AFM Imaging and Force Microscopy on Polydimethylsiloxane(PDMS) Efficiency

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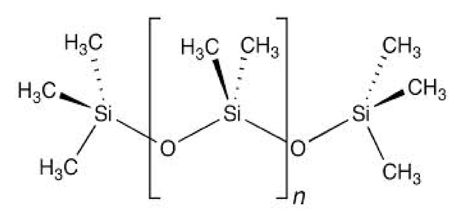
ABSTRACT

Polydimethylsiloxane (PDMS) is a silicon-based organic polymer. PDMS is widely used in many areas including but not limited to; cosmetics, food, hydraulic fluids, anti-aging & anti-foaming and medicine industries. In this research, PDMS will be investigated as an organic substance transfer agent and then improvement methods will be studied.

PDMS structure:



PDMS is widely used to transfer organic& inorganic samples in many labs. For such duty, an ideal PDMS should possess a soft surface to prevent damaging investigated material, appropriate adhesion and leaves minimum residue behind.

Our goal is to discover the minimum-residue-leaving PDMS by manipulating the mixing ratio. Producer company suggests, 10:1 ratio for mixing the base and curing agent and small derivations of 9.9:1 and 10.1:1 ratio mixtures are investigated.

OBJECTIVE

Discover the most efficient: Least residue leaving PDMS mixing ratio as a sample transfer agent.

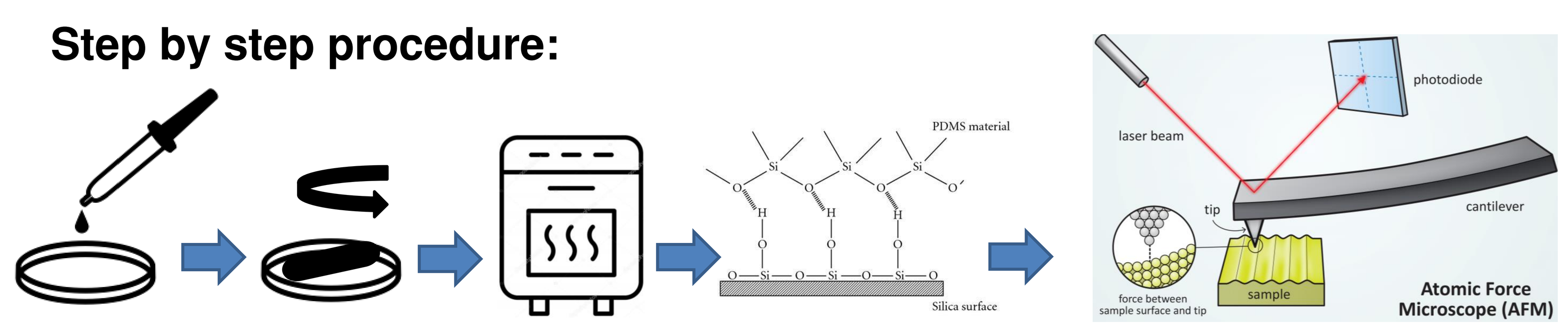
METHODOLOGY & STATISTICAL ANALYSIS

Polymers are uniformly formed, stirred with magnetic rods, cured in an oven while all variables other than the mixing ratio are kept constant. PDMS samples are first placed on gold evaporated SiO_2 chips and then pure SiO_2 chips. Those chips characterized by atomic force microscope. Half of the sample is exposed to PDMS and other half is kept clean. Sample chips are treated with acetone, isopropyl alcohol, and then plasma cleaning before PDMS exposure.

In average, 10 sample scans were performed on both clean and exposed side. Samples are compared according to their "surface area difference" to discover the least residue leaving PDMS ratio.

Statistical approaches such as mid 70% average and frequency distribution weighting are applied in calculations.

