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POLYMER BASED BIO-FILTER

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ABSTRACT

To investigate and analyze blood and to separate various blood components like WBC, RBC, PLATELETS and PLASMA from the blood. We use MEMS for this process as it requires only small samples of volume. Polymers do not show any interaction with biological fluids and they are cost effective and easy to fabricate. Polymers are more transparent, so easy to observe the process. The fabrication process is simpler and more cost effective than the conventional process which is lengthy and timely repeated process.

Keywords: Blood plasma, Polymers, Silicon and glass, plasma skimming effect, cross flow filtration, gravitational suppression.

1. INTRODUCTION

1.1. MEMS Technology

MEMS can be abbreviated as Micro Electro Mechanical System. This technology makes the system to have smaller devices or group of devices. The integration of mechanical and electrical subsystems is defined as MEMS. MEMS machines are minute systems whose dimensions range from micrometer (µm) to millimeter (mm). Motors, switches, power generators, basic actuators are categorized into MEMS devices which also involves applications in the field's viz., telecommunications, astronomy, aerospace and bio-technology [1]. MEMS is also mentioned to as Micro Electro Mechanical Systems. It deals with components present in micro levels. It also changed to Nano meter size called NEMS.

The various advantages for using MEMS are: In microelectronics industry the devices manufactured are cheaper because of the batch processing capability, the devices are much compact and are of lesser weight to size ratio, the perspective over the environmental concerns makes this field pioneer [2 & 3]. The fuel consumption in modern houses and cars is improved because of the invention of the MEMS systems. MEMS contains of microelectronics technology, where electronic devices can be added with electro-mechanical elements and to a substrate, the later acts as the physical parts of the system like legs and arms of the machinery, the former will be concerned as the brain or think tank of the integrated system [3]. MEMS rewrites the conventional engineering mechanics by ruling out the importance of gravity, thermal energy, inertia, stress, yield strength over the system by increasing the dependency only on the atomic forces and surface interactions. This establishes the less significant scaling laws in macro scale to be a king pin in the sub millimeter, Micro or Nano Scales [5].

Nano Technology works with the submicron scale where some structures which are working at the micron scale, it has to be scaled down to work in the nano scale in a period of time, leads to the evolution of the field to Nano-Electro-Mechanical-Systems (NEMS) [6]. In NEMS, the MEMS devices enjoy the added advantage of improvements in the system parameters because of scaling down. It also exploits the quantum efficiency to the maximum extent.

1.2. Bio- Filter

A Bio-Filter is a micro device used to measure and separate the plasma [7] and body fluids like serum from the blood, based on the principles of Plasma skimming effect and cross flow filtration. Bio-Filter functions contrarily depend on the method of filtering [4 & 10]. Virtually all prevailing micro fluidic Bio-Filters are on the basis of fluidic flow.

The basic classification of blood cell separation [11] techniques:

a) Size-based methods: It is relatively fast and simple .Based on the size and shape of the cell, separation of cells can be done. The disadvantage in this method is it is not too sensitive to small size variation of cells and its specificity is less.
b) Affinity based methods: Particle separation due to affinity to antibodies in the sample with high specificity and selectivity. The isolated cells may suffer from damages. The process is costly and complicated.
c) Size and Form based separation Electro-Hydro-Dynamic Flow: Blood enters cylindrical chamber where a needle tip is placed at an angle near the fluid surface. Voltage applied to the needle causes fuel to rotate. Opposing centrifugal forces at the bottom of the cylinder separate the particles from fluid (RBC, WBC, and PLATELETS). It requires high electric field.

2. SYSTEM DESCRIPTION

2.1 MEMS Bio-Filters

Blood cell components or any other body fluid components can be filtered by using Bio-Filters [10]. Micro fluidic systems have become a versatile tool in many research grounds as miniaturized components involve only small materials

and sample components. Filtration and separation of particles for bio molecule, clinical and environmental applications have initiated a wide growth in micro scale organization. Applications ranging from separation of organically destructive agents such as bacteria, protozoa involve continues flow filtration of large sample molecules [14]. Almost all of the micro scale filtrations such as fractionation, Electrophoresis, Di Electrophoresis [8] and acoustic separation [9] involves in batch mode but not in continuously flowing mode. In all LAB-ON-A-CHIP applications however, continues on chip process and separation of particles is desired for faster identification, analysis and detection. Lab-On-a-Chip (LOC) became popular among researchers because they can perform the whole set of operations on a single microchip. These investigations on a cell can be carried out in LOC as the dimensions of cell are in the same scale as a micro channel [15, 16, 17 & 19].

