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DESIGN OF A NEW MICROFILTER FOR SEPARATION OF MICROPARTICLES IN LAB-ON-A-CHIP APPLICATIONS

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ABSTRACT

Lab-On-a-Chip systems are one of the new growing technologies which offer miniaturization of analysis systems. In this paper we present a simple and low cost fabrication of a micro filter using in different applications in Micro Total Analysis Systems. This method uses typical microscopic glass slides as a substrate for fabrication of microfilters for Lab-On-Chip applications. Based on flow control, micro channel and micro filter design particle separation is performed by hydrodynamic filtration. This micro filter allows the target particles to flow through and unwanted larger particles flow to other micro channel. Particularly, separation of different particles from automobile oil, based on particle size is studied. This device can also be used for other biomedical applications such as cell separation. The geometry of this filter eliminates the clogging effect that is an important factor in micro filter designs.

Keywords: lab-on-chip, micro fluidics, micro channels, micro filter, glass.

1. INTRODUCTION

The motion of particles suspended in a fluid flowing through a microscopic channel has been a topic of central interest in numerous micro fluidic and nano fluidic applications e.g. drug delivery, biomedical applications, and micro-pumping mechanism [1-4]. With the advent of micro fluidic systems and MEMS in the last decade, the study of the motion of small particles in narrow channels was applied to many chemical and biological applications.
Accurate size separation and size measurement of various kinds of particles, including polymer beads, ceramics, cells, and pharmaceutical emulsions, are one of the most important technologies in the fields of industrial production, environmental assessment, and chemical or biological research [5].

Many studies have investigated particle separation, using field flow fractionation (FFF), [6-9] hydrodynamic chromatography (HDC), [10-12] capillary hydrodynamic fractionation (CHDF), [13-14] or split-flow thin (SPLITT) fractionation [15-17]. Pinched flow fraction using laminar flow profile in a specific micro channel geometry has been reported in reference [5]. With these methods, not only particles but also macromolecules which their diameters are typically from 1nm to 100µm can be separated.

In the present study we propose a new and simple method for separation of different size particles in a micro channel using laminar flow effect novel filter with elimination of clogging effect of pores which is a disturbing effect in mechanical filtration issues. The design, simulation and fabrication of micro filter for separation of different particles with the range of 10 to 50µm are presented. The particles are successfully separated using a specific filter structure and laminar flow effect, which allow the target particles to flow through and unwanted larger particles to flow away due to hydrodynamic forces.

1.1 Fabrication and performance procedure

Commercially available microscopic glass slides (75mm×25mm×1mm) were utilized as substrate. The photo-masks were designed using Corel-Draw software. SU-8 is a high aspect ratio negative photo resist which has been widely used with MEMS applications for many years. We used SU-8 2035 as the main substrate and also master mold for PDMS molding process. The fabrication process starts with cleaning of the glass substrates in acetone and methanol in 10 minutes separately and boiling in piranha solution for 15 minutes. Immersing in DI water and drying with nitrogen gas is the next step. Removing residual humidity on glass substrate can be achieved by putting them in an oven with 100ºC for 15 minutes.

Using spin coater to coat the glass with SU-8 is the next step. After coating the soft-baking procedure for de-bubbling and removing humidity is applied to avoid sticking the PR to the transparent photo-mask under the UV exposure. Hard baking step is applied next. Removing of unexposed regions using diluted acetone is the next step. The completed steps are shown in Figure-1.

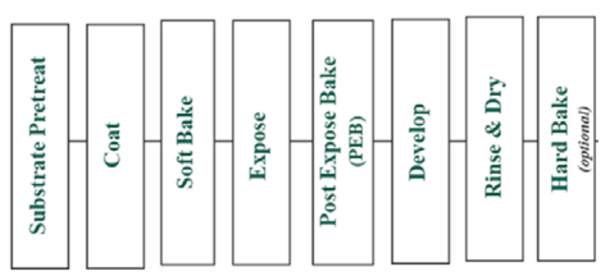

Figure-1. SU-8 process.

Figure-2 illustrates the design of entire chip with two inputs and two outputs. Figure-3 shows the filter design.

