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Comsol simulation of electrokinetic valve for the separation of ions

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ABSTRACT

Separation of ions is a major problem in chemical industries. There are several techniques to separate ions, one of the technique is the use of electrokinetic valve. Electrokinetic valve is used to separate ions by applying external electric field. Earlier it is designed using CAD software. In this paper we present an approach of designing electrokinetic valve using COMSOL multiphysics in a miniature way.

Introduction

Over the last five years, microfabricated fluidic devices coupling sample processing and chemical reactions to chemical separations have brought promising results The initial idea of performing rapid electrophoretic separations on the microchip quickly evolved into the concept known as a Lab-on-a-Chip. The microchip is a more complex sample processing unit Microchips allow active manipulation of fluids and samples inside a microfabricated channel network as a part of its operating cycle rather than just simple elution afforded by electrophoretic transport and retention. Such fluidic manipulations are based on electrokinetic transport of material exploiting the phenomena of eletrophoresis. Electrophoresis is a motion of electrically charged particles in a medium. As the Lab on-a-Chip technology addresses more complex analysis problems, more complex fluidic designs and electrokinetic valve strategies are required. The main issue on this field of research is complex and separation of two fluids is difficult. our project is to separate a two fluids by applying external electric field.

Mathematical Modeling

Our primary interest in computer modeling is to be able to simulate the temporal sample evolution inside the channel manifold. Sample mass transport in electrophoresis is the result of three major mass transport mechanisms: convection, electrophoretic transport, and diffusion. Bulk convective flow of liquid arises from one or a combination of the following factors: (i) a pressure difference applied to the separation column ends, (ii) electroosmotic flow which has its origin at the column walls, and (iii) thermal convection due to Joule heating. Electrophoretic transport is determined by the electric field distribution which depends upon the boundary conditions and the conductivity of the solution at each point along the channel, which in turn depends on the chemical composition of the solution. Diffusion takes place whenever a spatial non-uniformity in the composition of the solution exists. These three sample transport mechanisms depend on other physical phenomena accompanying electrophoresis: heat transport in the solution, chemical reactions within the(Mosher) buffer, and of course, the electric field distribution. Mathematical models of electrophoresis formulated previously 12, 13 take into account all the phenomena mentioned above, but in many situations the contributions of different phenomena to the evolution of the electrophoretic system are not equally important.

Implementation

Nowadays Electrokinetic valve is used in separating ions. In this paper Electrokinetic valve is implemented using COMSOL multiphysics software.

Electrophoresis

Electrophoresis is the motion of dispersed particles relative to a fluid under the influence of a spatially uniform electric field. This electrokinetic phenomenon was observed for the first time in 1807 by Reuss (Moscow State University),who noticed that the application of a constant electric field caused clay particles dispersed in water to migrate. It is ultimately caused by the presence of a charged interface between the particle surface and the surrounding fluid. The dispersed particles have an electric surface charge, on which an external electric field exerts an electrostatic Coulomb force.

According to the double layer theory, all surface charges in fluids are screened by a diffuse layer of ions, which has the same absolute charge but opposite sign (Babskii) with respect to that of the surface charge.

The electric field also exerts a force on the ions in the diffuse layer which has direction opposite to that acting on the surface charge.

This latter force is not actually applied to the particle, but to the ions in the diffuse layer located at some distance from the particle surface, and part of it is transferred all the way to the Particle surface through viscous stress. This part of the force is also called electrophoretic retardation force.

Microfluidic Devices

A microfluidic device can be identified by the fact that it has one or more channels with at least one dimension less than 1 mm. Common fluids used in microfluidic devices include whole blood (Fletcher) samples, bacterial cell suspensions, protein or antibody solutions and various buffers. Figure 1 shows flow of liquids in microfluidic devices. Microfluidic devices can be used to obtain a variety of interesting measurements including molecular diffusion coefficients, fluid viscosity, chemical binding coefficients and enzyme reaction kinetics.

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Other applications for microfluidic devices include capillary electrophoresis, isoelectric focusing , immunoassays, flow cytometry , sample injection of proteins for analysis via mass spectrometry, PCR amplification, DNA analysis, cell manipulation, cell separation, cell patterning and chemical gradient formation . Many of these applications have utility for clinical diagnostics.

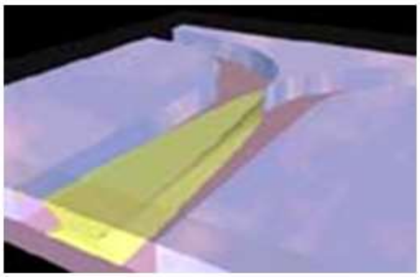

Figure 1: Flow of liquids in microfluidic devices

The use of microfluidic devices to conduct biomedical research and create clinically useful technologies has a number of significant advantages. First, because the volume of fluids within these channels is very small, usually several nanoliters, the amount of reagents and analytes used is quite small. This is especially significant for expensive reagents.