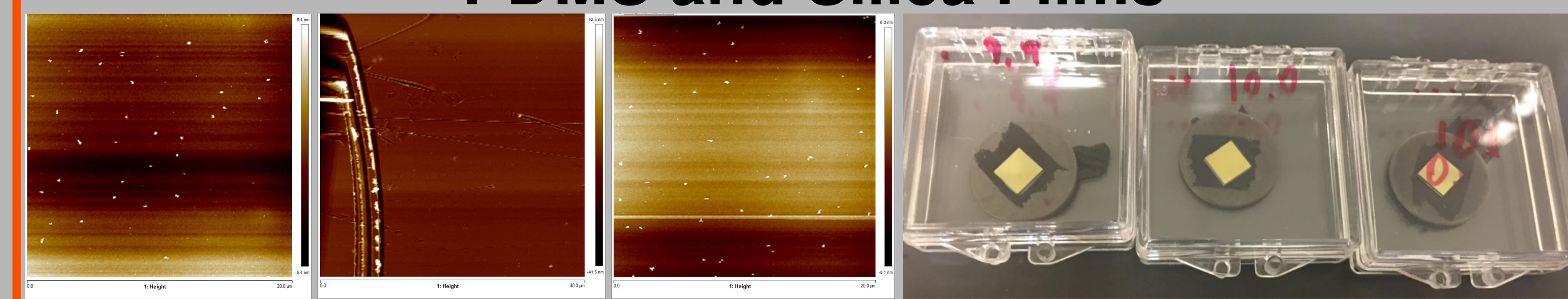
Step by step procedure:



Mix polymer base and curing agent. → Stir with magnetic rod & stirrer. → Cure in an oven. → Clean the silica film and expose PDMS. → Scan with an AFM.

- All variables other than the mixing ration were kept constant.
- PDMS was cured in an oven at 60°C for 24 hours.
- A 0.5 N weight was placed on the PDMS over the silica to increase exposure.
- 10 measurements were taken on both clean and PDMS exposed area.

PDMS and Silica Films



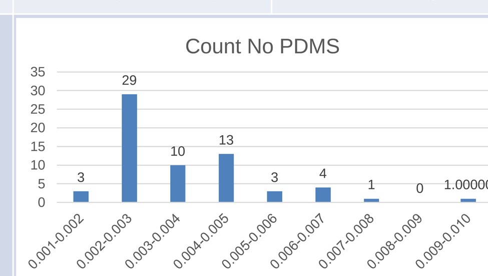
3 sample AFM scans for clean and exposed side. PDMS on gold evaporated silica.

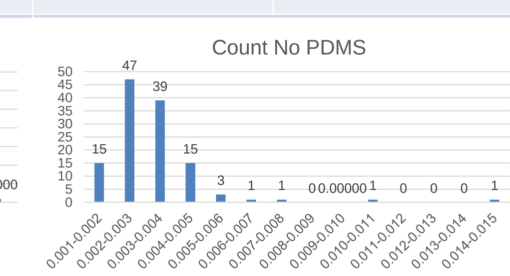
Data Analysis

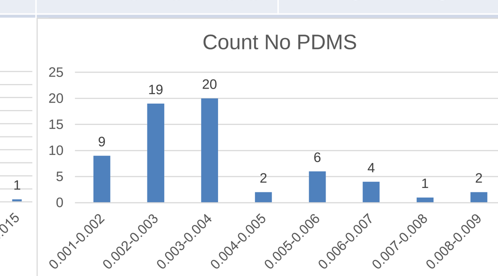
Gold On Silica Film: Statistical touch ups: Frequency distribution and mid 70% average techniques have been applied for a more accurate analysis.

