TECHNICAL PAPER

How to avoid the trade-off between purity, plasma resistance and high temperature performance of elastomer seals

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In semiconductor manufacturing, it can be challenging to find a quality sealing material with both high purity and plasma resistance when exposed to 300°C and above. There is often a trade-off between these requirements when searching for the best-suited elastomer for any given application.

Perlast® Helios is a novel FFKM material family offering excellent sealing performance at high temperatures, without trading off any of the material's other key properties. Perlast® Helios G7HA – the first material in the range – was launched in September 2018, and has since undergone various benchmarking tests against the leading sealing materials currently on the market. This whitepaper documents the testing and describes the comparative results.

Perlast® G67P high purity O-rings and sealing components

Plasma Resistant, High Temperature, and High Purity for Semiconductor Applications

Qualification of an elastomer material can carry significant risk, and can prove expensive for semiconductor fabs and OEMs. The risk is heightened if the elastomer part is specified for a particularly critical location, for example, close to the wafers or exposed to plasma. It is therefore important to gather as much data as possible and provide the customer with a good level of confidence before the qualification of a new material starts on their equipment. For this reason, PPE conducted a series of benchmarking tests to reduce the risk of wasting precious tool time or the contamination of equipment.

As a leading seal manufacturer, PPE is often asked for a "material compatible with all processes and chemistries". Unfortunately, it is not so simple. The type of plasma process, chemistries and tools are all important considerations. Additional key requirements include the temperature of the application, the level of purity required to minimize contamination and the expected mean time between cleans (MTBC). The simple answer is there is no one material suitable for all processes in semiconductor applications.

For example, a material which performs very well in oxygen plasma may be comparatively poor in fluorine radical plasma. A thorough understanding of each semiconductor application is crucial in the selection of the right sealing material.

Perlast® Helios G7HA has a fully organic formulation with excellent sealing and plasma properties. It is a 70 Shore A hardness elastomer with continuous high temperature rating of +310°C.

Perlast® Helios G7HA: Facts on plasma resistance

Plasma exposure benchmarking results compare the new Perlast® Helios material against popular competitor grades and some existing PPE materials.

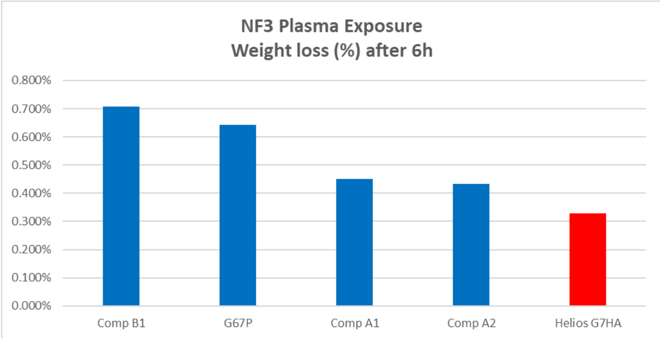

Figure 1: RIE NF3 Plasma exposure, elastomer weight loss percentage after 6 hours

NF3 is one of the most commonly used gases in cleaning, making elastomer seal resistance to NF3 plasma very important. O-rings were exposed to NF3 plasma in an RIE tool for six hours. The Perlast® Helios material was benchmarked against common competitor materials and was shown to have a significantly lower erosion rate, 27% lower than Competitor A1 and A2.

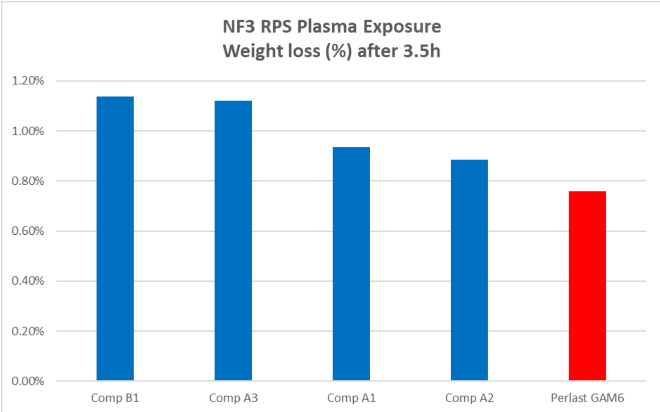

Figure 2: NF3 remote plasma source exposure, elastomer weight loss percentage after 3.5 hours