Electrokinetic Valve

Electrokinetic phenomena are a family of several different effects that occur in heterogeneous fluids or in porous bodies filled with fluid. The term heterogeneous here means a fluid containing particles. Particles can be solid, liquid or gas bubbles with sizes on the scale of a micrometer or nanometer. Electrokinetic valve is used to separate ions by applying external electric field. Figure 2 shows the geometry of Electrokinetic valve and the concentration of the buffer and the sample solution.we assume the sample ions. concentration to be small compared to the concentration of the buffer solution and the conductivity of the solution to be uniform throughout the liquid volume(sergey V.Ermakov).At the same time the concentration of the buffer solution is large enough so that the thickness of the electric double layer on the channel walls is negligible compared to the channel dimens

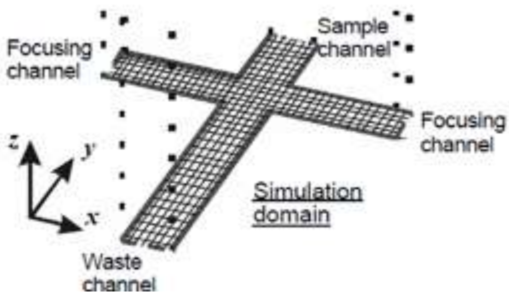

Figure 2: Geometry of electrokinetic valve

Focusing is obtained through pressure-driven flow of the sample and buffer solution, which confines the sample in the focusing channel. When the system reaches steady state, the pressure-driven flow is turned off and an electric field is applied along the channels. This field drives the dissociated sample ions in the focusing zone at right angles to the focusing channel and through the injection channel. A clean separation of the sample ions is important, so the model examines the effect on ion separation of different configurations of the electric field. The device operation and hence the modeling procedure takes place in two stages: focusing and injection. In the focusing stage, the device injects a buffering solution through pressure-driven convection into the vertical channels from the top and bottom. At the same time, it forces the sample solution through the horizontal focusing channel.The buffering solution neutralizes the acids contained in the sample except for a very thin region confined to the crossing between the horizontal and vertical channels. This means that the dissociated ions are only in a needle-shaped region in the focusing zone. In the injection stage the device turns off the convective flow and then applies a vertical field to migrate the sample from the focusing channel to the injection point at the lower end of the vertical channel. The sample ions are negatively charged and migrate in opposite direction to the electric field. This model studies two different configurations for the applied electric field.In the first configuration, electric field is only applied in the vertical direction. In the second configuration electric field is applied both in horizontal and vertical direction.

Comparison of various separation methods

The following are the various techniques for detection of lung cancer namely Chromatography, microfiltration. These techniques are explained clearly in brief way to show how the system helps to Separate two liquids and how it varies from MEMS.

Ion exchange chromatography

Ion exchange chromatography uses ion exchange mechanism to separate analytes. It is usually performed in columns but can also be useful in planar mode. Ion exchange chromatography uses a charged stationary phase to separate charged compounds including amino acids, peptides, and proteins. In conventional methods the stationary phase is an ion exchange resin that carries charged functional groupswhich interact with oppositely charged groups of the compound to be retained. Ion exchange chromatography is commonly used to purify proteins using FPLC.

Composite hollow fiber membranes

In removal of heavy metal ions from waste effluents and separation of ions, membrane technology has become increasingly attractive as a low-cost generic separation technique for environmental problems. Membrane processes compete with a variety of processes, s precipitation, metallic replacement, ion exchange, electrolysis, adsorption, flotation and biological approaches. This membranes could be an omnipotent technique to take the place of all the classical separation sections in the production of ammonia and acid/base.

Above are the various methods of separating ions, but these are complex methods , it requires more time and space to separate the ions.But the Electrokinetic valve is a simpler way and separation can be done in a miniature way.

Results

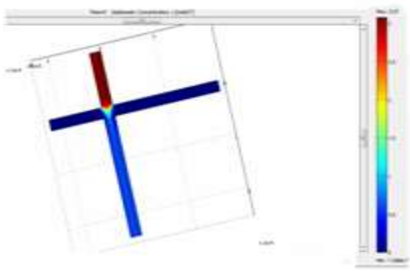

Figure 5: Electrokinetic valve

In the electrokinetic valve we have used sodium carbonate as buffer for analysis. We can separate ions of any samples.For example crude oil contains more hydrocarbons, using this electrokinetic valve we can separate hydrocarbons. Figure 5 shows the separation in electrokinetic valve.

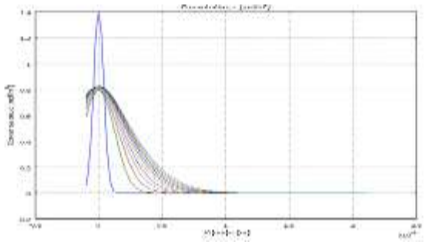

Figure6: Concentration profile along the injection channel

Conclusions

The concentration profile along the injection channel and its outcomes shows that the modeling approach allows estimating separation of ions in a reasonable way using Electrokinetic valve using this electrokinetic valve we can easily separate ions. Due to its small size complexity is much reduced and the system become more compact.

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