Proceedings of the ASME 2010 3rd Joint US-European Fluids Engineering Summer Meeting and 8th International Conference on Nanochannels, Microchannels, and Minichannels
FEDSM-ICNMM2010
August 1-5, 2010, Montreal, Canada

FEDSM-ICNMM2010-31241

IMPROVING THE ELECTROKINETIC PROPERTIES OF PDMS WITH SURFACE TREATMENTS

Zeyad Almutairi
Department of Mechanical and Mechatronics Engineering
University of Waterloo
Waterloo, ON, N2L 3G1
Canada
Email: zalmutai@uwaterloo.ca

Carolyn Ren*
Department of Mechanical and Mechatronics Engineering
University of Waterloo
Waterloo, ON, N2L 3G1
Canada
Email: c3ren@mecheng1.uwaterloo.ca

Leonardo Simon
Department of Chemical Engineering
University of Waterloo
Waterloo, ON, N2L 3G1
Canada
Email: lsimon@uwaterloo.ca

INTRODUCTION

PDMS (Polydimethylsiloxane) is widely used as a microfluidic chip material for various applications due to its desirable properties [1, 2]. However PDMS has several drawbacks that limit its utilization in a number of microfluidic applications [1–4]. Properties such as the hydrophobic nature, sample absorption, and low electrokinetic properties (low zeta potential) are some issues that must be considered before using PDMS for numerous applications [3]. In many PDMS based chips electroosmotic pumping is used for fluid flow and sample transport along the microchannel networks. Simplicity of implementation in microfluidic chips, fast response time, and the plug-like velocity profile are the major advantages of electroosmotic flow compared to other fluid pumping techniques [2]. This type of flow utilizes the formation of electric double layer (EDL) in microchannels and the movement of ions under an applied external electric field. Thus, the surface properties of the channel material and liquid properties (ionic concentration, pH, and viscosity) play major roles in electroosmotic pumping for different solutions in microchannels.

To overcome the unwanted characteristics of PDMS surface property alteration received interest in the microfluidics community. One approach for changing the surface properties of PDMS to a desirable state is done by plasma treatment [2,4]. This treatment is a one step procedure that changes PDMS to a hydrophilic condition [2, 4]. Moreover the zeta potential of plasma treated PDMS is higher than native PDMS. However, plasma treated PDMS surfaces regain their hydrophobic nature with time due to the diffusion of non-cured PDMS molecules to the surface [4]. This phenomenon has a crucial effect on electrokinetic flow since it changes the pumping stability with time [2]. For this reason other approaches and protocols for treating PDMS in order to get stable surface properties are important.

In this work a number of chemical based surface treatments for PDMS were studied. The major goals of the treatments were: increase the zeta potential of PDMS microchannels, stabilize the electrokinetic properties with time, and to maintain a hydrophilic condition for PDMS surfaces. The surface treatments that were examined are chemical based surface treatments [1, 2, 5, 6]. The attempted treatments were: grafting of monomers (HEMA-hydroxyethyl methacrylate and PEG-polyethylene glycol based monomers) on the PDMS surface [5,6], pre-doping PDMS with monomers [1], and extraction of PDMS [2]. Several experimental studies were done on each attempted protocol in order to fully understand the effects of the treatments on the PDMS surface. The characterization of the surface treatments were done with: static contact angle observations, dry storage analysis, zeta potential measurements, and chemical group identification.

*Address all correspondence to this author.

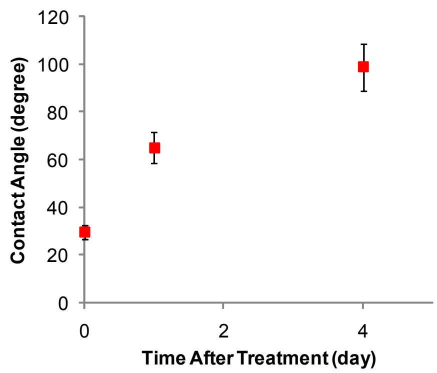

Figure 1. STATIC CONTACT ANGLE CHANGE WITH TIME FOR PDMS SAMPLE GRAFTED WITH HEMA.

EXPERIMENTAL FINDINGS

Experimental results from this work show that some of the attempted surface treatment protocols have improved the stability of the hydrophilic state in PDMS. This was observed in different monomer grafting and PDMS extraction protocols. Results from static contact angle observations and dry storage analysis of treated microchannels confirmed this finding. Typical experimental outcomes from the contact angle and dry is presented in Fig. 1.