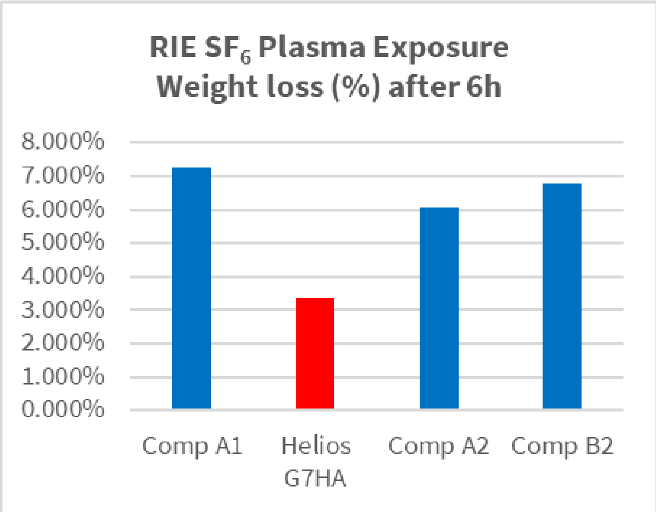

Figure 3: RIE SF6 plasma exposure

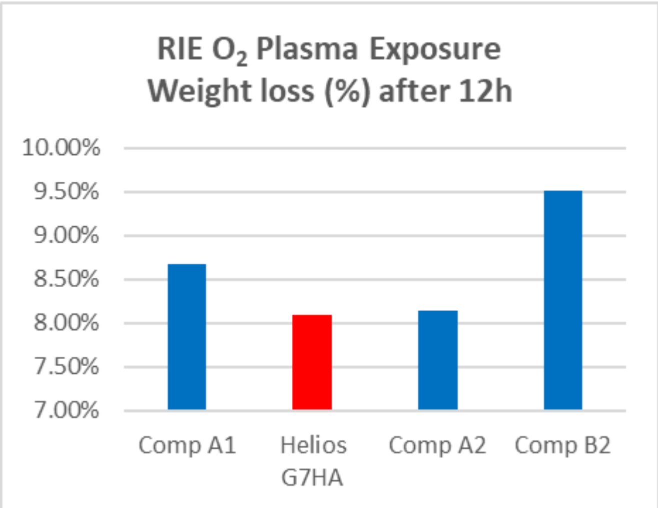

Figure 4: RIE 02 plasma exposure

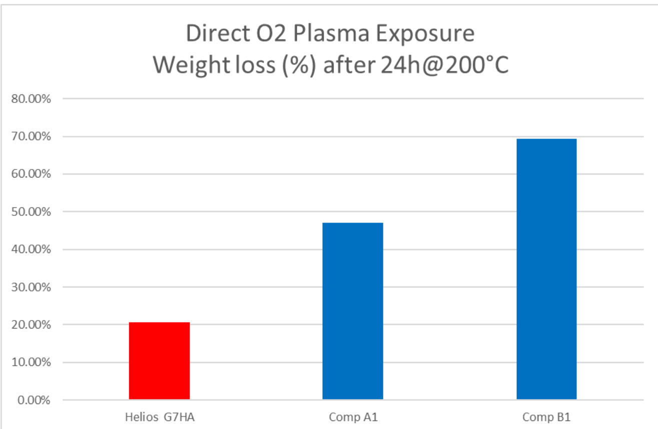

Figure 5: Direct O2 plasma exposure

Perlast® Helios G7HA outperformed competitors in SF6 RIE plasma, O2 plasma and in direct O2 plasma.

Mechanical properties of Perlast® G7HA

Compression set is another important property of an elastomer seal. Compression set is the percentage deformation of a test specimen, at a temperature under a given amount of compression. The test piece can be a button or a standard size O-ring. As the result of compression set test is deformation, the lower value corresponds to better recovery of the shape. G7HA was tested against one of the market leading elastomer sealing materials used in the semiconductor industry (coded in the following figures as Competitor A1).

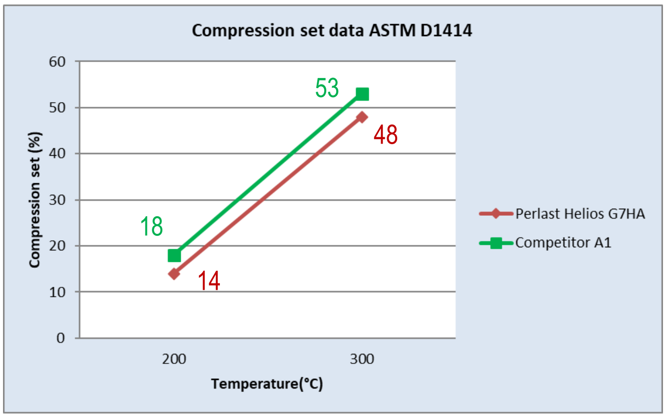

Figure 6: Compression set testing of Perlast Helios G7HA compared to leading competitor grade

However, compression set testing does not always give an accurate indication of the elastomer's sealing performance. Some materials can recover almost fully after compression but the sealing force generated by the elastomer may not enough to provide robust sealing in some applications. Compressive stress relaxation testing provides a much better prediction of long-term sealing performance.