In order to collect the micro cells the filter should have an array of micro size holes [12, 13& 18]. Several investigators reported that the hole of a micro filter ranges from 1 micro meter to 12 meters and the thickness ranges from 1 to 3 micro meters. Blood has almost 4000 components. Among them the 4 important components are RBC, WBC, Blood platelets and Plasma. The diameter of RBC ranges from (6-8µm), WBC ranges from (10-15µm) and diameter of platelets ranges from (2-4µm). So these components can be easily filtered by using Bio-Filter.

2.2 Materials used in Bio-Filters

2.2.1 Silicon and glass:

The material silicon is abundantly available element in the environment. Different techniques are used for this fabrication process to make flow analysis in Mixers, Filters, Pumps and Valves. However, these are several shortcomings when devices made of silicon are used in biomedical applications as the bio incompatibility and cost ineffectiveness. Because of being one time usage only, and larger than the successors, costlier materials processing, silicon based bio-MEMS structures are economically least preferred and the unavailability of clean room facilities makes it worsen. In vivo, protein absorption is minimized by silicon based bio-MEMS devices; although the brittleness of the silicon material makes it difficult to process.

2.2.2 Polymers:

Plastic composites and polymers are used in BIO – MEMS as they are easily fabricated, readily go with micromachining and special manufacturing techniques like rapid prototyping methods, as well as have minimal cost. Polymers give faster results compared to other systems. We can run adverse polymer applications on a single system. Polymers have high strength and are heat resistive.

2.2.3 Biological materials:

Proteins, tissue and artificial organs are Micro scale manipulated and patterned. This was used for high throughput single cell analysis, and multi cellular architecture. Patterning of biological materials can be done using photolithography, Micro printing and self-assembled monolayers.

2.3 System Analysis Structure

Generally micro filter consists of 3 chambers as shown in figure 1. They are the top Cover plate, the center Filtering Plate, and the bottom receiving plate. The general structure of micro filter as follows.

The existing system contains the Darcy friction factor hf=6.06

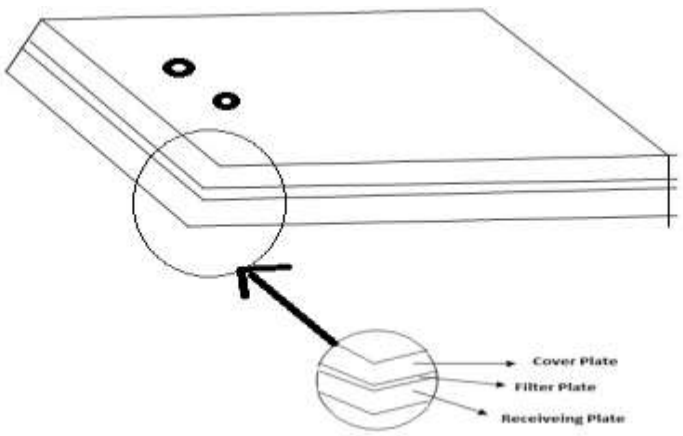

Figure 1: Blood filtering chip

2.3.1 Cover plate

To achieve the separation efficiency the transfusing channel was constructed in the bottom of the cover plate as shown in figure 2. The transfusing channel should have the following properties,

1. The flow analysis of blood should have the smooth changes of pressure and velocity through channel.
2. The blood cell accumulated should be considered. It should be low as possible.
3. The flow of blood should flow in the full structure.