A schematic diagram of the micro fluidic device is shown in Figure-2. It is composed of one sample inlet,

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one buffer inlet, two outlets, a sample flow channel, a buffer flow channel and 12 filtering structures. As shown in Figure-3, the angle of each filter structure is 25º which is designed to induce a laminar flow. The width and the depth of input and output channels are 300µm and 50µm, respectively. With this design, a buffer solution injected into the buffer flow channel is used to squeeze the sample flow to form a narrow stream so that the particles can be pushed closer to the filter structures to obtain higher separation efficiency. This is schematically illustrated in Figure-4(a). The filter structure has a gap of 15 µm and a depth of 50µm. It is used as a micro filter such that particles with a diameter of about 10µm can be separated from oil and collected in the output1. This unique structure also allows larger particles to flow downwards instead of clogging the gap.

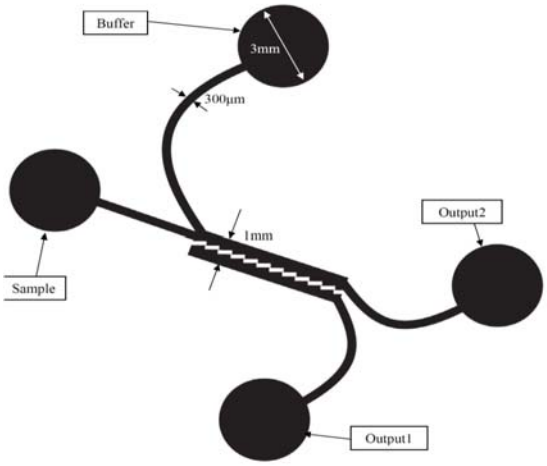

Figure-2. Schematic of mask design.

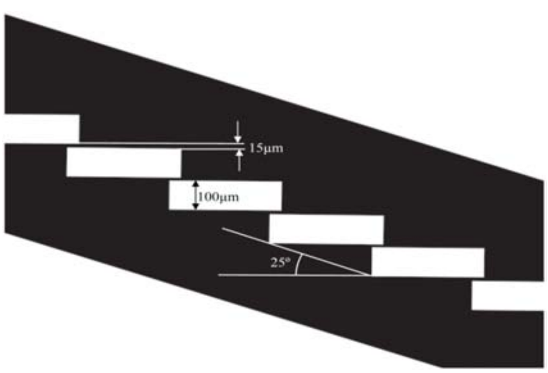

Figure-3. Schematic of filter design.

The separation mechanism for particles with different sizes is illustrated in Figure-4. The main mechanism is physical separation of particles based on blocking the objects. However, in this study, a filter structure was adopted to cleverly direct particles to flow through or along the structure. When the volume flow ratio (sample/buffer) becomes smaller, more small particles pass through the filter because the particle flow can be pushed closer toward the gap by the larger velocity of the buffer flow. As a result, the separation efficiency of small particles can be improved by controlling the volume flow ratio. For large particles, when they leave the corner of the first filter structure, they hit the long side of the second filter and cannot flow through the gap between the filters (Figure-4(c)). As a result, they flow along the long sides of the filter structures and finally are collected in the output 2. Note that the length and width of the each filter is 470µm and 100µm, respectively.