Extended Lifetime of Perlast® G7HA

Compression Stress Relaxation (CSR) testing provides valuable data on the sealing performance of a material. It measures the retention force of an elastomer material at a set temperature. Stress relaxation is a reduction in the counterforce for maintaining the applied strain, the force is not constant but decreases with time when the material ages. This is expressed as a percentage of the initial force in a typical CSR curve.

In this test a standard size O-ring is placed in a load cell and compressed by 25%. It is then placed into a constant temperature oven, which in this case is 300°C. The initial sealing force is measured, then the decay in sealing force measured over a period of time.

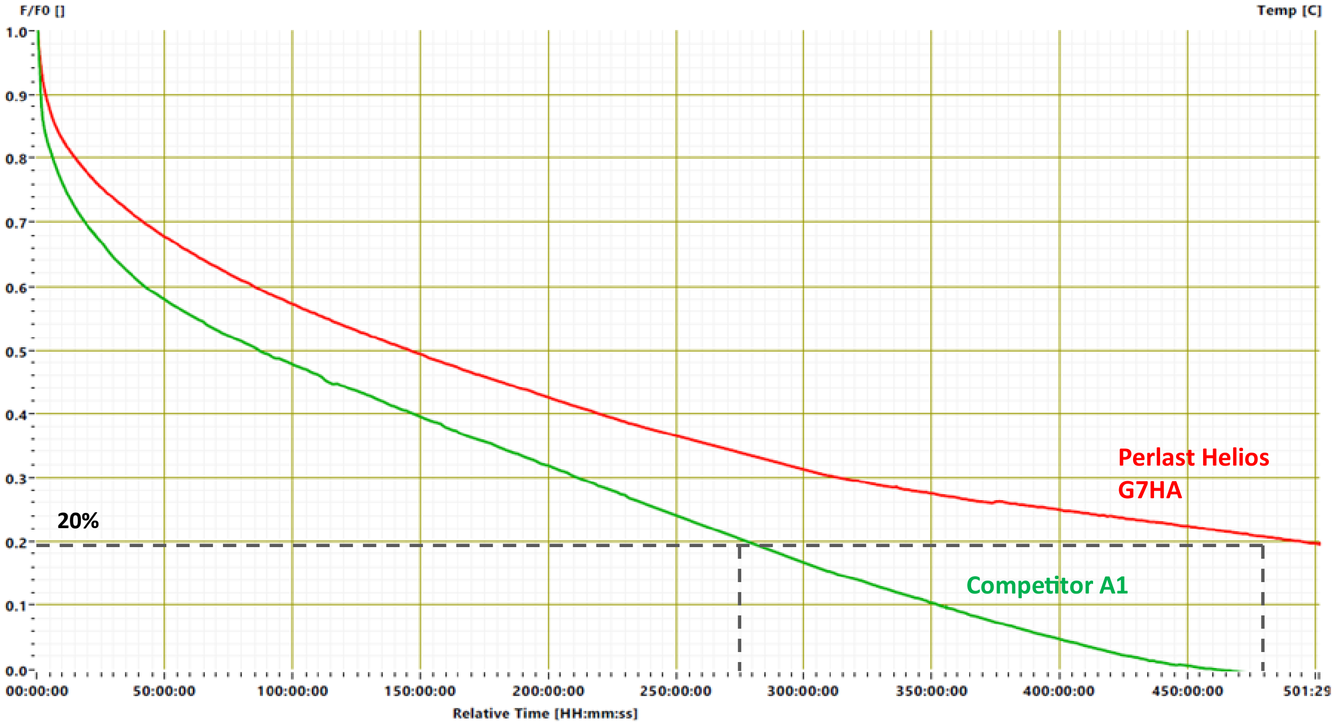

Figure 7: Compressive Stress Relaxation (CSR) comparison between Perlast Helios G7HA and competitor grade

