DESIGN OF PROGRAMMABLE DIFFUSION BIOASSAYS BASED ON MHD MICROFLUIDIC SYSTEM

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ABSTRACT

Integrated bioassays is an emerging research field for its potential applications [1, 2] in complex and heterogeneous systems. Bioassay system comprising of separators, mixers, filters, detectors [3] can be integrated on microsystems platform with high performance and low cost. Separation of molecules or particles in microfluidic channel is achieved by diffusion, where the flow is laminar. The distance L by which a spherical particle of diameter d diffuses is given by the Einstein's equation,

$$L = (\frac{RT}{N}\frac{t}{3\pi\eta d})^{0.5}$$

where R=8.31 X 10^7 , N=6.023 X 10^{23} and η is the viscosity of the solvent. This suggests that the size of the particle or molecules forms a critical parameter in the diffusion driven assay. In this abstract we show how MHD pump is of great use in the high concentration extraction of certain molecular species from a biofluid mixture based on diffusion at low Reynolds number [4].

In a fully integrated system, MHD pumps serve as the flow or velocity controller and are built in the microfluidic channels. MHD pumps have no moving parts and can generate continuous flow. MHD pump is a powerful system [5] because the flow or velocity is controlled by controlling the voltage across the electrodes. The fluid used in MHD devices is conductive and is compatible with solutions containing biological specimen. Thus MHD devices have the potential to be implemented on an integrated microfabrication platform to form complex fluidic manifolds for biochemical analyses.

We have developed a novel fabrication method to fabricate polymer microfluidic systems. The process flow is shown in figure 1. Titanium (Ti) followed by a layer of gold (Au) were deposited on the glass substrate using e-beam evaporation. Electrodes were patterned then using photolithography. SU-8 layer was then spun and patterned to expose the electrodes for electroplating. After plating copper/platinum electrodes, the first layer of SU-8 was removed and left the electrodes standing on the substrate. A second layer SU-8 was spun on and patterned to form the microchannels with proper alignment to ensure the electrodes are exposed to the channels. A flat PDMS cover was used to encapsulate the channels and electrodes.

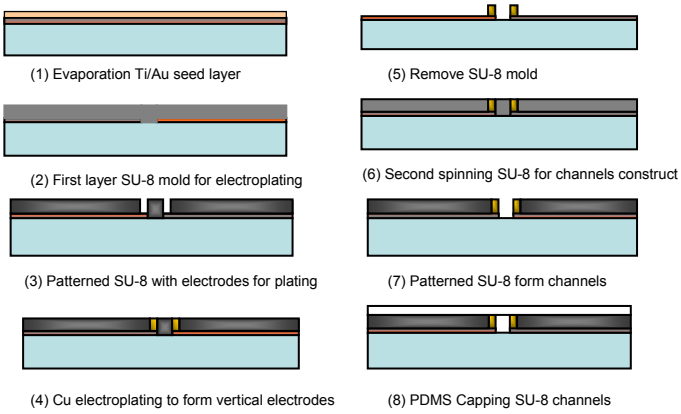

Figure 1 Fabrication processes of MHD micropumps

Figure 2a shows an on-chip controlled sample extraction process in which the sample is driven by MHD pumps and

extracted by the diffusion in an H-filter containing three inputs and three outputs. Fig 2b is an optical microscopic image of the H-filter with the pumps. The sample of this device comprises of different sizes and concentration of molecules or particles and is pumped into the diffusion area by the MHD pump. Diffusion causes the separation of the particles in the horizontal channel depending upon their sizes. Small particles diffuse into the width of the channel and are collected at the outer well. By adjusting the flow of the streams of buffer and channel width, the sample separation of particles can be optimized. Figure 2c shows the simulated number of particles separated from a mixture of small and big particles. It is understood that the larger the size difference of the particles to be separated the better the separation. This enabled us to design a new strategy for separating the particles.