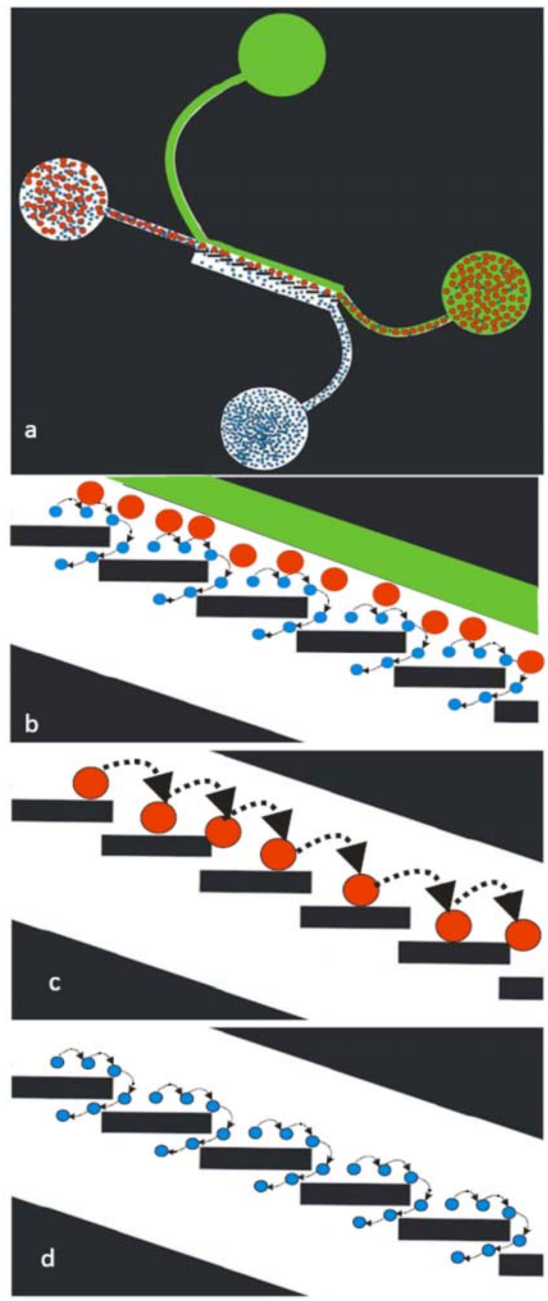

Figure-4. (a)Schematic of microfilter structures with particles, (b) Laminar flow effect on particle separation, (c) Elimination of clogging effect, (d) small particle filtration.

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1.2 Model definition

This model analyzes the steady-state condition of the fluid flow as well as the convection and diffusion of a dissolved substance in a separation filter. It models fluid flow whose velocity is of a magnitude that suggests laminar behavior. The fluid flow in the channels and in the filtering chamber can be solved with the incompressible Naiver-Stokes steady state equations.

$$-\nabla.\eta(\nabla u+(\nabla u)^T)+\rho(u.\nabla)u+\nabla p=0$$
$$\nabla.u=0$$

where ρ denotes density (kg/m3), u is the velocity (m/s), η denotes dynamic viscosity (Pa·s), and p equals pressure (Pa). The fluid in this case is water, with the corresponding density and viscosity values.

The boundary conditions for the inlets and the outlet assume a set pressure; they also assume vanishing viscous stress:

$$\left[\nabla.\eta\left(\nabla u+(\nabla u)^T\right)\right].n=0$$
$$p=p_i$$

The system applies different pressures of Pi on inputs to drive the flow through the filtering chamber to where there is zero pressure. At the chamber exit the flow velocity has components only in the normal direction of the boundary. On the micro channel and filter walls, the no-slip boundary condition applies.

The following convection-diffusion equation describes the concentration of the dissolved substances in the fluid:

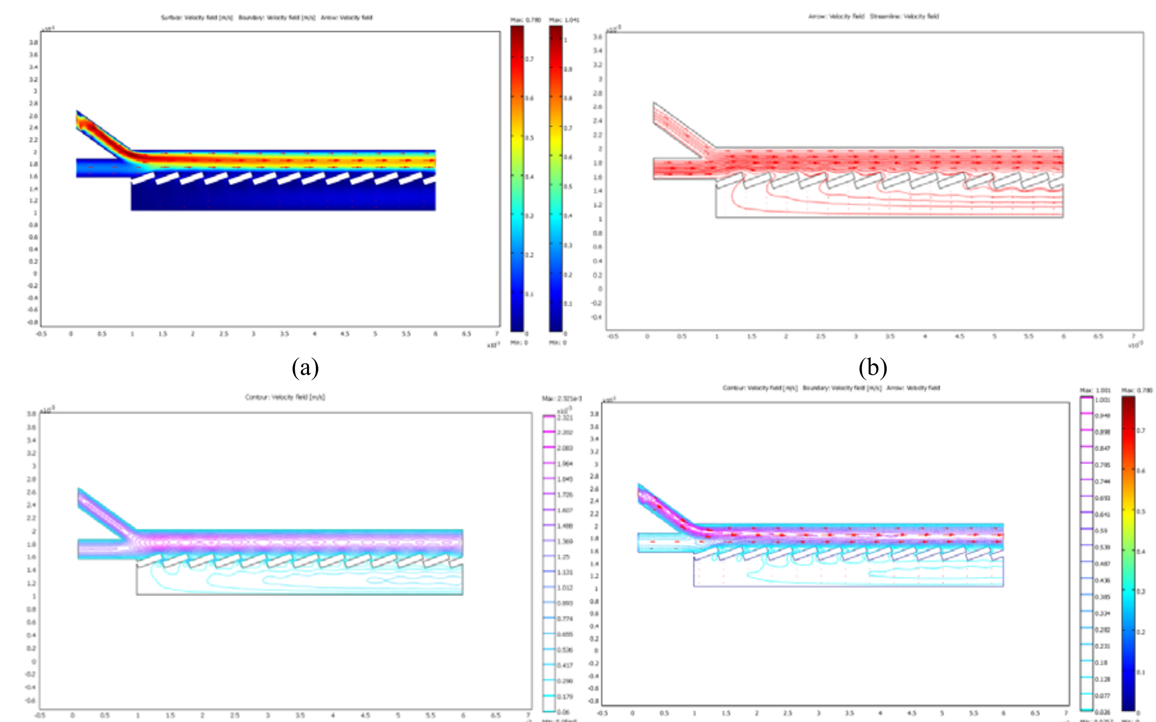
$$\frac{\partial c}{\partial t}+\nabla.(-D\nabla c)=R-u.\nabla c$$