Gold Silica	9.9 : 1 Mix Ratio		10.0 : 1 Mix Ratio		10.1 : 1 Mix Ratio	
Approach1: Raw Data Average(%)	Clean	0.00363	Clean	0.00327	Clean	0.00357
	PDMS	0.00436	PDMS	0.00469	PDMS	0.00660
	Difference	**20.22**	**Difference**	**43.60**	**Difference**	**84.93**
Approach 2: Mid 70% Average(%)	Clean	0.00328	Clean	0.00304	Clean	0.00327
	PDMS	0.00411	PDMS	0.00373	PDMS	0.00455
	Difference	**25.30**	**Difference**	**22.69**	**Difference**	**39.14**
Approach 3: Stat.Frq. Dist.Avg(%)	Clean	0.00321	Clean	0.00285	Clean	0.00277
	PDMS	0.00446	PDMS	0.00292	PDMS	0.00394
	Difference	**39.10**	**Difference**	**-2.23**	**Difference**	**42.49**
Approach 4: Excld.<Mid 70%	Clean	0.00328	Clean	0.00304	Clean	0.00327
	PDMS	0.00465	PDMS	0.00500	PDMS	0.00527
	Difference	**41.76**	**Difference**	**64.48**	**Difference**	**61.45**

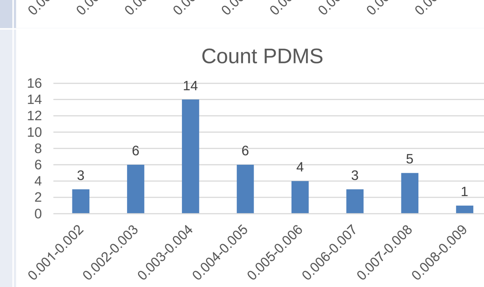
Statistical Frequency Distribution (Clean)

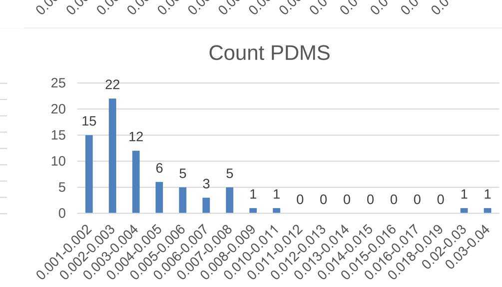


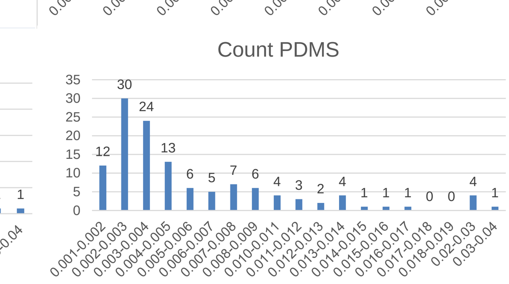




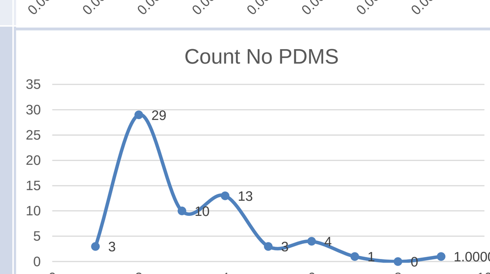
Statistical Frequency Distribution (PDMS)

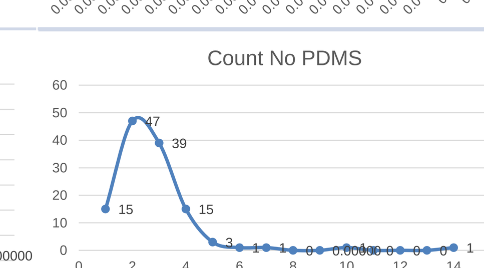


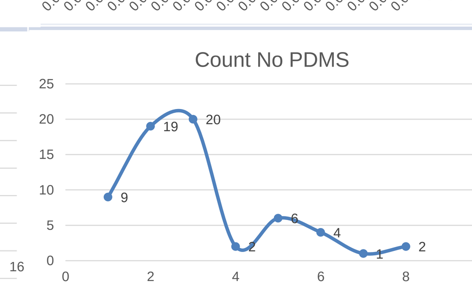




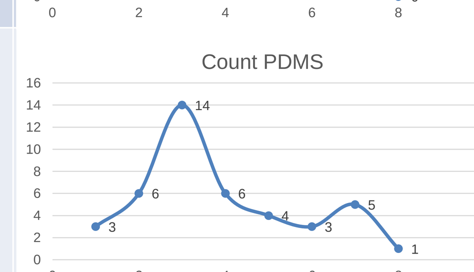
Statistical Frequency Distribution (Clean)

