Student Paper

The influence of channel surface coating on ζ potential causing electroosmotic flow

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1. Introduction

The Electrophoretic Coulter Method (ECM) approach proposed by Takahashi *et al*. enables the simultaneous determination of information on individual specimens such as their number, size, the velocity of electrophoresis and the resultant ζ potential [1, 2].

However, ECM is affected by problems relating to electroosmotic flow [3]. This results from the ζ potential of surfaces in micro channels, which occurs in the direction opposite to that of electrophoretic flow and prevents specimens from going through the aperture in ECM devices.

Against such a background, we clarified the influence of the channel surface coated with different 2-methacryloyloxyethyl phosphorylcholine (MPC) concentrations on the ζ potential causing electroosmotic flow near the channel surface in this study, and validated usefulness for our ECM with respect to specimens.

2. Experiment

The surface elements of polydimethylsiloxane (PDMS) before and after the MPC coating were analyzed using X-ray photoelectron spectroscopy (XPS). The PDMS was soaked in different MPC concentrations (0.1M MPC solution diluted by deionized water) at 40 °C for 12 h.

The velocity of a specimen v_{total} is expressed by Eq. (1) [4, 5].

$$v_{total} = \left(\zeta_{EO} - \zeta_{EP}\right) \cdot \frac{\varepsilon}{\eta} \cdot \frac{V_a}{l_a} + v_{DF} + v_{PS} \quad \cdots (1)$$

where ζ_{EO} is the ζ potential causing electroosmotic flow near the channel surface, ζ_{EP} is the ζ potential of the specimen, ε is the dielectric constant of the solution, η is the viscosity of the solution, V_a is the voltage across the aperture in the channel, l_a is the length of the aperture in Fig. 2a, ζ_{DF} is the velocity caused by the gradation of the solution's concentration, and ζ_{PS} is the velocity caused by pressure. In Eq. (1) the ε, the η, and the l_a is constant as far as the same devices is used.

First, ζ_{SP} is measured using dynamic light scattering (DLS) method as substitute for ζ_{EP}. ζ_{SP} is defined as ζ potential of the specimen, which causes electrophoretic flow in the specimen and which is equivalent to ζ_{EP}. A solution containing polystyrene particles with a diameter of 3 μm (Duke Scientific) diluted with phosphate-buffered saline (PBS) is used for the specimens.

Second, v_{total} is measured in the variable V_a and the value of $\zeta_{EO}-\zeta_{EP}$ in Eq. (1) is estimated using ECM measurement with microchannels coated with different MPC concentrations. All surfaces are coated with MPC in order to prevent polystyrene adhering to the channel surfaces [6]. In the ECM system, PDMS (TSE3450; Momentive) as a micro channel is molded using lithographically patterned SU-8 2010 (Microchem) [7, 8], and the 3-μm polystyrene particles are injected into the channel. A voltage is then applied, and a series of pulse signals is observed using a 4156C semiconductor parameter analyzer (Agilent). The data are shown in Fig.2b. From the acquired data and l_a, velocities of particle are estimated.

Third, ζ_{EO} was estimated from the sum of ζ_{SP} and ($\zeta_{EO}-\zeta_{SP}$).

3. Results and discussion

After the surface of PDMS was grafted with MPC, Figs. 1(a-c) show C-O, C=O, N, and P derived from the hydrophilic group of MPC. And then, normalized intensities of C, N, and P as shown in Figs 1(d-f) have peaks around 40 % MPC concentration. We measured the zeta potential of the each particle using microchannels coated with 20 and 40 % MPC. The ζ_{SP} value of the 3-μm polystyrene particles is shown in Table 1, and the electrical field dependence of the average velocity of the specimens is shown in Fig. 3. The resulting ζ_{EO} values are also shown in Table 1. The ζ_{EO} reduces remarkably even when MPC concentration is 40 %, while the ζ_{EO} remains high when MPC concentration is 20 %. This suggests that

the electroosmotic flow which a specimen is received should be minimized with optimal MPC coating and Zeta potential of each specimen should be characterized accurately in our ECM systems.

4. Conclusions

In this study, the surface elements of PDMS before and after the MPC coating are analyzed using XPS, and.the dependence of ζ_{EO} on MPC concentration in ECM devices is investigated. The results suggest that microchannel coated with 40 % concentration MPC is most effective in suppressing electroosmotic flow.

We validate the accuracy of the ECM devices in comparison with conventional methods using laser Doppler velocimetry and microscopy.

