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A trapping mechanism of a single-particle inside a triangular microwell

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Introduction & Background

In the field of regenerative medicine, several regenerative technologies have recently been developed using various biomaterials to address some 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.

Objective

This study aims to reveal a trapping mechanism using computational simulations of COMSOL MULTIPHYSICS® to enhance an efficiency of single particle or cell entrapment.

Computational Methods

The computational domain was designed as shown in Fig.1a and 1b. 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. 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.

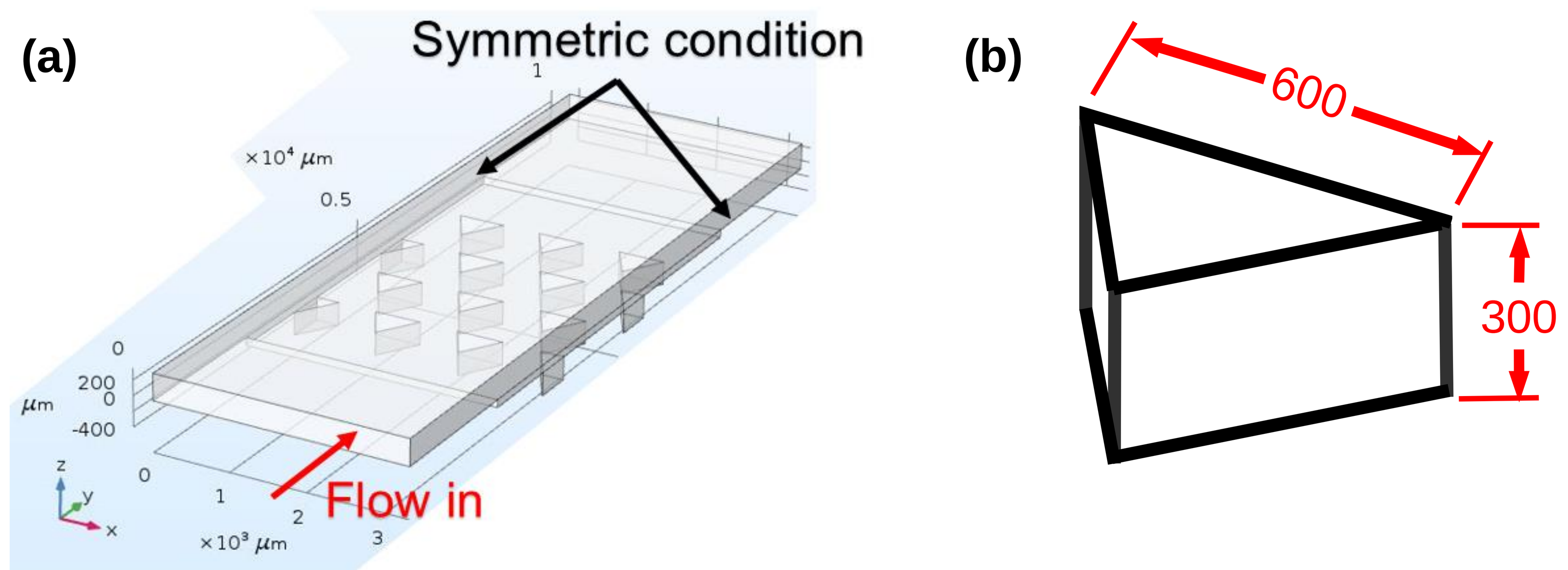

Figure 1. Computational domain; (a) a computational model with a symmetric boundary condition, (b) The dimensions of the equilateral triangular microwell (µm).

Results

Streamlines were plotted within the microwell as shown in Figs.2a and 3c. Among the various conditions, the recirculation pattern generated inside the triangular microwells was similar. Two flow-structures consisted of the counter-rotating streamwise vortices and the lateral vortex were plotted as shown in Figs.2 and 3 respectively. Specifically, Fig.3 shows the efficiency for single cell entrapment of a particle that travels along the streamline at the apex compared to the one travels to the side of the microwell. Moreover, the amplitude of shear rate within the centroid of microwell produced only 9.205×10^{-6} Pa that significantly influenced cells growth without killing them during the trapping process.