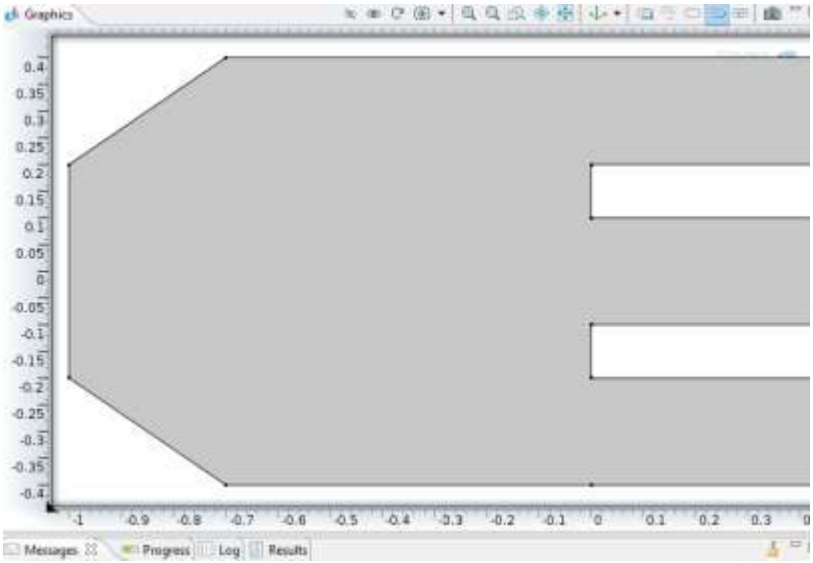

Figure 2: Cover plate

2.3.2 Filtering plate:

The porous in the filter plate are corresponding to the channel within the cover plate and it should be distributed equally as shown in figure 3. The porous are in the rectangular shape. The rectangular porous are 7 to 8 µm in nature. Also the diameter average of the erythrocyte is 7µm and leukocyte is 10µm also this choice is perfect to achieve filtering of the blood.

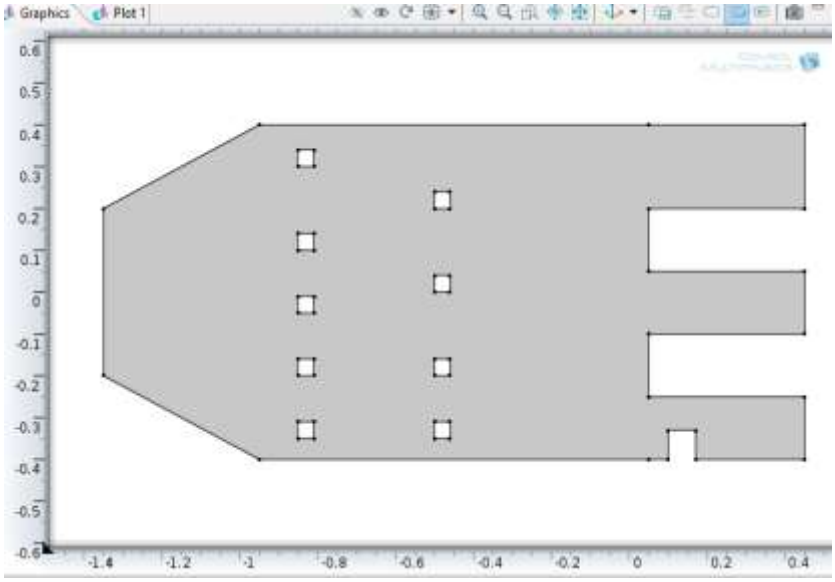

Figure 3: Filtering plate

Darcy Friction factor=$fD.\frac{L}{D}.\frac{u^2}{2g}$

Where hf head loss due to friction, fDdimentionless coefficient, L length of the pipe, D diameter of the pipe, u average velocity, g accelarotor gravity in pipe 9.8m/s. The Reynolds number for blood is 2000.fD=64/Re=0.032 hf=0.060

2.3.3 Receiving plate:

The Receiving plate shape is correspond to filter plate as shown in figure 4. It has outlet which collects erythrocytes and the plasma and it will be enter in to the vacuum bag. This will be helpful support.

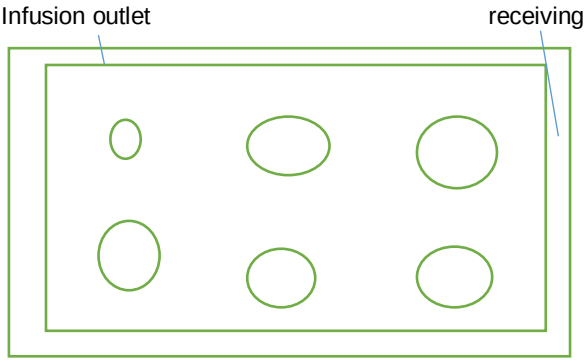

Figure 4: Receiving plate

3. PRINCIPLES AND ANALYSIS OF BIO-FILTERS

The whole blood filtering are done by suing the plasma skimming effect and cross flow filtration used. We designed the Bio-filter which is on the principle of gravitational suppression. By using the filtering techniques can easily separate the blood cells from whole blood. Plasma skimming effect and micro centrifugal effect are used in improving the plasma separation efficiency. The centrifugal force (F) can be given:

$$F=m.v^2/R$$

Where m-mass of the molecules

v-the velocity of molecules motion

R-the radius of molecules motion

The velocity can be accustomed by pressure through the fabrication process. The Radius of molecules and motion and radius of channel should be same. The semicircular channel should increase the separation effectiveness of plasma through the device. The isolation of plasma is achieved by the plasma selectivity. The plasma selectivity is defined by the equation

$$\sigma=100\ (1-c1/c0)\%$$

where c0 and c1 are cell concentration in the inlet and first outlet reservoir. The 100% of plasma selectivity implies that no cells are entering in to the channel.