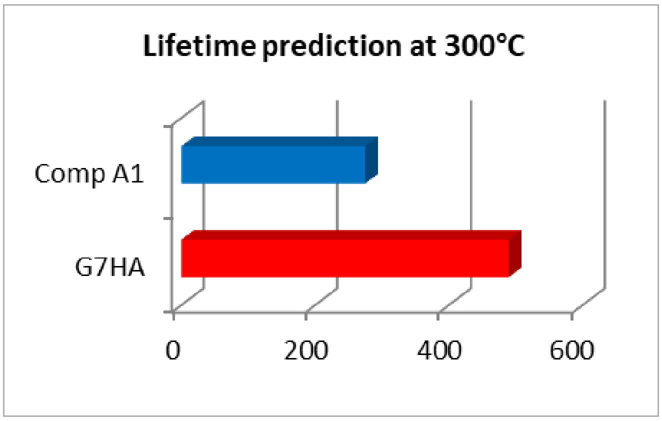

Figure 8: Lifetime prediction at 20% original force

Summary of the CSR results

After 500 hours exposure at 300°C Helios G7HA demonstrated longer lifetime by more than 44% and retained higher sealing force of more than 22% against Competitor A1

The lifetime of a seal is dependent on many parameters, including compression rate, temperature, groove type and the aggressiveness of chemical media. While we cannot model these variables and mirror real-world conditions having the benchmarking data against a common competitor material gives a very strong indication about the real lifetime of the new material.

High-purity sealing materials to reduce the risk of process contamination

It has been proven that fully organic materials reduce the risk of process contamination in critical semiconductor applications. One common method of determining the composition of an elastomer material is thermogravimetric analysis (TGA). This technique measures the mass of a sample while it is heated, cooled or held at constant temperature in a defined atmosphere.

During this test, a small portion of the elastomer material is placed on a very sensitive balance within a furnace. The temperature is increased to 600°C in a nitrogen environment, then air is added to burn off the organic compounds. The temperature is then further increased to 1000°C to only leave any ash residue from inorganic ingredients. If the material is fully organic, there will be no residue left after the test. If the material is inorganically filled then the inorganic fillers – those which are stable at temperatures over 1000°C – will be observed as residue.

Using TGA, Perlast® Helios G7HA, Competitor A1 and one of PPE's leading materials Perlast® G67P were compared. From the results in the graph below (Figure 9), goes down to zero for all the curves, meaning that all materials tested were fully organic.

Another method of measuring the purity of elastomers is trace metal content analysis. In this test the trace metal content of 30 common elements were measured using ICP-MS equipment, by a leading

