COMSOL Multiphysics Simulation For Microfluidic Separator As Sample Delivery System In Sensing Domain

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Abstract- Recently, the development of fluid delivery system such as microfluidic has drawn attention among research because of its unique advantages on label-free biosensor. Microfluidic consists from several parts such as microchannel, micromixer, microchamber, separation, concentrator, valve and micropump. The COMSOL multiphysics 4.3a engineering simulation software is a powerful tool and environment facilitates all steps for any modeling, process by defining your geometry, meshing, specifying physics logic, solving and then visualizing the results. This paper presented a design and simulation of two microfluidic patterns and geometry by using different width as fluidic delivery system that will be used in sensing domain.

Keywords: microfluidic, separation, COMSOL multiphysics engineering simulation, geometry.

I. INTRODUCTION

In year 1979, the very first active microfluidic system device has developed by S. Terry et al.\textsuperscript{1} which consisted of a working gas in device and has fabricated on silicon substrate. Since that, researchers began to pay attention and start working on microfluidic system because of their unique ability to deliver micron sizes cell and particle contains in fluid or gas\textsuperscript{2} and in the early 90’s, researcher began producing a micron-sized total analysis system (the μTAS)\textsuperscript{3}. This μTAS could perform all kinds of functions such as sample preparation, particles separation, mixing for chemical reactions and detection in an integrated microfluidic circuit for system integrated in a single chip.

Microfluidic devices provide several advantages by taking the size of microfluidic as an important factor; a faster temperature change\textsuperscript{4}, ease in applying higher electric fields\textsuperscript{5}, reduced fabrication cost and devices are easy handling\textsuperscript{6}. Separations are an important set of applications of microfluidic devices and techniques applied for separation of cells or particles play an important role in biotechnology. Usually, these biological mixtures often consist of a wide variety cell or particle types such as DNA, protein, viruses or diseases and blood cell in varying concentrations.

In the biomedical analysis technology, a reagent is often mixing with a target sample such as disease or biomarker in order to attract antibody or antigen. When dealing with micro-scale feature, pressure will move the fluid in separation channels unless if it involving cell separation then both magnetic and electric force must be applied into microfluidic in order to functioning and one common example is a separate the type of human blood cells from the native cell. Normally, all the microfluidic separators work in laminar regime and it depends on the flow rate\textsuperscript{7}. In biosensing technology, the development of the channel length and height must be in balance.

II. EXPERIMENTAL

In designing a pattern or model, there is basic rules need to follow such as model dimension, application mode, parameter, expression and description. The simulation will become error if any of this is not filled. Fig.1 below shows design of microfluidic with one inlet channel and three separator outlet channels in two dimension geometry, while Fig.2 shows microfluidic after extrude to three dimensions that used in this research. The complete geometry with specific parameter has been put on the simulation.

![Figure 1: (a) 2D design for 1 micron microfluidic separator, (b) 3D design for 1 micron microfluidic separator.](image)

In other hand, microfluidic with 2 micron channels in Fig.2 have been design in order to study effect of width
mirochannels towards pressure and fluid flow. Every parameter has a different functionality toward geometries or modals such as density ($\rho$), viscosity ($\eta$), diffusion constant ($D$), pressure drop ($p_0$), inlet concentration ($c_0$) and Viscosity $c^2$-term prefactor ($\alpha$). Sometimes wrong parameter could lead to errors in modeling.

Afterwards, next process continued with meshing. Meshing is a process that splitting the geometry design or model into small units and at the same time simulation program trying to compute the allowed maximum meshing element size which means mesh element cannot be larger than minimum prescribed local element size by all mesh parameter has been set as Fig.3 shows both of geometries after meshing process.

After meshing process is completed, results are obtained as shown in Fig.4 and Fig.5 which solving and post-processing completed models. Firstly, solving is a model that shows a flowing rate with concentration at the certain point as shown in figure below. Red colour shows fluid at high flowing rate because it locates close to the inlet of microfluidic and fluid continuing flow until at separator junction. Figure below give a full picture of this explanation.

Meanwhile, 2 micron microfluidic shows a very same result for solving and posting process because geometry for both models is almost the same just the width of microfluidic is diverse from previous model. Figure below is the 2 micron microfluidic.

III. RESULT AND DISCUSSION
Velocity field (Fig.6) that happened in 1 micron microfluidic system always seemed to be increased from \(\sim 0.5 \times 10^{-6} \text{ ms}^{-1}\) (from inlet) until to \(21 \times 10^{-6} \text{ ms}^{-1}\) (reach outlet) with arc-length of the microfluidic is about 5.258 \(\mu\text{m}\). Now by comparing to 2 micron microfluidic system as show below, the velocity field of system is almost proportional to the arc-length. Velocity field of 2 micron microfluidic system (Fig.7) measurement is starting from \(0 \text{ ms}^{-1}\) and keep increased until \(270 \times 10^{-6} \text{ ms}^{-1}\). By comparing those two results, microfluidic with smaller width of microchannel is faster than the bigger width because smaller microchannel or microfluidic system will provide low resistant toward fluids to flowing.

Pressure is one of important data in microfluidic because flowing rate of microfluidic is affected by pressure from atmosphere. Fig.8 shows result from 1 micron microfluidic and meanwhile Fig.9 shows result from 2 micron microfluidic. Both results should be directly proportional between pressure and arc-length because natural pressure cause by gravity (atmosphere pressure) is usually constant. This matter happened when fluid flow through inside the microchannels, it will undergo ‘pressure drop’ because the frictional force toward the fluid that causes by a resistant to flow. Any fluids always flow in the direction of the least resistant (less pressure) in microchannels.
IV. Summary

COMSOL Multiphysic simulation has a promising simulation application because it provides useful data or information to researcher before the real design could be transferred on the reticle or mask for fabrication process. Simulations also make researchers able to choose the suitable geometry for the next stage of biosensor domain by according to velocity field and pressure result which very useful for designing microfluidic. Furthermore, this simulation provides low cost simulation and accuracy while working on for certain geometries. Simulation is a

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