A Trapping Mechanism of a Single-Particle Inside a Triangular Microwell

Phakpoom Yingprathanphon[1]

[1]Chulalongkorn University, Thailand

Abstract

Transplantation of organs and tissues remains the solution for repair of damaged tissue, yet the shortage of donor human organs for transplant is another issue as well. In the field of regenerative medicine, several regenerative technologies have recently been developed using various biomaterials to address these limitations. Culturing cells on scaffolds, derived mainly from various non-autologous organs, has become an emerging treatment approach[1-3]. Microfluidic device, which consists of an array of triangular microwells[4-5], seems to be another interesting platform for entrapment of a microsphere scaffold and cultured cells together before injecting into a patient body.

This study aims to reveal a trapping mechanism using computational simulations of COMSOL MULTIPHYSICS® to enhance an efficiency of single particle or cell entrapment. Consequently, the optimized parameters which can generate the proper flow structures within the microwell would be considered in order to efficiently catch either particles or cells. The computational domain was designed as shown in Fig. 1a. A 10×20 array of triangular microwells, with a side-length of 600 μm and depth of 300 μm, was extended downward on a bottom surface. Water properties were employed with a uniform flow velocity varied from 2.3, 23 and 230 μm/s, and the backflow at outlet was suppressed in the simulation. Symmetry boundaries were employed on side walls to reduce the size of the computational domain. A grid independence test was simultaneously conducted with a mesh-distribution function and free trihedral meshing type.

Streamlines were plotted within the microwell as shown in Figs. 1b-c. Among the various conditions, the recirculation pattern generated inside the triangular microwells was similar. Two flow-structures were the lateral vortex at the upper part of the microwell as shown in Fig. 1b, and the counter-rotating streamwise vortices at the leading-edge of the microwell as shown in Fig. 1c. The former one might help preventing the trapped particle slipping out as a covering barrier while the latter one might help aligning the trapped particle at the middle of the microwell. Accordingly, the particle size should be matched with the extent of these flow structures for a single-particle trapping. Otherwise, the particle might be pulled out along the counter-rotating vortices.

Specifically, Fig. 1d shows a particle that travels along the streamline at the apex of the microwell might be pulled into the microwell by the lateral vortex, and immobilized at the bottom easily. On the other hand, the particle that travels to the side might bump onto the streamwise vortex, and run over the microwell. Therefore, the microwell shows a high possibility of a trapping in a single-particle manner.

Figures used in the abstract

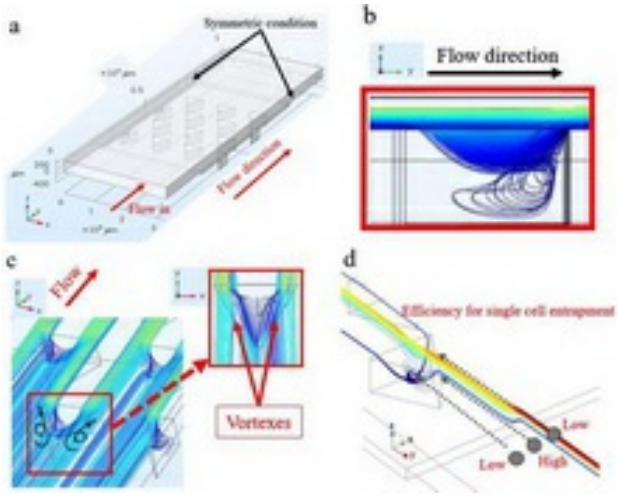

Figure 1: Fig. 1 Computational domain and results; (a) a computational model with a symmetric boundary condition, (b) lateral circulating structure on the top of microwell, (c) counterrotating vortices along both leading-edges of well and (d) high possibility of trapping for a cell that travels through the apex of the well. On the contrary, low possibility was at the side path.