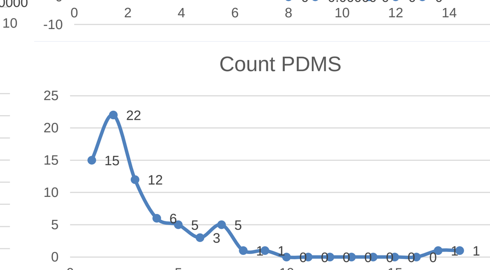


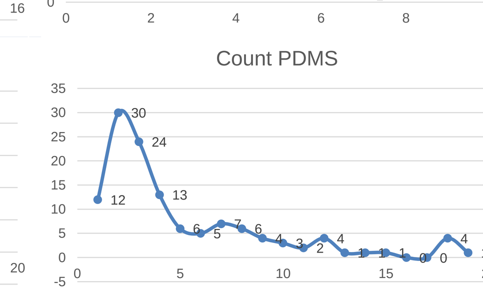




Statistical Frequency Distribution (PDMS)







Approach 1: Raw data average without any statistical method application.
Approach 2: Linear middle 70% average, excluding low 15% and high 15%.
Approach 3: 70% average of the highest frequency distribution sector.
Approach 4: Excluding PDMS data if higher than clean mid 70% average.

SiO_2 Film: Smoother surface with no statistical approach need.

SiO_2	9.9 : 1 Mix Ratio		10.0 : 1 Mix Ratio		10.1 : 1 Mix Ratio	
Raw Data Average (%)	Clean	0.00470	Clean	0.00402	Clean	0.02386
	PDMS	0.00608	PDMS	0.00562	PDMS	0.03817
	Difference	**29.33**	**Difference**	**39.87**	**Difference**	**59.93**

CONCLUSIONS

More than 12 polymers were prepared and tested on both gold and silicon dioxide films. All variables other than mixing ratio were kept constant.

For gold film analysis: 9.9 ratio was the most efficient(least residue leaving) polymer with raw data approach; 10.0 ratio for mid 70% approach; 9.9 ratio for the statistical approach (#3) (excluding negative difference); and 9.9 for approach #4.

Silicon dioxide films resulted 9.9 ratio as the most efficient polymer ratio by leaving lowest residue behind.

Such finding will assist organic and inorganic sample transfer efficiency.

FUTURE APPLICATION

Due to the limited time and availability, a few amount of samples were scanned and analyzed. More samples shall be tested to increase accuracy of the data and results.

Mixing ratio variation of two digits after decimal can be tested for the most efficient bonding ratio.

Curing times and oven temperatures shall be considered for polymer efficiency.

Different polymer ratios for distinctive purpose, such as; best ratio for biomolecule transfer or acidic molecule transfer shall be investigated.

STEM EDUCATION CONNECTION

According to RET program goals, such research shall be integrated in STEM education curriculum.

To fulfil this goal, researcher will create a lesson plan and instructional materials, where students follow complete engineering design process to create the most efficient polymer by altering the mixing ratio of the base and curing agent in the classroom.

Students will be brainstorming about the problem and then collaborate to hypothesize a mixing ratio and then create the polymer.

After curing the polymers, students will test them by using force sensor or spring scale and apply tension on both sides of the polymer until it breaks.

Students will present their methodology and results in class to increase their 21st century skills.

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