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Hydrophobic Recovery of Plasma-Treated Polymethylhydrosiloxane (PMHS) for Electroosmotic Flow in Microfluidic Chips



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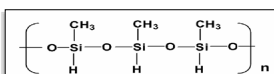
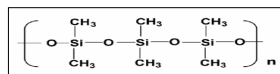
Abstract

Polymethylhydrosiloxane (PMHS) has been investigated as a candidate material for electroosmotic bioseparation processes in microfluidic devices due to its ability to be readily modified by hydrosilation. Furthermore, its low wavelength transparency makes it favorable for sample detection by UV methods. Plasma treatments prepare the surface for sustaining electroosmotic flow within the microchannels. However, the effect of plasma treatment decays over time and is evident in the changes in surface wetting. This study presents the experiments that were conducted in order to determine the hydrophobic recovery of plasma treated PMHS. Wetting angle measurements over a period of 96 hours were taken and analyzed. In addition to PMHS, the wetting angles of polydimethylsiloxane (PDMS) were compared. The most notable observation was that PMHS varied only by 25% over a 96 hour period whereas PDMS varied by 43%. Thus, the hydrophobic recovery of PMHS is slower than PDMS and is found to be far more stable.

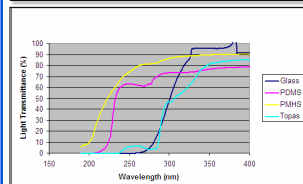
Background

Advantages

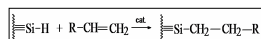
- Optical transparency in ultraviolet range (200-250nm)
- Low wavelength makes it favorable for UV detection
- Readily modified by hydrosilation for microchannel-based separation processes



PDMS (left) has wide-spread usage as a substrate material for microfluidic devices. Instead of a methyl group in PDMS, PMHS (right) has a hydride group along its siloxane backbone, making it well-suited for chemical modification by hydrosilation.



Comparing the UV optical transparency of PMHS with other materials commonly in use for microfluidic devices[1].



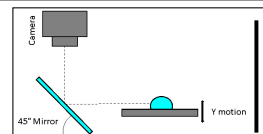
The hydrosilation reaction can be used to alter the surface by attaching functional moieties to the intermediate Si-H bond of PMHS. This creates a product that has desired surface properties for electrophoresis, such as resistance to accumulated adsorption of proteins on microchannel walls

[1] Lee, S. J.; Ghandehari, E. M.; Kapil, M. A.; Vey, M.; Paeck, J. J., "Polymethylhydrosiloxane (PMHS) as a functional material for microfluidic chips", *Journal of Micromechanics and Microengineering*, vol. 16, no. 2, Feb. 2006

Methods

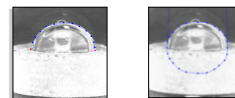
Test Parameters

- Measurement Period: 96 Hours
- Total Measurements: 54 (18 PDMS, 18 PMHS, & 18 PDMS/PMHS)
- Test Setup: 5 samples each for hour 24: 2 samples each for hours 48, 72, 84, 96
- Plasma Settings: RF Power level - 30 Watts
- Chamber pressure - 500 mtorr
- Contact Angle Method: Sessile Drop Technique
- Contact Angle Measurement tool: Ecoles Polytechniques Fédérales - DropSnake Measurement Program [2]
- Storage temperature: 18°C
- Droplet Liquid: DI-ionized water
- Droplet Size: 20 μL



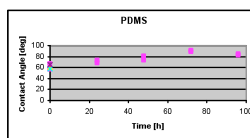
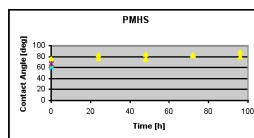
Contact Angle Setup:

The substrate was placed on the horizontal platform. The tip of a microliter pipette was positioned 1 cm away from the surface. The image was then recorded and the contact angle was measured using a computer software.



[2] A.P. Steiner, G. Koth, D. Segel, L. Barthelet, F. Hoffmann, "A Snake-Based Approach to Accurate Determination of Sessile Contact Angles and Contact Angles", *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, vol. 288, no. 1-3, pp. 60-65, September 2006

Results

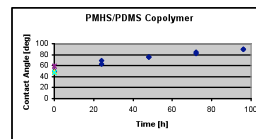


Significant Findings

The most notable observation was that PMHS varied only by 25% over a 96 hour period whereas PDMS varied by 43% and the copolymer by 71%.

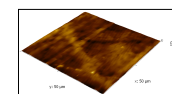
- Initial contact angles for PMHS, PDMS and PDMS/PMHS copolymer were 65, 60, and 50 degrees respectively.

- The contact angles for both PMHS and PDMS increased with time and leveled to 84 degrees. PDMS/PMHS ended at 89 degrees [3].

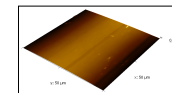


[3] D. Steiner and C. Khan-Mahd, "Hydrophobization and hydrophobic recovery of PDMS by oxygen plasma and chemical treatment: a 3000 investigation", *Surfaces and Interfaces*, W. Chemical, vol. 12, pp. 168-175, 2019

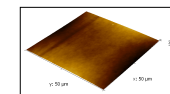
Discussion



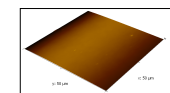
Pristine PMHS



Plasma treated PMHS



Pristine PDMS



Plasma treated PDMS

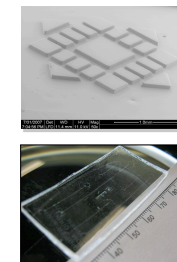
Topography

- Pristine PMHS and PDMS have more surface roughness
- AFM Images show plasma treated PMHS and PDMS become more smooth

- Decreases Stability
- Slows down hydrophobic recovery process
- Lower contact angles with higher variability

Conclusion

- The hydrophobic recovery of PMHS is slower than PDMS or PDMS/PMHS copolymer.
- PMHS is found to be far more stable in comparison to PDMS and PDMS/PMHS copolymer stabilizing within hours to a contact angle of 84 degrees.
- In addition, both PDMS and PDMS/PMHS copolymers start at lower values for contact angles end with substantially larger values.



Acknowledgments

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