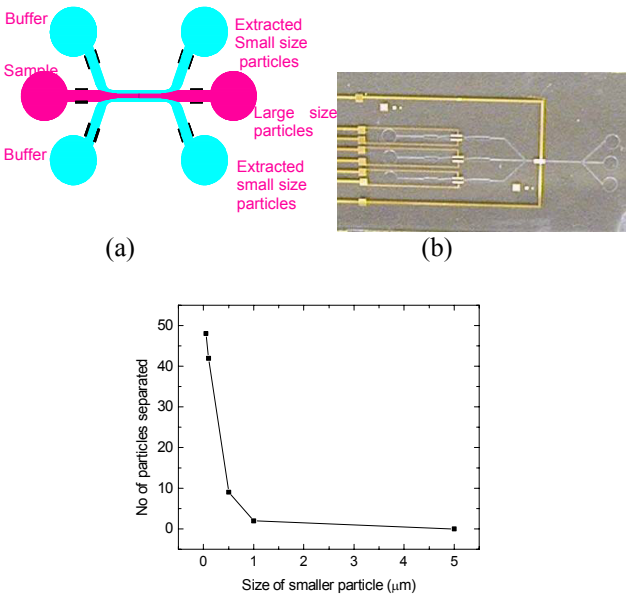

Figure 2 (a) Extraction of particle in MHD network bioassay by diffusion. (b) Image of MHD micropump. (c) Simulation Results with H- filter series

We designed a modified H-Filter (developed by Micronics Inc. Redmond, WA) where the partially separated sample is fedback to the head of the fluid flow. Separation of particles is done at various steps or circulations. The double microfluidic loop is pumped by three MHD pumps, as shown in figure 3a. The partially separated particle in a cycle is further refined in the next cycle. By repeated feedback of separated particle, high sample concentration is achieved and so the quality of the sample is enriched. After an optimum number of cycles, another valve at the outlet releases the sample to the next stage. Figure 3b shows the simulated results of separation of particles in its initial configuration and after one separation cycle. The sample consists of particle of sizes 0.1um (blue) and 10um (red). The middle channel is pumped by a MHD pump with a voltage of 10V. The flow rates at the outer channels are adjusted to using the MHD pump in the channels. In this case a higher flow rate is required in the top loop in order to accomplish efficient separation and so 2.5V is applied the MHD pump in the top loop. The MHD pump in the bottom loop is not used in this simulation run. In each cycle the separation of particles are increased. Thus this design serves as a programmable bioassay for separation of cells, proteins or ions in a mixture.

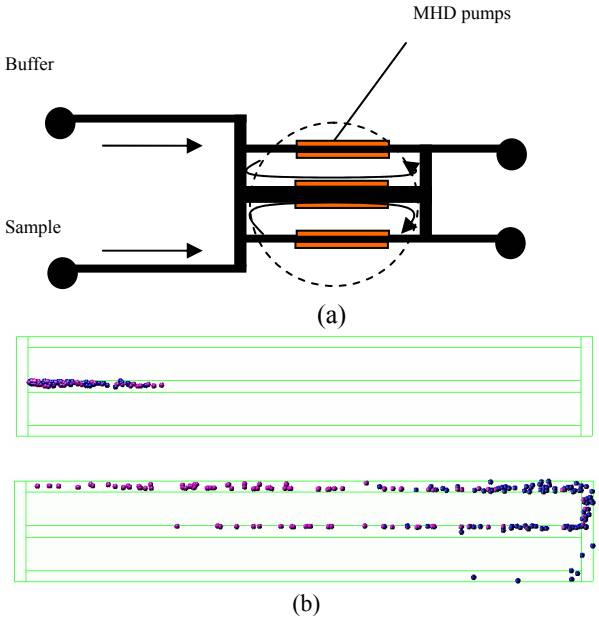

Figure 3 (a) Schematic of cyclic H filter. (b) Simulated results in the initial configuration and after one cycle circled parts in a.

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