APPLICATION NOTE

October 2025

Modulus™ MB101 Gel Residue Analysis

Introduction

GelSight® Modulus™ is a non-destructive, contact-based measurement system with an interchangeable lens design capable of delivering traceable results in places where traditional tools cannot access. The gel sensor, engineered with a proprietary contrast layer, conforms to the inspection surface to create images with ideal contrast. Light scattering and reflectivity from the material, surface finish, and ambient lighting often cause artificial spikes, data dropouts, or excessive compute time in non-contact optical measurement systems- challenges that GelSight® Modulus™ inherently avoids. The gel also controls depth of field, enabling fast, easy, handheld measurements with no fixtures or external support required.

Figure 1: GelSight® Modulus™

Figure 2: MB101 Gel Cartridge

GelSight is used across many industries on a wide variety of surfaces, ranging from aerospace composites to transparent materials and operators may find it important to consider what residues could be deposited by any metrology method. GelSight® Modulus™ has a rigorously developed gel that minimizes residual contaminants with a focus on user and product safety for our typical markets. To inform GelSight customers, a study to quantify key compounds gel contact may leave as residues was performed by a certified lab. This included quantification of fluorinated and chlorinated compounds, as well as silicones. GelSight selected to investigate halogens like fluorine and chlorine, as they are known to cause early corrosion on commonly used metals in the aerospace industry, including aluminum, stainless steel, and titanium alloys. Halogens also are controlled under various environmental regulations. Silicone was selected due to known interactions with paints, sealants, and adhesives, as well as impacts on fuel or fluid system performance. The testing was performed by independent lab Cambridge Polymer Group (CPG). CPG is ISO 9001:2015 certified and ISO 17025:2017 accredited (Certification Number 3930.01).

Experiment Summary

This experiment was designed to assess whether silicones, chlorinated compounds, and/or fluorinated compounds are transferred through contact with the GelSight® Modulus™ gel, and if so, quantify the amounts. The ability to clean a surface with acetone to remove any residues was also evaluated. This testing was performed using GelSight's MB101 silicone-free, thermoplastic elastomer gel formulation, which is used for the straight (L1600) and 90-degree (L1690) Modulus™ lenses.

One MB101 calibrated gel cartridge was used to acquire 100 scans of a stainless-steel groove target and two MB101 calibrated gel cartridges were used to acquire 500 scans of the same stainless-steel groove target to create wear on the surface of the gels. The wear was intentionally introduced to simulate the use of used gels in the field, as gel abrasion starts to breakdown the integrity of the top layers which act as a sheathing, further limiting residues when new. This approximates the real-world transfer of residues within the lifecycle of the gel, not just when new, and less likely to leave surface contaminants. All three MB101 gel cartridges were pressed onto separate glass plates repeatedly ten times with a 3.9 kg weight and an approximately two-second hold to simulate a user pressing the probe onto a surface to make a GelSight scan. One of the two glass plates used to acquire 500 scans was then wiped clean with acetone. Each glass plate was rinsed with hexane, and the solution was transferred to individual clean glass vials. The hexane was then partially evaporated prior to transferring the samples to quartz pyrolysis tubes.

As a positive control, a 1μg sample of silicone oil was also evaluated, along with one blank consisting of an empty quartz tube in which a droplet of hexane evaporated. CPG conducted pyrolysis gas chromatography-mass spectroscopy (GC-MS) on the residues left on each glass plate sample, as well as the positive control and the blank. Sample A will refer to the residue left on the glass plate after 10 presses from the calibrated gel cartridge used to acquire 100 scans, Sample B will refer to the residue left on the glass plate after 10 presses from the calibrated gel cartridge used to acquire 500 scans, and Sample C will refer to the residue left on the glass plate after ten presses and cleaning with acetone from the calibrated gel cartridge used to acquire 500 scans. The pyrolysis testing was conducted using a CDS 6200 Pyroprobe, and the compounds released from the pyrolysis sampler were analyzed by GC-MS for characterization of chemical species.

Result

To measure the silicone residue, CPG performed pyrolysis GC-MS. The extracted ion chromatograms (EICs) generated from m/z values typically associated with cyclic siloxanes characteristic of silicone degradation is displayed in Figure 3. Sample A refers to residue left from scans 101-110, Sample B refers to residue left from scans 501-510, and Sample C refers to residue left from scans 101-110 after the surface was cleaned with acetone. The silicone residues were quantified using the sum of the base peak areas of each cyclic siloxane compared to that of the positive control. Fluorinated and chlorinated compounds were not detected as residues across all samples.

