

Elucidation of Protein Adsorption Behavior Based on Molecular Dynamics around Polymer Brush Surface

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Statement of Purpose: The materials that were exposed to physiological environments should have two distinct properties; one is the suppression of unfavorable biological responses, and the other is the effective induction of specific biological responses at the material surface. Because these biological responses are related to the adsorbed protein layer on the material surface, the protein adsorption behavior should be clearly understood to control them. In particular, the inhibition of protein adsorption is one of the essential properties that biomaterial surfaces must possess. Although a variety of molecular designs for biocompatible material surfaces have been proposed, the determining factors for controlling the protein adsorption behavior were not fully understood. The comprehension of protein adsorption behavior would lead to a novel molecular design for the biomaterial surface with non-protein adsorption. The perspective of this study is to elucidate the protein adsorption behavior at biomaterials surface from viewpoint of the molecular dynamics working around the material surface. In this study, the direct interactions working in nano newton order between protein-surface or surface-surface were analyzed form the colloid probe scientific method by using well-defined polymer brush structure as a model surface. Additionally, the motility of water molecules around the polymer brush surface was evaluated by nuclear magnetic resonance (¹H-NMR).

Methods: Several kinds of the polymer brush layers, poly(MPC) (PMPC), poly(SBMA) (PSBMA), poly(CBMA) (PCBMA), poly(TMAEMA) (PTMAEMA), and poly(HEMA) (PHEMA), were prepared at the initiator-immobilized silicon wafer [1] or silica beads (diameter: 10 μm) by using the surface-initiated atom transfer radical polymerization (SI-ATRP) method (Fig. 1). The polymer brush layers were characterized using X-ray photoelectron spectroscopy (XPS) and spectroscopic ellipsometer. As the direct interaction between the proteins and polymer brush layers, the adsorption force of the proteins against the polymer brush layers was evaluated in phosphate-buffered saline using the force-versus-distance curves mode operated in atomic force microscopy with bovine serum albumin (BSA)-

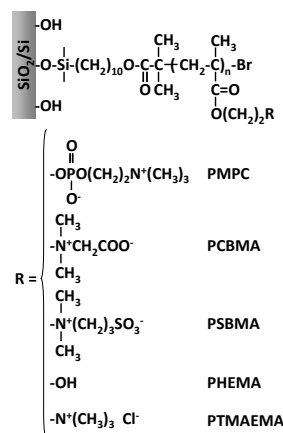


Fig. 1. Chemical structures of polymer brush layers.

immobilized cantilever. As the motility of water molecules around the polymer brush layers, the silica beads with the polymer brush layers were suspended in pure water and the relaxation time (T_1) of the enclosed water was evaluated using the inverse recovery method in ¹H-NMR measurement [2] at 37 °C.

Results: From the XPS results, the peaks attributed to each monomer unit were observed at the polymer brush surfaces. From the ellipsometric thickness analysis, the grafted polymer chain densities in PMPC, PSBMA, PCBMA, PTMAEMA and PHEMA brush layers were 0.26, 0.48, 0.67, 0.31, and 0.79 chains/nm², respectively. These results confirmed the formation of the highly dense polymer brush layers. Fig. 2 shows the histogram of the adsorption force between the BSA-immobilized cantilever and polymer brush layers or initiator-immobilized substrate at more than one hundred different positions. Large adsorption force of BSA was detected against the hydrophobic initiator-immobilized substrate and cationic PTMAEMA brush layer, while that against the nonionic PHEMA brush layer was suppressed at 0.8 nN. The adsorption forces of BSA against the zwitterionic polymer brush layers (PMPC, PSBMA, and PCBMA) were less than 0.4 nN, which was significantly smaller than that against the other polymer brush layers. T_1 values of water enclosed among the zwitterionic polymer brush layers were smaller than that among the nonionic or cationic polymer brush layers. This result indicated that the enclosed water molecules among the zwitterionic polymer brush layers would have less motility than that among the nonionic or cationic polymer brush layers [2].

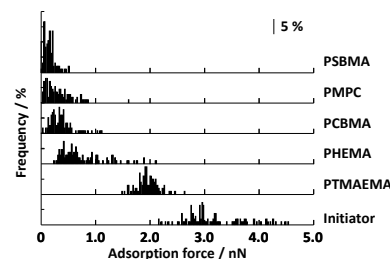


Fig. 2. Histogram of adsorption force of BSA.

Conclusions:

The adsorption force of BSA and motility of water molecules in respect to the well-defined polymer brush layers synthesized by SI-ATRP method depended on the chemical structure of their monomer units. It indicated that the motility of water around the polymer brush layer would influence on the suppression of the protein adsorption force. In particular, the zwitterionic polymer brush layers with the smallest motility of water molecules would have the excellent repellency of protein adsorption.

References: 1) Inoue Y. *Colloid Surf. B*, 2010;**81**: 350, 2) Tsukahara T. *Angew. Chem.* 2007;**119**: 1199.