論文の内容の要旨

Abstract of Dissertation

Title of Dissertation: Phospholipid Polymer Biointerfaces for Lab-on-a-Chip Systems

論文の題目 (ラボオンチップのためのリン脂質ポリマーバイオインターフェイスの創製)

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“Lab on a Chip” is a burgeoning field with important applications in chemistry, biology, medicine and other life sciences. Lab-on-a-chip devices offer the ability to perform laboratory operations on a small scale with significant lower reagent consumptions, quicker times, and better process controls. They also hold the possibility of massive parallelization and thereby the promise of integrating an entire laboratory onto a single chip. However, due to the high surface area-to-volume ratio in chip-based microfluidic devices especially in highly miniaturized and integrated systems, control of surface properties in lab-on-a-chip devices is an indispensable prerequisite for successful applications.

In this dissertation, from the angle of surface engineering, two critical problems in bio-related lab-on-a-chip devices are resolved. They are the control of bioadsorptions and the control of microfluidic flow. These two controls are usually very difficult to realize simultaneously, especially in an electrokinetic controlled lab-on-a-chip device, where surface charge is unfavorable to decrease bioadsorptions. These two controls were achieved by taking advantage of simple surface modifications based on three kinds of newly designed phospholipid polymers. They are, as presented in this dissertation, PMBSSi (an anionic phospholipid polymer), PMSi (a neutral phospholipid polymer) and PMBASi (a cationic phospholipid polymer). Main achievements of this dissertation are as followings.

Three kinds of phospholipid polymers (PMBSSi, PMSi and PMBASi) having different charge units (anionic, non- and cationic) and silane coupling units were designed with a view to be applied to the surface modification of EOF controlled silica-based Lab-on-a-chip devices. These polymers were easily synthesized by conventional radical polymerization techniques.

Permanent and homogenous charged/noncharged phospholipid polymer (PMBSSi, PMSi and PMBASi) interfaces were successfully constructed on silica-based substrates with simple one-step dip coating processes. Their interfacial properties were proved advantageous for lab-on-a-chip devices by systematically characterizations in combination of X-ray photoelectron spectroscopy (XPS), static contact angle (SCA), dynamic contact angle (DCA), and atomic force microscopy (AFM) techniques. The ζ-potential on the quartz surface can be modulated in a wide range from −24.2 ± 2.5 mV to 26.1 ± 0.6 mV at neutral pH after these interfaces were constructed.

Behaviors of protein adsorptions on the charged/noncharged phospholipid polymer (PMBSSi, PMSi and PMBASi) interfaces were investigated qualitatively and quantitatively both in chip and on substrate by using tools of fluorescence microscopy, AFM and microBCA protocol. The excellent protein-adsorption resistance (control) was validated. Proteins with various electrical (acidic and cationic) natures hardly adsorb on all three kind of interfaces (independent of protein's pI value), although PMBSSi and PMBASi interfaces are charged. Further, high cell adhesion-resistances were demonstrated on all three kinds of phospholipid polymer interfaces, which broaden the application of these biointerfaces to those cell-related lab-on-a-chip devices.

The electroosmotic flow (EOF) generated from the phospholipid polymer interface is significant and stable, and is only slightly influenced by the change in pH. The EOF on the interface can be easily regulated by adjusting the concentration of polymer solution for modification. Since this control is dependent on surface differences rather than the change in the buffer composition, it would be more suited for miniaturized systems for biological applications requiring neutral buffer conditions. The consequent variation in the EOF mobility resulted from protein adsorption was also suppressed. Therefore, to facilitate easy EOF control with compatibility to biomolecules delivered in the lab-on-a-chip devices, these phospholipid polymer interfaces could be a promising option.

As perspective, the research of this dissertation could provide a feasible approach to simultaneous control of multiple electroosmotic flows and simultaneously suppress non-specific bioadsorptions in lab-on-a-chip systems, which would significantly contribute to

control of chemical reactions, biomolecule analysis and cell interrogation on chip.