Thin Film Protective Coatings for Polydimethylsiloxane Rubber Substrates

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Background Information

Elastomer:

- A type of polymer that can stretch and relax without deforming
- Key number of crosslinks enables elasticity

Polydimethylsiloxane:

- A silicone rubber family
- Thermoset plastic elastomer
- Specific silicone rubber used here is Dow Corning Sylgard-184
- Is clear and has been used as a thermal and electric insulator in aerospace applications
- High Coefficient of Friction with strong "sticking" coefficient
- Attributed to surface properties of the polymer

Uses and Drawbacks

- These types of elastomers are heavily used in the aerospace and medical industry [1,2]
- They are also used as a base polymer to create Phosphor-doped PDMS for smart thermometry. [2.3,4,5]
- Accumulation of contaminants, dust, and frost buildup adversely affect the use of these elastomers in the industries mentioned above

The information above demonstrates the need for an antifouling and anti-frost coating compatible with PDMS that can be made thin enough to be transparent or translucent.

Objectives

- Determine whether 3715 is suitable for or delaminates from PDMS, tested via sonication, compression and COF
- Determine optimal RPM for maximum uniformity and minimum thickness
- Implement & test different ways to reduce surface variation using outgassing, a solvent, etc.
- Determine physical properties of 3715 coated PDMS, tested via compression, contact angle, and COF

Methods and Procedures

Sample Preparation

PDMS (Sylgard 184) and 3715: Using a microbalance, combine the base and curing agent in a 10:1 ratio by mass for 184 and 7:3 for 3715. Mix vigorously. All samples were spun for a total of thirty seconds. Due to a lack of surface uniformity, we attempted different methods for developing uniformity with a thinner film overall. Methods one through five are defined below.

1. 3715 deposited onto surface of 184 sample before it starts rotating
2. Sample spinning at 500 RPM before deposition
3. Sample already spinning at target RPM before deposition
4. Sample was full speed and the 3715 outgassed before deposition
5. Sample has the coating deposited directly onto surface and not spincoated

For 184, place in oven set to 70 degrees for an hour. In the case of 3715 place sample in petri dish and heat on hot plate set to 60 degrees also for an hour. Take microscope images of the edge, general surface, and center.

Data Acquisition

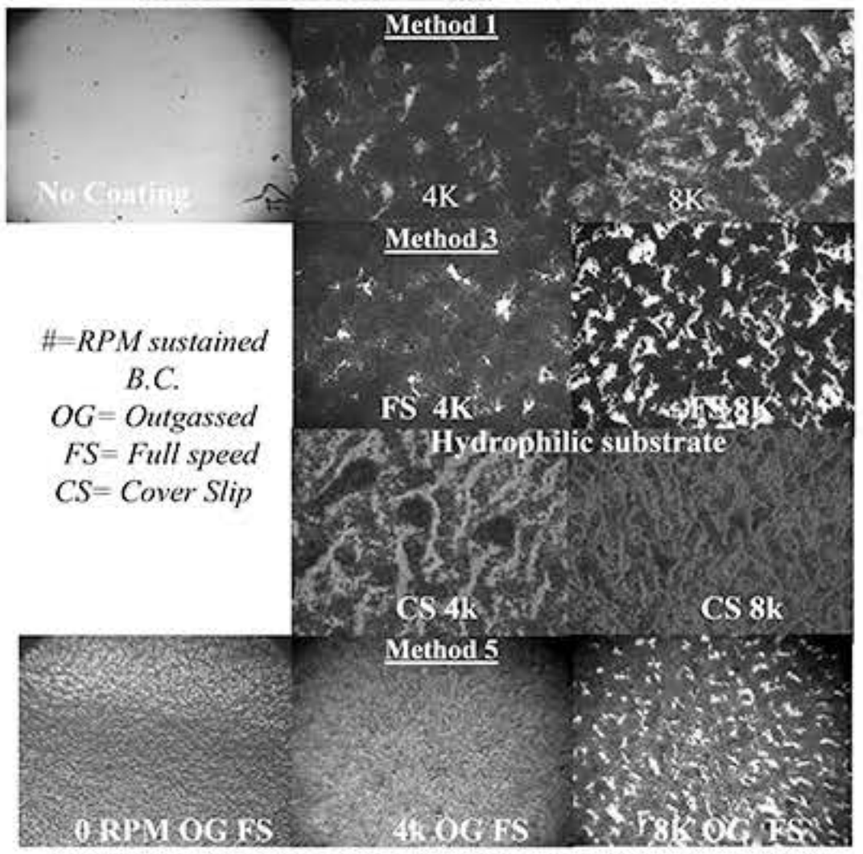
Coefficient of Friction Testing: Set up 20 lb COF gauge on Mark-10 tensile testing machine. weigh samples with steel block and record weight. Adhere sample to block and record load, time, and travel for approximately 25mm.

Contact Angle: Place sample in view of microscope and make sure vial is full. Let the water drop, capture the image, and record the angle measurement.

Delamination Testing: Place sample in beaker filled with isopropyl alcohol and let sonicator run for 15 minutes. Place sample under compression tool bit and gauge, run until 10lbF, repeat five times and record data.

