Lab-on-a-chip Bearing a Micro-fluidic Transistor for Surface State Biasing

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Résumé:

Medical check-up and throughout diagnostics require multiplexed sample treatments and high-resolution separations. After the separation steps, a sensitive detection of the biomarkers must be carried out. One way to efficiently separate groups of bio-molecules under an electric field consists in using micro-fluidic lab-on-chips. With a huge development of micro-technologies and nanotechnologies, the full-matrix on a single chip possess much smaller space and makes autonomy, portability and high-resolution possible. Among all, the electrophoresis is one of methods to separate efficiently those interests in electrolyte liquid. When a solid system is immersed in a fluid, a double layer will appear on the interface between the solid and the bulk liquid. The first layer is a dense layer that comprises ions adsorbed onto the surface due to chemical interactions, while the second layer is a diffuse layer that consists of ions attracted to the first layer via coulomb force. When applying an electric field across the channel, the ions can be dominated by the electrical force and generate a movement, this phenomenon is called “electrophoresis”. Those ions carry different movement orientations: along the direction of electric field or on the contrary, just according to their different electrical properties: positive or negative. The electrophoresis takes place to transport molecules under two contributions: the electro-kinetic mobility related to the size and charge of analyte and the electro-osmotic mobility that depends on the ionic distribution at the liquid/solid interface of micro-fluidic channels. Thus, the separation depends on the sum of these two mobilities carried by molecules.

In an electrolyte liquid, water molecules have a property of bipolarity. It causes the hydration of ions and makes them turn to be hydrated ions. When an electric field is applied, the hydrated ions movement in double layer leads the same movement of bulk liquid, we call this phenomenon “electro-osmose”. In a system with a large surface-to-volume ratio like micro-channel, the electro-osmotic flow (EOF) is the most significant role and is the cause of bulk liquid movement. The orientation of EOF depends on electrical property of substrate surface, for example: in a micro-channel made by glass, the surface charge is negative, to which the positive ions are attracted, thus the orientation of EOF is the same as that of electric field. Because the apparent flow is the sum of electrophoretic flow and EOF, for ions carrying different charges, the apparent mobility can be different. In the case mentioned above, the positive ions have the most important mobility due to the same orientation of electrophoretic flow and EOF, on the contrary, the negative ions possess the smallest one. Therefore, a separation can take place.

As EOF depending on the ionic distribution at the liquid/solid interface or said the electrostatic charge state of internal surface, most of the time analysts modulate EOF by adjusting pH or the ionic strength of their buffer (electrolyte) or just using surface treatments. However, these strategies cannot lead to real-time surface charge adjustment that is necessary to optimize difficult bio-separation. Thus, by tuning the surface charge or EOF in real time, we may succeed in an important analytical challenge: enslave the motion of the various species present in a biological sample. Therefore, our group has proposed an original approach: depositing a micro-fluidic transistor bearing a polarizable interface on the substrate surface of separation channel and commanding it by a slightly variable potential. Recently, our group has succeeded to integrate such a low-power consumption micro-fluidic transistor, to which the polarized layer can be directly immersed in a chemical solution, and we also succeeded to drastically modulate EOF in a -1V/+1V gate voltage in such a micro-fluidic chip.