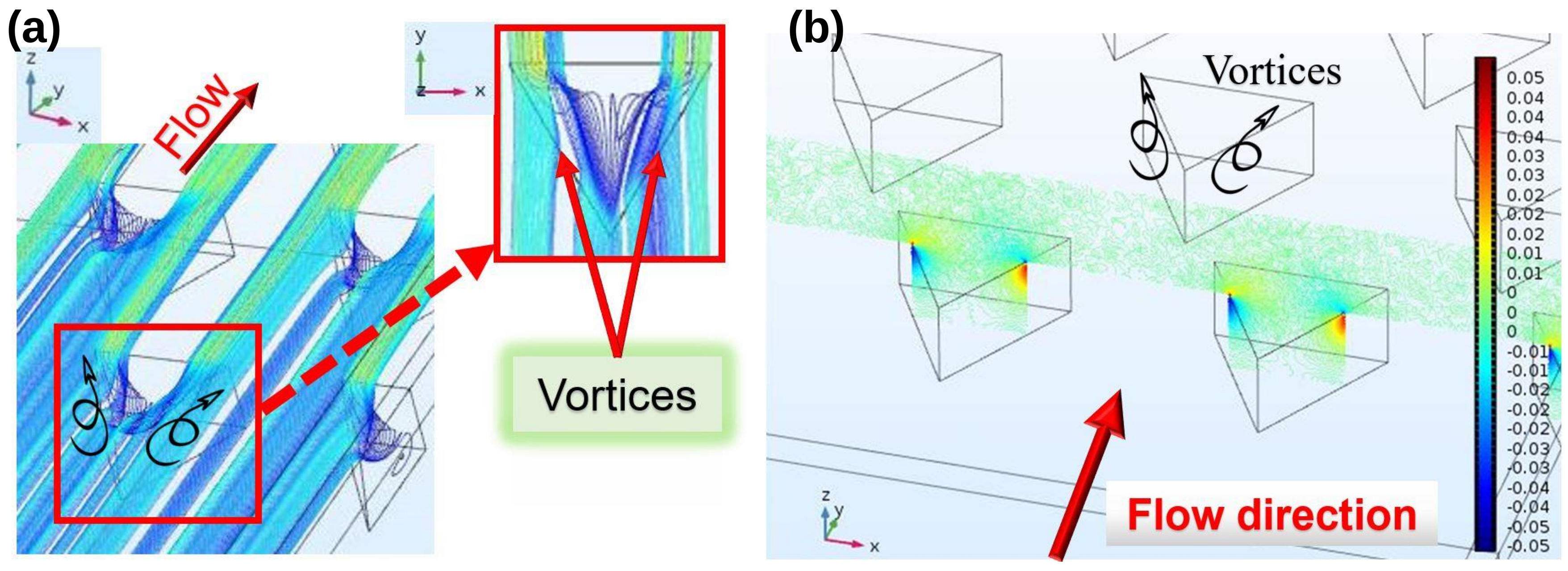

Figure 2. Results on vortices; (a) counter-rotating vortices along both leading-edges of well is another important structure controlling a particle to stay along with streamline at the apex of the well before trapping and (b) a contour plot, on a cut plane defined along the x- and z-axis, to visualize the magnitude of vorticities.

