 150nm. Subsequently, this can extend a preventative maintenance cycle for deposition process equipment since seals no longer have to be replaced as often due to particle contamination, leading to significant increase in yield.

The ability of high purity perfluoroelastomer seals to withstand high temperatures and aggressive plasma gases has often meant a trade off between purity and mechanical performance. However, recent developments have focused on improving the mechanical properties of high purity perfluoroelastomer grades. For example, the latest addition to the Perlast® range, Perlast® G100XT combines high purity with ultra-low outgassing and excellent mechanical properties to set a new sealing efficiency standard for perfluoroelastomers. The perfluoroelastomer has an exceptionally low compression set of 17% which, together with a low modulus, provides a very high sealing efficiency with low compressive forces. Importantly, the material is highly resistant to stress-induced chemical attack and consequently the effects of plasma attack are greatly reduced during processing. This leads to longer service life and reduced cost of ownership, in addition to near zero particulation.

New ALD technology raises purity requirements

With the growing importance of "nanotechnology" in semiconductor manufacture as organisations seek to create the next generation of high performance processors, existing thin film techniques are being extended to include processes that allow the deposition of nanoscale-level films with greatly improved electrical, chemical, and physical properties. Atomic Layer Deposition (ALD) offers semiconductor designers and manufacturers unprecedented levels of control for ultra-thin films at the atomic level. Regarded by many as the enabling technology for meeting production requirements of next-generation geometries below 65nm, it also creates a demand for unprecedented levels of purity in the seals and gaskets used in ALD equipment.



Engineers making the transition to ALD have their experience of PVD and CVD processes to draw on when selecting seals. However neither of these processes will provide complete answers they are looking for. PVD has relied on low-purity, fluoroelastomer seals for this less technically demanding process. CVD, on the other hand, has seen the greatest developments in seal purity for this high temperature and chemically aggressive process. Yet even here the levels of perfluoroelastomer purity may not be satisfactory for ALD processing.

The main advantage of ALD over other thin film deposition techniques is that ALD-grown films are orthomorphic, pin-hole free and chemically bonded to the substrate. As a result, it is possible to deposit coatings perfectly uniform in thickness inside deep trenches, porous media and around particles. The film thickness range is usually 10-200 nm. However, controlling film quality in ALD processes poses significant challenges compared with earlier deposition technologies. Repeatable stochiometry as well as uniformity control over 300mm wafer surface often require an extremely pure and low contamination environment.

Many sources of contamination can inhibit the ALD reaction, producing poor and low quality films. Sources of contamination can include: chemicals used in the ALD process, tubing, contamination introduced by chamber hardware and its sub-components. A key component in any vacuum system is the elastomeric sealing part used to seal the chamber as it is pumped down to very low-level vacuums. In an ALD process any impurity that either out-gasses or degrades from these elastomers could cause imperfections in film properties.

The adoption of Perlast G100XT perfluoroelastomer seals in ALD equipment has shown that it does not introduce impurities nor deposit materials in the sensitive ALD process. This is a good start to ensuring maximum seal life without compromising wafer quality. Long-term trials are now in progress to assess the impact of Perlast G100XT on the cost of ownership.

Reduction in ALD Equipment Cost-of-Ownership

From a production perspective, the knock-on effect of using organic filled elastomers in PVD processes, for example, has been a reduction in the Cost of Ownership of equipment by as much as 25%. For clarification, Cost of Ownership (CoO) is calculated based on: Variable (Operating) Costs, Depreciation Costs, Indirect Variable Costs and Indirect Depreciation Costs. Seals fall under the Variable Costs and this is one of the main factors in determining the Cost of Consumables (CoC) for a tool. When reducing CoC by utilizing better performing, longer lasting, cost effective seals, it brings down the tool's original CoO numbers.

High purity Perlast perfluoroelastomers in ALD equipment are expected to provide similar low levels of Cost of Ownership. In so doing they are setting a new standard in both seal purity and cost versus performance.