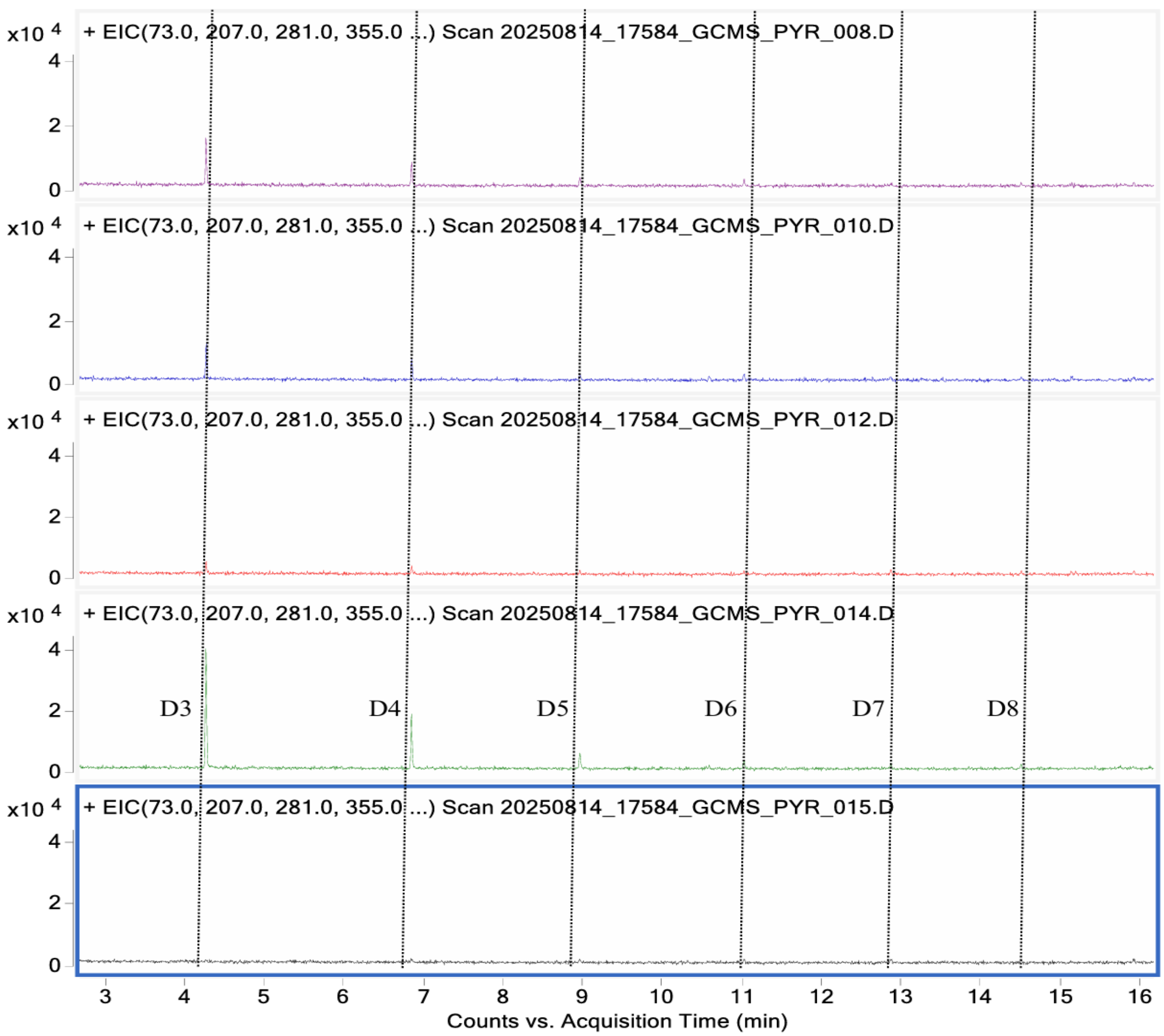


Figure 3: Extracted ion chromatograms for residues from Sample A (purple), Sample B (blue), Sample C (red), positive control (green) and the blank (black). Cyclic siloxanes are highlighted and labeled D3, D4, D5, D6, D7, and D8.

The total silicone residue was measured as a range by CPG and is included in the table below. The measured value was then normalized to the unit contact area using the area of the gel pad in this study, 791.73mm^2, and divided by the number of gel presses to calculate the per contact silicone residue normalized to unit contact area. This calculated result is also included in the table below.

		Sample A	Sample B	Sample C
Total Silicone Residue After 10 Gel Presses	µg	0.4	0.5	0.2
Per Contact Silicone Residue Normalized to Unit Contact Area	ng/mm^2	**0.05**	**0.06**	**0.03**

Discussion

Contamination control is critical to the safety of key components across industries including aerospace and medical. Residues left through any manufacturing or quality control process can lead to undesired effects. Halogens, like fluorine and chlorine, left untreated on surfaces are proven to cause accelerated corrosion. The National Transportation Safety Board (NTSB) has found that aircrafts especially used in coastal operations may be at a higher risk for propeller blade damage due to salt-laden moisture. The corrosion caused by chloride ions exposure can potentially result in propeller blade fracture and fatigue cracking. Failure to detect these damages early could lead to serious catastrophic consequences [1].

Due to the known severity of exposure on critical components in the aerospace industry, GelSight included fluorinated and chlorinated compounds in the residue testing performed by CPG. No fluorinated or chlorinated compounds were present in the results, meaning a scan taken with GelSight® Modulus™ will leave behind no traces of these compounds.

