SIMPLE AND FUNCTIONAL MODIFICATION OF PDMS SURFACE FOR MICROCHANNEL ELECTROPHORESIS

Takanori Shirai, Madoka Takai* and Kazuhiko Ishihara

Department of Materials Engineering, School of Engineering, The University of Tokyo, JAPAN

ABSTRACT
An optimal condition to modify poly(dimethylsiloxane) (PDMS) surface for microchannel electrophoresis in a quick and simple manner was investigated. 2-methacryloyloxyethyl phosphorylcholine (MPC), which has suitable property of protein adsorption resistance, was graft polymerized from the PDMS surface using UV irradiation. The resulting surfaces were characterized by zeta potential, and protein adsorption test. The high graft density of MPC polymer on PDMS can suppress both non-specific protein adsorption and electroosmotic flow (EOF).

KEYWORDS: Surface modification, PDMS, Electrophoresis, 2-Methacryloyloxyethyl phosphorylcholine (MPC) polymer, Surface Zeta Potential

INTRODUCTION
Microchannel electrophoresis has attracted increasing attention, as it has high sample throughput, low consumption of sample and reagents, and automatic control. Among various microfluidic systems, PDMS-based microfluidic devices are good candidates due to its low-cost, easy fabrication, etc. However, its inherent hydrophobicity causes non-specific protein adsorption, and its native negative charge also results in uncontrollable electroosmotic flow (EOF). These limitations make electrophoresis separation irreproducible. Therefore, surface modification is urgent for PDMS microchannel electrophoresis. Surface modification of PDMS by biocompatible polymer is a promising approach. However, physically coating on PDMS is not durable during the protein separation, and coating through swelling and deswelling process[1] is lacking in its uniformity. To solve these disadvantages, photoinduced graft polymerization on PDMS has been investigated for the microchannel electrophoresis in this study. The “grafting-from” polymerization of MPC on PDMS using UV light has advantages in simplicity and efficiency[2][3]. MPC polymer has excellent antibiofouling properties that resist protein adsorption and cell adhesion, and non-charged property. In this report, evaluation of non-specific protein adsorption in the microchannel and zeta potential of the PDMS sheet were conducted.

EXPERIMENTAL
Surface oxydized PDMS sheet and microchannel were immersed in acetone solution containing benzopheone and dried. Then the photo-induced polymerization was curried out. The protocol was shown in Figure 1 and Figure 2. The MPC polymer grafted PDMS surfaces of sheets were characterized by X-ray photoelectron spectroscopy(XPS), and surface zeta potential of the samples were measured by light scattering photometer. Fluorescein isothiocianate (FITC) labeled bovine serum albumin (BSA) in phosphate buffered saline (PBS) was used as the protein adsorption test, the amount of protein adsorption in microchannel surfaces was measured by the fluorescence intensity.

---

978-0-9798064-3-8\&TAS 2010/$20©2010 CBMS

14th International Conference on Miniaturized Systems for Chemistry and Life Sciences
3 - 7 October 2010, Groningen, The Netherlands
The precursor of PDMS (Silpot 184®, Dow Corning Toray Co., Ltd.) and cross-linker (Catalyst of Silpot 184®) were fully mix at the ratio of 10:1 by mass. The mixtures were evenly spread on a glass plate and degassed in vacuum for 2hr. The curing reaction was then carried out at 60°C for 6hr. The samples were cut into pieces (20 mm × 30 mm, 1.5 mm thickness). The PDMS was etched by oxygen plasma (85 W, 100 mL/min gas flow) for 30s in advance. The membrane was immersed in a 30 mL acetone solution containing benzophenone (50 mM) for 1min. The photo polymerization on the PDMS surface was carried out. After the reaction, the membrane was successively washed in water and dried in dark-vacuum condition at room temperature. The atomic ratio of the coated surfaces was investigated by X-ray photoelectron spectroscopy (XPS). The zeta potential was measured by light scattering photometer.

Microchannels (20 mm×200 µm×40 µm) were made for the protein adsorption test. A glass wafer positive relief features fabricated using negative tone photoresist (SU-8, MicroChem Co.) patterned by backside diffused-light photolithography was used as a mold. PDMS mixture was pored on the mold and cured at 25 °C for 24hr. The cured negative replica with channel features was peeled off from the mold and punched with holes for fluid accesses. Each PDMS membrane were treated by oxygen plasma (85 W, 10sec) and sealed against each other. These channels were fullled with FITC labeled BSA in PBS (4.5 g/L) at 37°C for 1h, and washed by PBS. The amount of protein adsorption was measured by the fluorescence intensity.

RESULTS AND DISCUSSION

Figure 3 shows the results of fluorescence microscopy images taken after protein adsorption test using FITC labeled BSA solution. From the photograph, protein adsorption was effectively reduced by the condition of photografting 0.50 M of monomer concentration and 60min of photo irradiation time. Figure 4 shows the amount of the protein adsorption of the each channels with various preparation conditions. These results imply that photo-induced grafting with higher monomer concentration and longer irradiation time achieved great suppression of the non-specific protein adsorption.

Figure 5 shows the surface zeta potential of the samples. The surface zeta potential of the sample prepared by 0.5 M of MPC monomer concentration and 60 min of photo-irradiation time shows almost the same value of bared PDMS surface event though the low protein adsorption evaluated by the FITC labeled BSA test. Therefore we checked the MPC polymer surface coverage by XPS. The resulting atomic ratio of P/C is shown in Figure 6. For low MPC monomer concentration (0.25 M 0.50 M), with high concentration of MPC monomer solution and long irradiation time, P/C has increased and surface zeta potential has also been suppressed. This is because of the increased density of the grafted-polymers. However, in high MPC solution (1.0 M), gelation in the MPC solution has processed, the formed MPC polymer gel was removed from the surface and it cause low P/C.

Figure 3. Images of fluorescence microscopy after protein adsorption.

Figure 4. Amount of the non-specific adsorption of FITC labeled BSA on the PDMS microchannel.
(50 mM benzophenone solution was passed through the channel before UV irradiation.)
Figure 7 shows the possible mechanism of reduction of protein adsorption and EOF produced by zeta-potential. At low density grafting of MPC polymer, the lots of proteins can insert in between the polymer chain and proteins adsorbed on the PDMS surface. The large surface zeta-potential originated from native negative charged PDMS can not decrease due to remained PDMS surface in the condition of the MPC polymer thickness of around 30 nm. When MPC polymer chain is covered perfectly on PDMS surface with high density of MPC polymer chain and long polymer chain, protein can not reach to the surface and the surface charge can be shielded by the thick polymer layer. Finally we can get the low zeta potential below -10 mV at the condition of low monomer concentration (0.25 M) and long irradiation time (3 hr).

CONCLUSION

We reported the preparation of MPC polymer grafted PDMS in order to enhance its surface hydrophilicity, anti-biofouling property, and biocompatibility and to decrease the large negative surface charge. The graft layer thickness is controlled by the UV irradiation time. The grafted density is controlled by the monomer concentration. Optimal modification on PDMS to suppress the protein adsorption and zeta potential is achieved with low monomer concentration and long UV irradiation time.

ACKNOWLEDGEMENTS

This work was supported by Grant-in-Aid for Scientific Research on Innovative Areas “Molecular Soft-Interface Science” from the Ministry of Education, Culture, Sports, Science and Technology of Japan.

REFERENCES


CONTACT
*M. TAKAI, tel: +81-3-5841-7125; takai@mpc.t.u-tokyo.ac.jp