Simulation of Gravity-Driven Flow Through a Microfluidic Device on a Rocker Platform

B. Srinivasan[1], J. Hickman[1], M. Shuler[2]

[1]University of Central Florida, Orlando, FL, USA
[2]Cornell University, Ithaca, NY, USA

Abstract

A micropump delivers fluid between different components of a microfluidic device in a controlled manner. The elimination of micropump can reduce the design complexity, simplify fabrication, shrink the device footprint and decrease the set-up time required for the operation of the microfluidic device. One such pumpless microfluidic device for body-on-a-chip application for drug toxicity studies has been reported(1) and is based on placing the microfluidic device on a rocker platform to achieve a gravity driven flow that mimics the human blood recirculation. Figure 1 shows a 2D schematic of a microfluidic device on a rocker platform where the tilting of the device causes liquid to flow from one well (inlet/outlet) to the other. A bi-directional flow is achieved as the flow direction changes when the rocker platform oscillates and switches between clockwise and anti-clockwise directions.

A 2D COMSOL Multiphysics® simulation was performed using a combination of the Laminar flow interface from the COMSOL CFD Module and the Transport of Diluted Species interface from the Chemical Reaction Engineering Module.

The laminar flow simulation was defined by horizontal and vertical components of the gravity vector. The angle of tilt and frequency of oscillation of the rocker platform were used as input parameters. A time-dependent flow simulation was performed and it was observed that the flow direction changes in accordance with the tilt direction of the rocker platform. Also, the flow rates were observed to increase with increase in tilt angle and frequency of oscillation. Figure 2 shows the change in direction of the velocity vectors as the tilt direction changes. The change in flow rates with respect to the frequency of oscillation and angle of tilt of the rocker platform was estimated. Shear stress has been known to induce mechanotransduction in tissues and is an important factor for in vitro tissue culture. The shear stress distribution on the bottom surface of biological tissue and the microchannel chambers was analyzed.

A time-dependent simulation studying transport of dilute species coupled with previous flow simulation results was performed to study the diffusion transport, residence time and consumption of analyte introduced into the microfluidic device. An enzyme kinetic reaction was defined on the surface of the biological tissue to predict the consumption rate of the analyte. The concentration distribution of the analytes with respect to time was plotted. Figure 3 shows the results of the surface concentration distribution of the analyte diffusing through the microchannel. The diffusion

and convection model provides the residence time and consumption rate of the drugs introduced into the microfluidic device and is important for drug toxicity study experiments.

Reference

1. Sung JH, Kam C, Shuler ML. A Microfluidic Device for a Pharmacokinetic-Pharmacodynamic (PK-PD) Model on a Chip. Lab on a Chip, 2010;10(4):446-55.

Figures used in the abstract

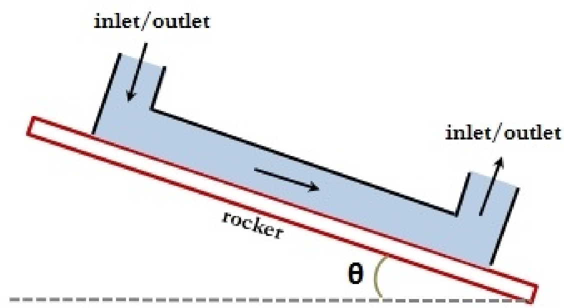

Figure 1: A 2D schematic of a microfluidic device on a rocker platform.

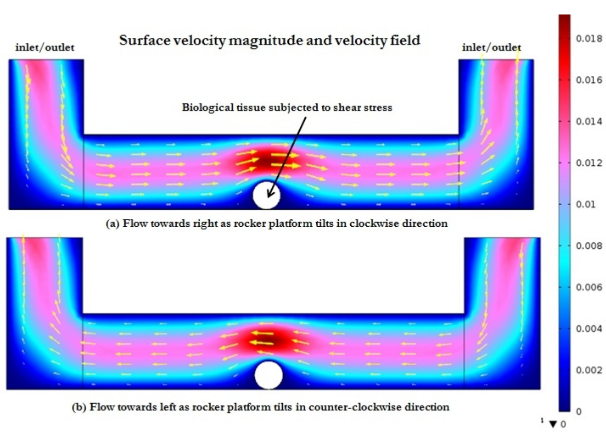

Figure 2: Change in flow direction with change in tilt direction of the rocker platform.

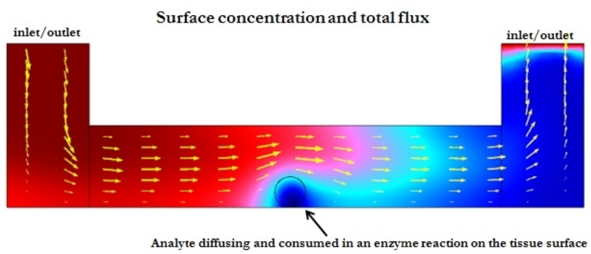

Figure 3: Diffusion of analyte and consumption of analyte within the biological tissue.