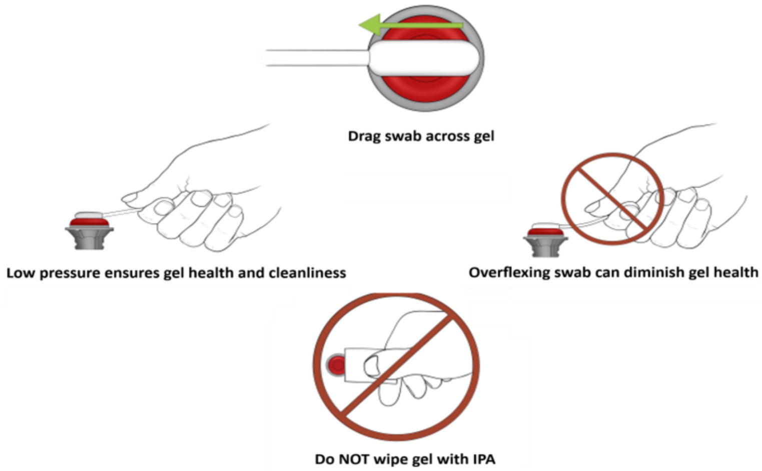
In aerospace applications, silicone contamination can create a hydrophobic layer that prevents successful application and/or bonding of paints and adhesives. Issues with coatings are not just cosmetic, as they can create decreased corrosion resistance or lead to delamination. Given this known sensitivity of some applications to silicone contamination, GelSight specifically set up to test for silicone contaminants. Reference standard IEST-STD-CC1246E, Product Cleanliness Levels – Applications, Requirements, and Determination, was developed to define cleanliness standards for high-reliability systems. Section 5.2.2 of this standard defines levels specifically for Nonvolatile Residue (NVR). The silicone residue can be quantified as an NVR cleanliness level, per Annex C of the standard [2].

Samples A and B, the gel residues without a cleaning procedure, were measured as a range from 0.05 to 0.06 ng/mm^2, which is at an amount less than the silicone oil control. According to IEST-STD-CC1246E, this silicone residue has an NVR level of R1E-2. Sample C, the sample that was cleaned with acetone, further reduced the NVR level of silicone to R5E-3. The acceptability of these cleanliness levels will depend on the specific application. While the MB101 gel formulation does not consist of any silicone-containing ingredients, the presence of cyclic siloxane signals in the results could be attributed to it being produced in a facility that handles silicone-based materials. Thus, the option to clean the surface with acetone after scanning should be considered in the most stringent applications, including fuel tank components and composites.

Acetone is a widely used solvent that is effective at capturing in solution a variety of substances. It is already common practice to use acetone for cleaning surfaces in many environments. The results from the residue testing show that acetone acts to effectively remove silicone residues, so for applications where silicone residues are not acceptable at the reported levels, acetone use to clean the inspection surface is highly recommended.

Gel Cleaning and Best Practices

Use a dry foam swab to gently swipe any dust or debris off the surface of the gel membrane as shown below. Alternative cleaning tools or methods may result in premature gel wear. GelSight recommends the 1” Wide Foam Swab [reference: Uline part number S-25213]



The lifespan of a gel cartridge is application dependent. To prolong the lifespan of the gel, it is important to apply an appropriate level of force to the inspection surface while minimizing shear forces to the gel membrane. The simplest way to keep the gel free of any debris is to clean the inspection surface before acquiring a scan, shown in Figure 4. Exposure to machine oils or isopropyl alcohol will cause premature wear. If alcohol, or any solvent, is used to clean the inspection surface, allow time for it to evaporate before making surface contact with the gel.

Figure 4: Cleaning a glass surface with alcohol and a foam swab

Replacement of the gel is recommended if any wear is present through the red pigment layer, or if an excessive amount of debris is present within the measurement regions.

Conclusion

GelSight® Modulus™ brings a novel capability enabling metrology in locations previously difficult or impossible to non-destructively test. The consumable gel cartridge allows GelSight to see the inspection surface with ideal contrast and does not require surface treatment preparations or coatings. The gel has been rigorously designed using concerns shared by customers to minimize measurement contamination in these sensitive new environments.

While the MB101 Modulus™ gel formulation does not contain any silicone ingredients, use could leave behind trace amounts of residue as quantified in the report. In some sensitive applications, it is important to quantify the residue to ensure it does not exceed a quantity that could affect performance, wear, or cosmetic properties of a component. Per IEST-STD-CC1246E defined standards for cleanliness levels of particles and non-volatile residue (NVR), the silicone residue left behind by a single scan on a worn gel would meet the requirements for NVR level R1E-2. Cleaning the scanned surface with acetone has shown to be effective at reducing the silicone residue to a quantity that would meet an NVR level of R5E-3. No fluorinated or chlorinated compounds were present in any residues tested.

References

[1] NTSB, “Aluminum Propeller Blades: Prevent Fractures with Proper Inspections and Maintenance,” www.ntsb.gov, April 1, 2024. https://www.ntsb.gov/Advocacy/safety-alerts/Pages/SA-090.aspx

[2] IEST-STD-CC1246E, “Product Cleanliness Levels – Applications, Requirements, and Determination," Institute of Environmental Sciences and Technology (IEST), 2013.