Nonbiofouling Anionic Phospholipid Polymer Modification for Electrokinetic Micorofluidic Device

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Statement of Purpose: Protein adsorption, or the so-called "biofouling", is a serious problem in silica-based (quartz and glass) microfluidic devices, which greatly limits their applications in biological areas. Various surface coatings are effective for suppressing protein adsorption, but simultaneously eliminating the surface charge which is an indispensable prerequisite for electroosmotic flow (EOF) actuated microfluidic devices. Here, an anionic phospholipid polymer was synthesized for coating the quartz microchannel to suppress the protein adsorption and as well as to retain the surface charge and the EOF.

Methods: 2-methacryloyloxyethyl phosphorylcholine (MPC), *n*-butyl methacrylate (BMA), potassium 3-methacryloyloxypropyl sulfonate (PMPS) and 3-methacryloxypropyl trimethoxy-silane (MPTMSi) were used to synthesize poly (MPC-co-BMA-co-PMPS-co-MPTMSi) (referred to as PMBSSi, shown in Figure 1) by a conventional radical polymerization technique. A chip with a single microchannel whose dimensions were 180 μm, 30 μm and 8 mm in width, depth and length respectively was fabricated on quartz plates (20 × 20 × 0.5 mm^3). The PMBSSi alcoholic solutions were used to coat quartz surfaces. In the case of the plate, a dip coating process was applied. In the case of the microchannel, a filling method was applied. To make quantitative evaluation of the protein adsorption, a serials of proteins(0.32 g/L) whose isoelectric point (*pI*) varies from 1.0 to 13.0 were used. The amount of absorbed protein on quartz plate surfaces was determined using a micro BCA method by a standard protocol [1]. The surface ζ-potential was measured in 10-mM NaCl solution condition using an electrophoretic light-scattering spectrophotometer (ELS 8000, Otsuka Electron Co., Osaka, Japan) with a plate cell. The EOF behavior was measured by observing the migration time of neutral beads (polystyrene microspheres (Polybead®) Polysciences Inc., Warrington, PA, USA) at pH7 in the microchannel under a certain voltage [2].

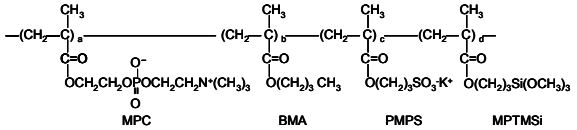

Figure 1. The chemical structures of PMBSSi.

Results/Discussion: In the PMBSSi (Figure 1), the MPC units are for constructing phosphorylcholine group segments onto the substrates. Since the PMPS units have an anionic group, they were expected to generate or modify the ζ-potential and the EOF in the modified channels. The polymer can be dissolved in ethanol, which is advantageous in the modification of microfluidic devices. The modification processes for not only the plate substrate but also the microchannels are very simple as described in Methods. The coating is a permanent coating owing to the MPTMSi units in the polymer, which are silane coupling agents and can be chemically bonded with silica-based substrates. The EOF determination (Table 1) indicates that the PMBSSi modified quartz surface retained a significant amount of cathodic EOF. For example, in the case of PBS, pH 7.0, the EOF mobility of the 0.3 wt%-PMBSSi-coated microchannel was (0.99 ± 0.14) × 10^{-4} $cm^2/V{\cdot}s$, which is roughly more than half (53%) that of the uncoated microchannel at the same buffer condition. Besides, this is in good agreement with the result of the ζ-potential (Table 1). After coated by 0.3 wt% PMBSSi, the ζ-potential was altered to –24.2 ± 2.5 mV (at neutral pH), which is approximately 51% of that of the unmodified quartz plate. As shown in Fig. 2, at neutral pH, the non-specific adsorptions of various proteins on quartz plates were effectively suppressed to a very low level independent of *pI* by the PMBSSi coatings. Even the low concentration 0.03 wt% coating had significant effect in decreasing protein adsorption.

Table 1. ζ-potentials and EOF mobilities of the quartz surfaces with and without PMBSSi coatings.

	Bared quartz	0.3 wt% PMBSSi coated quartz	0.03 wt% PMBSSi coated quartz
ζ-potential /mV	−47.4±0.9	−24.2±2.5	−14.3±1.9
EOF mobility /×$10^{-4}$$cm^2V^{-1}S^{-1}$	1.88±0.14	0.99±0.14	0.60±0.04

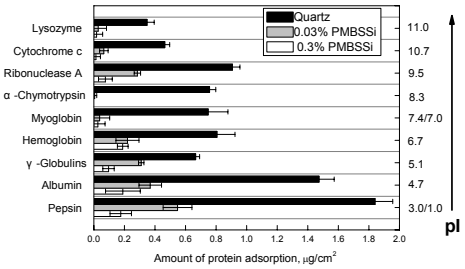

Figure 2. Amounts of various proteins adsorbed on the quartz plates with and without PMBSSi coatings. Proteins whose *p*I varies from 1.0 to 11.0 were used.

Conclusions: PMBSSi coating can effectively suppress adsorptions of both anionic and cationic protein and as well as retain a significant cathodic EOF on the silica based microchannel. Thus, PMBSSi coating is promising to be applied in electrokinetic microfluidic systems for bilogical applications.

References: [1] Pierce, in 2003–2004 Applications Handbook and Catalog. 2003; 241–243.
[2] Rathore A. S., Electrophoresis. 2002; 23:3827–3846.