As observed in Fig. 1 the static contact angle changes with time for HEMA grafting samples. However, the degree of change is less compared to plasma treated PDMS [7]. This helps improve the stability of the hydrophilic properties for PDMS. Results from the dry storage analysis for HEMA treated PDMS showed similar trend. The same analysis was applied for all the attempted treatments and results changed for some treatments.

Further examination of the attempted surface treatments was done with ATR-FTIR measurements to find changes in the surface chemistry and indicate the newly formed chemical groups. For the PDMS extraction and pre-doping there were no observed changes in the surface chemistry compared to PDMS samples [7]. The samples that were treated with monomer grafting (PEG and HEMA) showed formation of new chemical groups. Figure 2 presents the infra read spectra obtained for HEMA and PEG grafted PDMS samples.

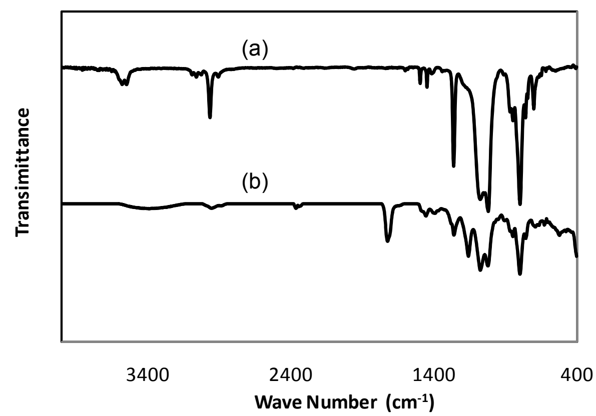

Figure 2. INFRARED TRANSMITTANCE SPECTRA OF PDMS SAMPLES TREATED WITH MONOMER GRAFTING PROTOCOLS. (A) PDMS SAMPLE GRAFTED WITH PEG (UV-INDUCED GRAFTING), AND (B) PDMS SAMPLE GRAFTED WITH HEMA (PLASMA-INDUCED GRAFTING).

Conclusion

In this work different PDMS surface treatment protocols were attempted and throughly studied. Characterization of the outcome of the treatments were done with four experimental techniques. It was observed that the PDMS extraction protocol along with plasma treatment gave the most stable surface properties. Also monomer grafting protocols improved the stability of the surface properties of PDMS. Moreover, the chemical structure of the PDMS surface changed the monomer grafting.

ACKNOWLEDGMENT

The authors acknowledge the support of research grants of the Natural Sciences and Engineering Research Council, and the Department of Mechanical Engineering at King Saud University for sponsoring Zeyad Almutairi.

REFERENCES

[1] Luo, Y., Huang, B., Wu, H., and Zare, R. N., 2006. "Controlling electroosmotic flow in poly(dimethylsiloxane) separation channels by means of prepolymer additives". *Analytical Chemistry,* ***78***(13), pp. 4588–4592.

[2] Vickers, J. A., Caulum, M. M., and Henry, C. S., 2006. "Generation of hydrophilic poly(dimethylsiloxane) for High-Performance microchip electrophoresis". *Analytical Chemistry,* ***78***(21), Nov., pp. 7446–7452.

[3] Toepke, M. W., and Beebe, D. J., 2006. "PDMS absorption of small molecules and consequences in microfluidic applications". *Lab on a Chip,* ***6***(12), Dec., pp. 1484–1486. PMID: 17203151.

[4] Chen, I., and Lindner, E., 2007. "The stability of Radio-Frequency Plasma-Treated polydimethylsiloxane surfaces". *Langmuir,* ***23***(6), Mar., pp. 3118–3122.

[5] Hu, S., Ren, X., Bachman, M., Sims, C. E., Li, G. P., and Allbritton, N. L., 2004. "Surface-Directed, graft polymerization within microfluidic channels". *Analytical Chemistry,* ***76***(7), Apr., pp. 1865–1870.

[6] Bodas, D., and Khan-Malek, C., 2006. "Formation of more stable hydrophilic surfaces of pdms by plasma and chemical treatments". *Microelectronic Engineering,* ***83***(4-9 SPEC ISS), pp. 1277–1279.

[7] Almutairi, Z., 2008. "Electroosmotic flow characterization and enhancement in pdms microchannels". Master's thesis, University of Waterloo.