4. RESULTS AND DISCUSSION

Blood constitutes of red blood cells (RBC), white blood cells (WBC) and platelets. The dimensions of RBC's are 8µm in diameter and 2.5µm in thickness respectively and are in discoid shape. The corresponding dimensions of WBC's are 8-12µm in diameter which is of spherical structure. The discoid shaped Platelets are having a diameter of 2-3µm. In this paper, filtration channel depth is less than the dimension of the blood cells (2µm). Using dropper 2(µl) of blood sample was introduced to the inlet of the micro filter. The plasma flow, RBC, WBC's velocity and pressure in the filters was also measured and the simulation results are shown in figure 5 & 6. Figure 7 shows the velocity distribution in the filter.

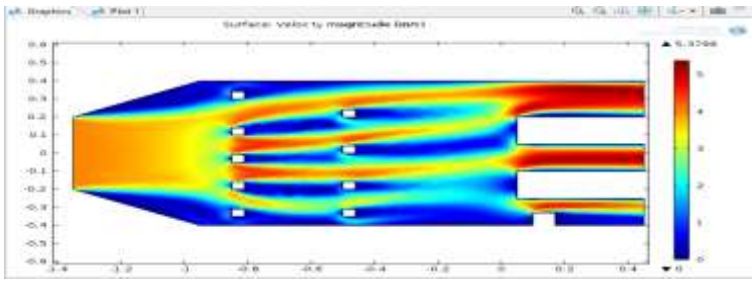

Figure 5: velocity change

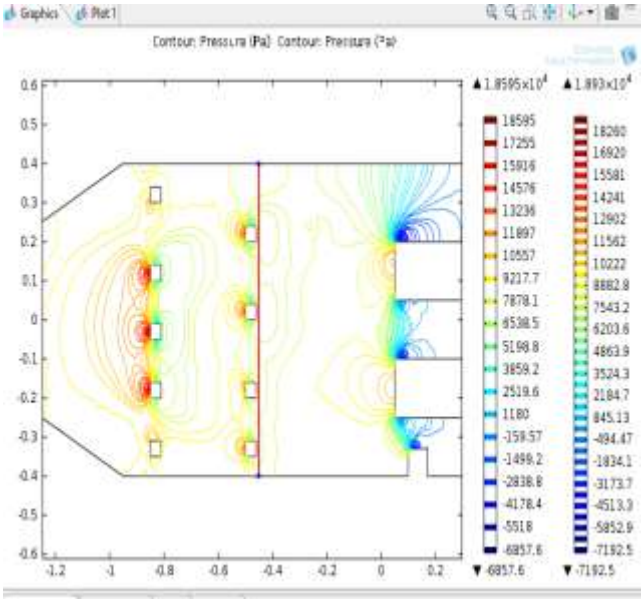

Figure 6: pressure change

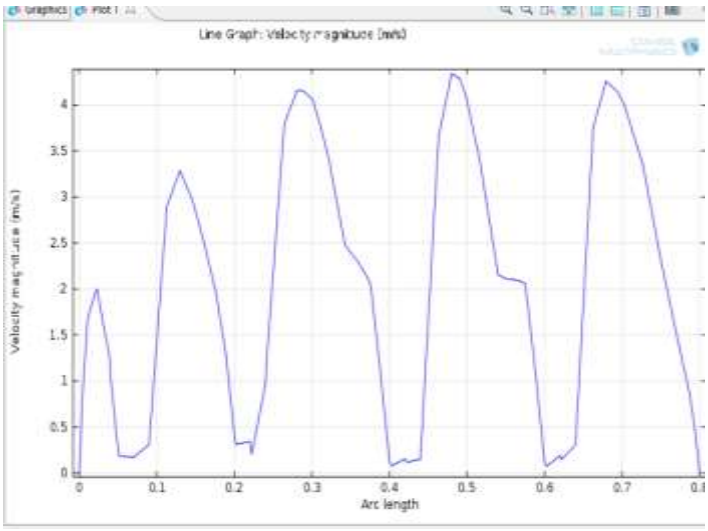

Figure 7: velocity distribution

5. CONCLUSION

A microfluidic bio-filter is designed by means of COMSOL Multiphysics in this paper. The principle of plasma skimming effect and cross flow filtration is employed and extracted the blood plasma RBC and WBC from whole blood sample. Advantages of this filter structure are simple, high efficiency and fluid flow can be achieved without external force. This can be used for point of care diagnostics.

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