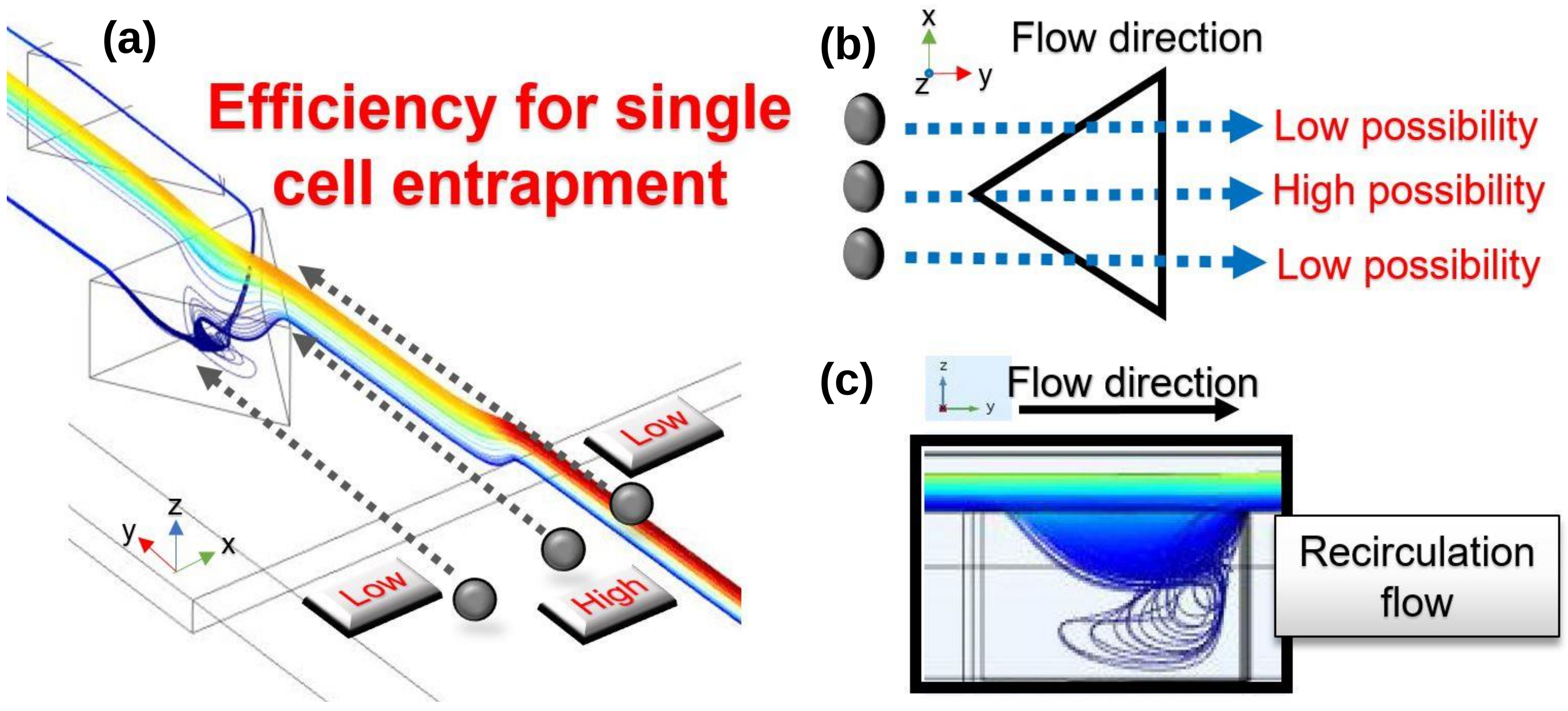

Figure 3. Results on the efficiency for single cell entrapment; (a) side view and (b) top view present high possibility of trapping for a cell that travels through the apex of the well due to the lateral vortex. On the contrary, low possibility was at the side path, as the particle that travels to the side might bump onto the streamwise vortex, and run over the microwell. (c) Side view of triangular microwell presents lateral circulating structure, generated from the upper part of microwell, is the important mechanism to pull a particle into the bottom.

Conclusions

This study revealed a trapping mechanism inside the triangular microwell using computational simulations of COMSOL MULTIPHYSICS® to enhance an efficiency of single particle or cell entrapment. Triangular wells are advantageous for generating groups of vortex which qualified as significant mechanisms to place single particles toward the bottom surface of microwell.

Acknowledgements

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