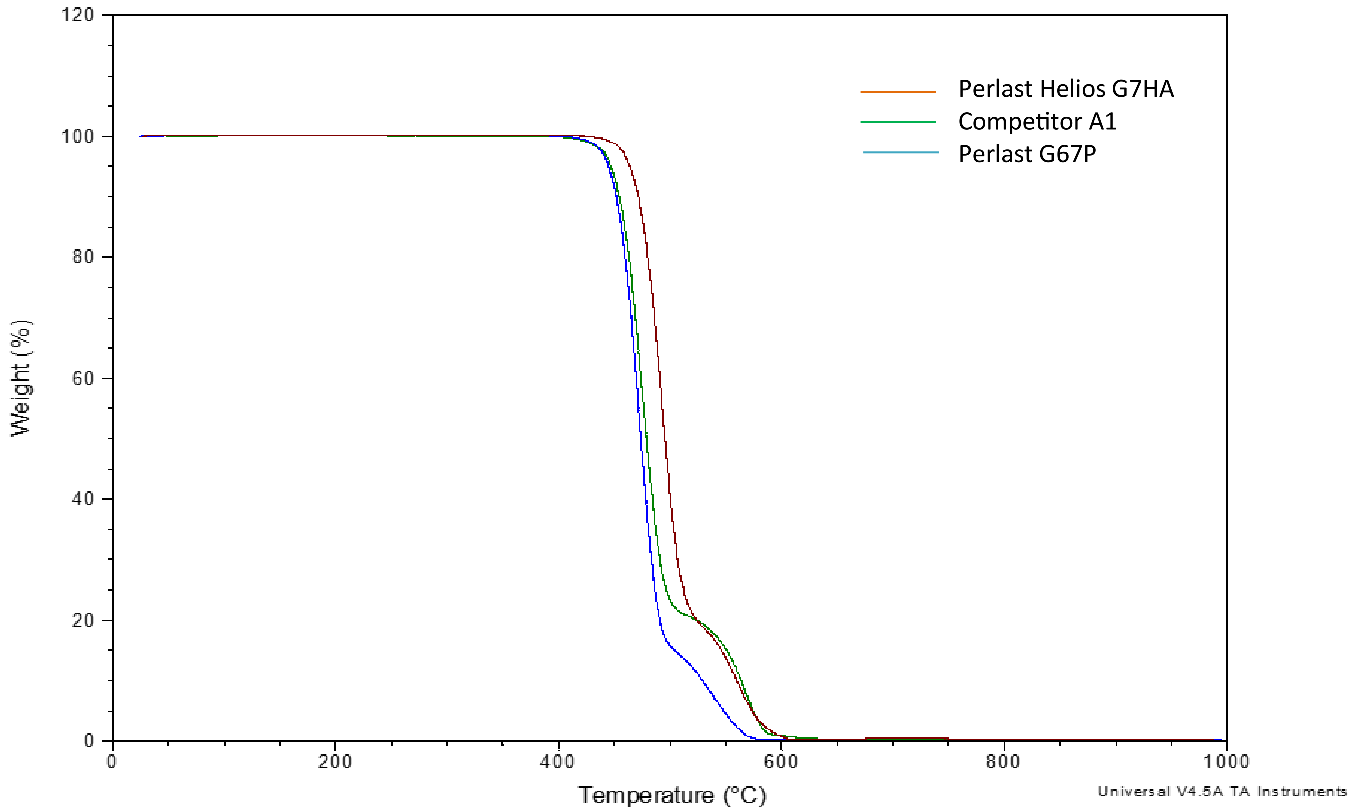

Figure 9: Thermogravimetric analysis (TGA) of Perlast® Helios G7HA compared to competitor grade

third-party analytical lab. Determining the levels of trace metal impurities of elastomers is very important to maintain the high yields in semiconductor manufacturing. The metal elements in elastomers, after plasma etch or contact with process gasses, can end up on wafers and diffuse into it, contaminating the wafer. Using high purity seals will reduce the risk of particulation and improve wafer yields.

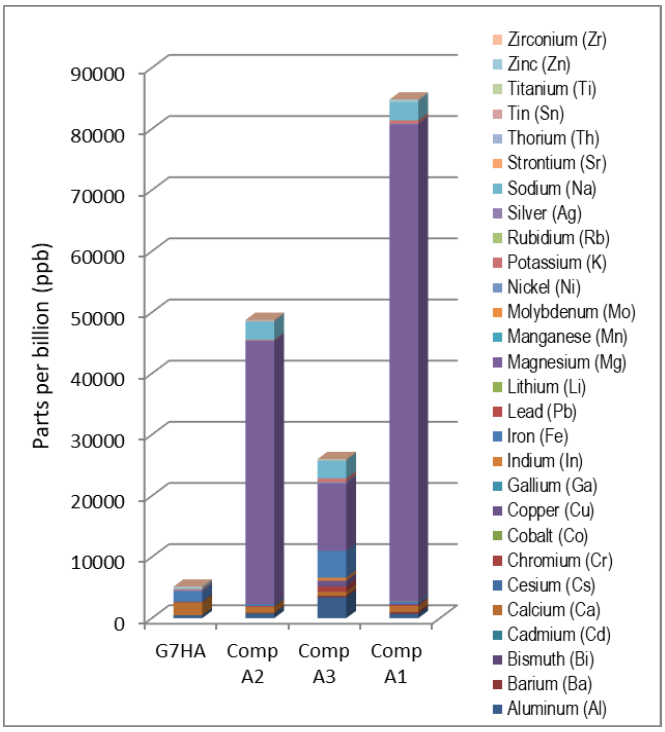

Figure 10: Trace Metal content by ICP-MS Analysis.
Source: Balazs Nanoanalysis Labs

Figure 10 shows the total metal contaminants of PPE materials, which are extremely low. Perlast® Helios G7HA is also a very pure material surpassing the nearest competitor materials by some margin.

Conclusion: Unique mix of Plasma Performance at High Temperature, combined with High Purity

The number of elastomer sealing materials available for semiconductor applications is vast. Until now, for the most challenging and critical environments there has been a trade-off between high purity, mechanical properties, high temperature capability and plasma resistance.

Perlast® Helios G7HA has been extensively tested to demonstrate its unique combination of excellent plasma performance in variety of different chemistries, in addition to excellent high temperature sealing performance and ultra-high purity. With Perlast® Helios G7HA, semiconductor operators no longer have to choose which feature is most important – they can have them all.

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