where c is the concentration, D is the diffusion coefficient, and R is the reaction rate.

2. RESULTS AND DISCUSSIONS

Figure-5(a) shows the velocity field as combined slice and arrow plot through the geometry. This figure also displays the pressures at the walls. As can be seen because of the laminar flow in micro channels the buffer thrust the sample to the filter structure and cause the smaller particles pass through the pores. Figure-5(b) illustrates the velocity streamlines to show the filter performance. For comparison between different input pressures Figure-5(c) and Figure-5(d) nicely show the role of different sample pressures in separation of particles. In Figure-5(c) the input pressure is more than Figure-5(d) with both the same values for sample input pressures.

Figure-6 shows the SEM results of fabrication of micro filter. Figure-6(a) illustrates the filter structures with a clearance between them. The input holes can be seen in Figure-6(b). In addition the angle between inputs can be observed in Figure-6(c).



(a) (b) (c) (d)

Figure-5. (a) Model of microfilter structures, (b) Streamline velocity field, (c) contour velocity field with more buffer pressure, (d) contour velocity field with less buffer pressure.

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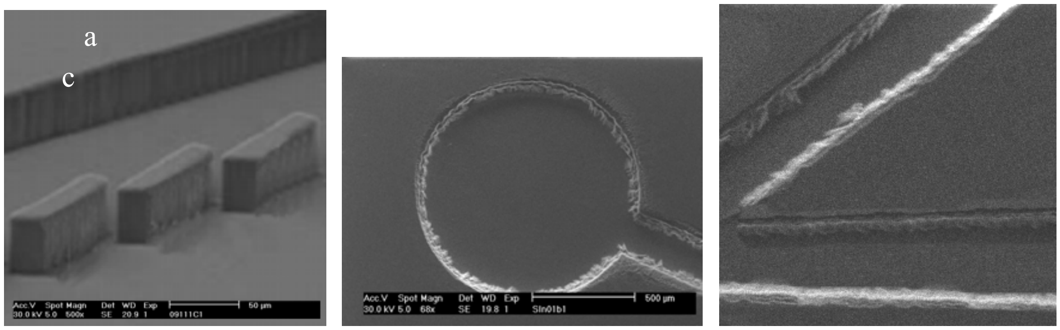

(a) (b) (c)

Figure-6. SEM of the fabricated micro filter, (a) filter structure, (b) input holes, (c) angle between inputs.

3. CONCLUSIONS

A simple and low cost fabrication of a micro filter using in different applications in Micro Total Analysis Systems was presented. This method uses typical microscopic glass slides as a substrate for fabrication of micro filters for Lab-On-Chip applications. Based on flow ratio control of sample and buffer, micro channel and micro filter design particle separation was performed by hydrodynamic filtration and modeled using FEM software. This micro filter allows the target particles to flow through and unwanted larger particles flow to other micro channel using a specific pressure on sample and buffer inlets. The geometry of this filter eliminates the clogging effect that is an important factor in micro filter designs.

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