Results

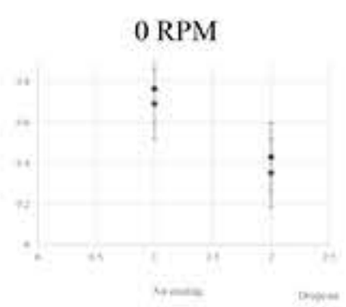
Reflective Microscope Images: Taken with a 5X lens



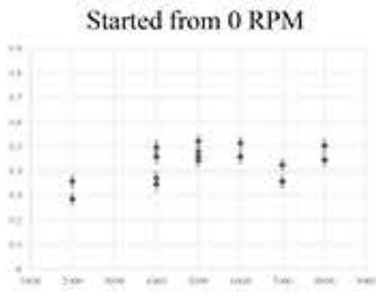
#=RPM sustained B.C.
OG= Outgassed
FS= Full speed
CS= Cover Slip

Above optical microscope depict the clear difference in surface coverage between distinct RPMs and non-outgassed versus outgassed. There is also a clear difference in coverage comparing the hydrophobic substrate to the hydrophilic cover glass substrate.

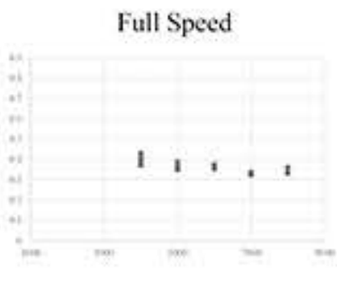
Coefficient of Friction Data: Sorted by method of coverage

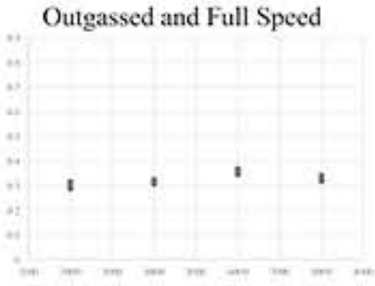


A comparison between COFs of PDMS and manually coated PDMS



A comparison between distinct target RPMs and sample COFs





Above Left: A comparison of target RPMs and sample COFs with deposition occurring at 500 RPM. **Above right**: A comparison of target RPMs and sample COFs with deposition occurring at full speed. **Right**: A comparison of target RPMs and sample COFs with deposition occurring after outgassing of the coating and full speed. Clearly, there is no correlation between RPM, method, and coefficient of friction.

Contact Angle Data: Acquired using an AST VCA Optima

The images and table below are an overview of the contact angle data. The table shows the contact angle average according to method of coating and sorted by approximated coverage inferred from microscope images. The averages are from eight data points derived from four drops using left and right measurements.

Sample	Avg. Angle
4000 RPM OG	113.3375
0 RPM	108.375
4000 RPM FS	109.825
4000 RPM	109.8
PDMS No Coating	111.2125

Conclusion

We were able to determine a basic understanding of the physical properties of PDMS with a thin film coating of 3715.

Sonication

- Mostly indicated no delamination, save for consistently slightly higher COFs for each trial of every sample
  - However, the 8000 RPM method three sample have an uncharacteristically high COF
  - This furthers the conclusion that the 3715 coating partially delaminated

Coefficient of Friction

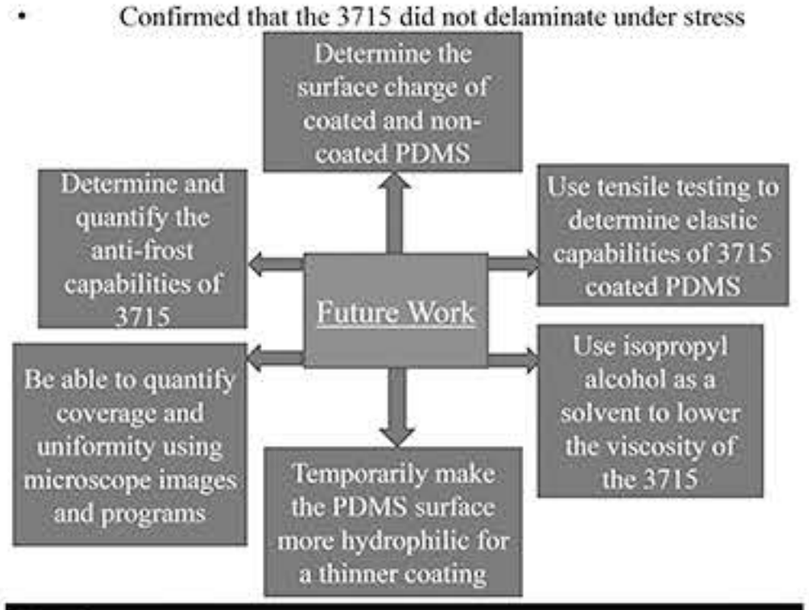
- The data established that at any RPM the COF dropped significantly comparing coated to non-coated
- RPM had no detectable effect whatsoever on the COF of the coated surface.

Contact Angle

- The contact angle data confirmed that both uncoated and coated PDMS are hydrophobic
- Showed slight variation in hydrophobicity
- Showed that coated PDMS was slightly more hydrophobic

Compression

- Confirmed that 3715 bonded to the surface of the PDMS
- Confirmed that the 3715 did not delaminate under stress



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