

Shear Stress Analysis in High-Throughput Dual-micropillar-based Microfluidic Platform

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Abstract

We developed the dual-micropillar-based microfluidic platform to control cellular behavior. 4×4 dual micro-pillar based platform (Figure 1) consists of 16 circular-shaped outer micropillars and 8 saddle shaped inner-micropillars. We simulated various shapes of inner micropillars to analyze the shear stress inside the inner micropillar. Therefore, this dual-micropillar-based microfluidic platform could be useful to understand cell biology and single cell analysis.

Introduction: We simulated shear stress profile using COMSOL Multiphysics®. We simulated profiles for different depth of inner saddle-shaped micropillars and different shapes of inner micropillars. We used CFD module to calculate shear stress at different average inlet flow rate. This analysis was important to develop a microfluidic platform to direct embryonic stem (ES) cell fate.

Use of COMSOL Multiphysics: The steady state Navier-Stokes Equation for incompressible Newtonian fluids was solved using COMSOL Multiphysics®. The Perfusion medium was modeled as an incompressible, homogeneous and Newtonian fluid of density 1000 Kg/m³ and dynamic viscosity 0.001 Pa.s. Fluidic domain meshed using finer mesh.

Results: Shear stress increased linearly with average inlet flow rate but the rate of increase of shear stress for $d = 12 \mu\text{m}$ with increasing average inlet flow rate was negligible with respect to $d = 3, 6 \mu\text{m}$ (Figure 2.c). The rate of increase of shear stress inside inner micropillars was negligible as compared to only outer micropillars or outside the micropillars condition (Figure 2.d).

Conclusion: We simulated shear stress at different position of platform. For different depth of saddle-shaped inner micropillars, we found different profiles of shear stress for the microfluidic platform consisting of 16 outer circular micropillars and 8 saddle-shaped inner micropillars. We found that the shear stress was negligible at $d=12 \mu\text{m}$ of saddle-shaped inner micropillars so in our microfluidic platform we choose $d=12 \mu\text{m}$ of saddle-shaped inner micropillars and the platform was used to direct ES cell fate. As we have seen that on increasing average inlet flow rate very negligible change in shear stress for $d=12 \mu\text{m}$ so this microfluidic platform was used for high-throughput.

Reference

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2. Jong min Lee, Ji-eun Kim, Edward Kang, Sang-Hoon Lee, Bong Geun Chung et al., An integrated microfluidic culture device to regulate endothelial cell differentiation from embryonic stem cells, Electrophoresis, 32(22), 3133-7 (2011)
3. Jong Min Lee, Ji-eun Kim, Jayant Borana, Bong Hyun Chung, Bong Geun Chung et al., Dual-micropillar-based microfluidic platform for single embryonic stem cell-derived neuronal differentiation, Electrophoresis, In Press(2013)

Figures used in the abstract

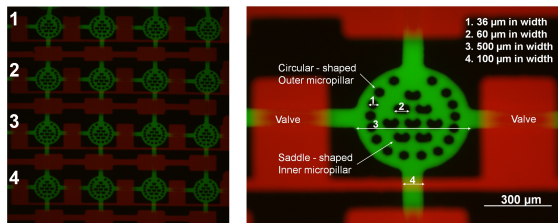


Figure 1: Fluorescent Image of the dual-micropillar-based microfluidic platform containing microvalves

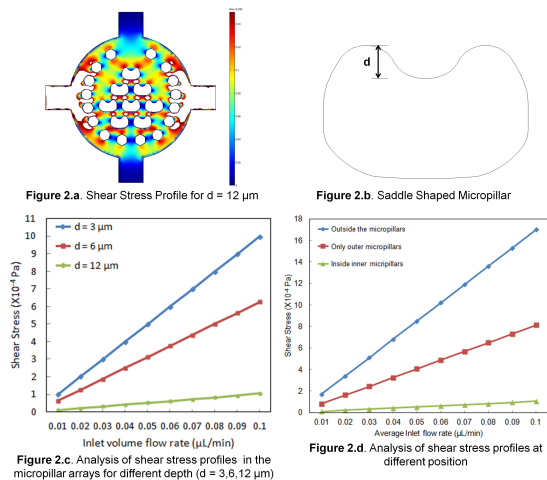


Figure 2: Results