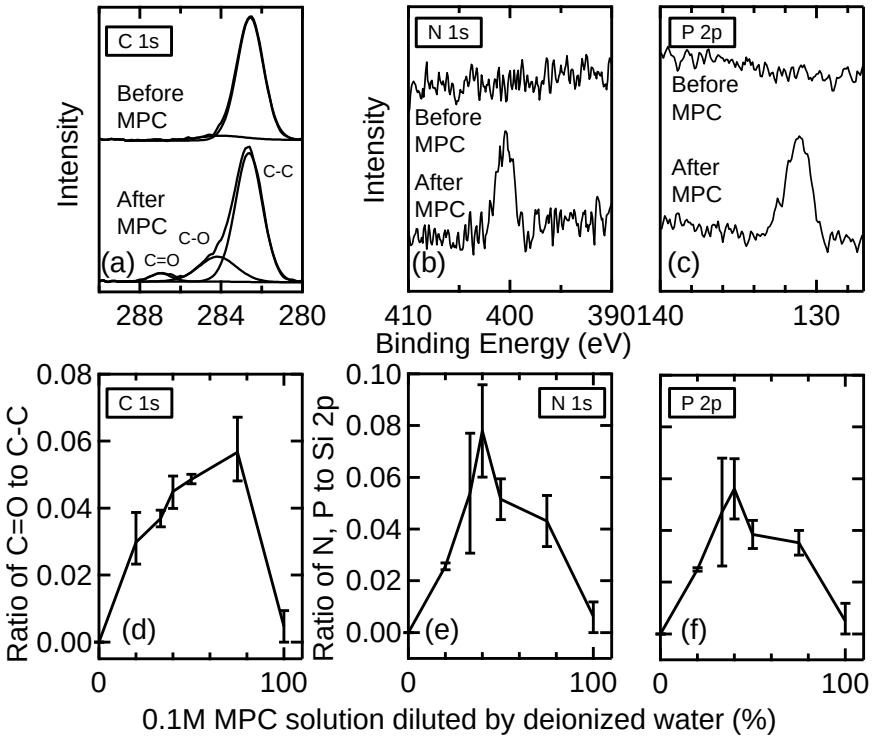

Fig. 1. XPS spectra of (a) C_{1s}, (b) N_{1s}, and (c) P_{2p} at the surface of PDMS before and after MPC coating. Normalized intensity of (d) C, (e) N, and (f) P at the surface of PDMS coated with different conc. MPC (%).

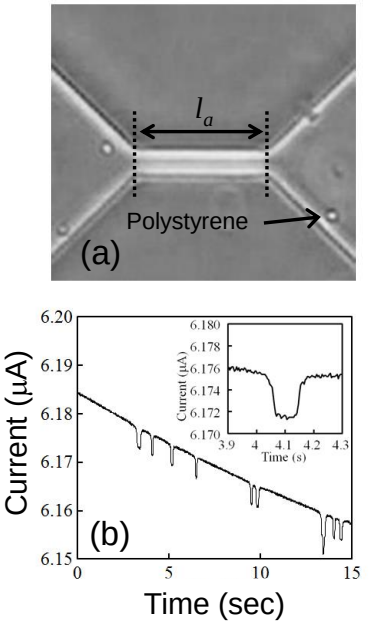

Fig. 2. Top view of an aperture in a micro channel and 3μm polystyrene particles in (a). Typical Ion current pulses obtained from ECM measurement in (b). Each pulse is caused by a single particle passing through the aperture.

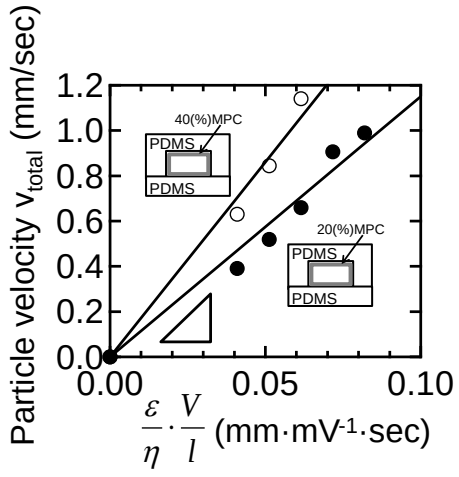

Fig. 3. Electrical field dependence of specimen velocity in ECM devices.

Table 1 ζ_{SP} measured using DLS and ζ_{EO}, ζ_{EP} measured ECM.

MPC conc. (%)	ζ_{SP} (mV)	ζ_{EO} (mV)	ζ_{EP} (mV)
20	-21.4	-9.9	-11.5
40	-18.8	-1.6	-17.2

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