Positioning System for Particles in Microfluidic Structures

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Abstract

The detection of particles in a lab-on-a-chip device is a challenging task. Besides transport and detection processes, deposition of the particles on the sensor area has to be considered. There are several possible solutions to this problem, like positioning the particles by employing electric or magnetic gradients. Another approach has been introduced by [1] to solve this problem using gravity and buoyancy effects. Therefore a ramp like structure (Figure 1) is used to create a flow profile which increases the capture rate of the device compared to a straight channel. The ramp has been analyzed for flow velocities up to a few hundred micrometers per second, which can be achieved by hydrostatic pressure. For these velocities it is sufficient to use ramps with a small outlet to inlet area ratio (X) of about one, to receive a significant increase in the capture rate, compared to a straight channel. For higher velocities, which are considered in this work, this is no longer possible. For the case of incompressible fluids considered here, high X ratios lead to a decrease of the fluids velocity. Thus the particles have more time to reach the floor and the capture rate increases. COMSOL Multiphysics is utilized to compute a mapping of the initial height to the landing position of the particles on the geometry's floor. Only half of the geometry (Figure 2) is generated as the structure has a distinct plane of symmetry. To evaluate the fluid flow profile, the linearized Navier-Stokes equation set has to be solved. This is done with the Creeping Flow physics interface. The mapping itself is received by a convection and diffusion model, where the diffusion constant is zero and the inlet concentration equals the height (Figure 2). This changes the concentration distribution to a mapping of the initial height, which is also known as Level-set-method. As expected it is possible to alter the ramps geometry in such a way, that it can be used at higher velocities (Figure 3). For velocities above a millimeter per second, an outlet to inlet area ratio above three is required. Alternatively the landing area can be enlarged to increase the duration particles need to pass through the device, which on the other hand leads to a sparse distribution of the particles on the target area. COMSOL Multiphysics has been used to calculate the capability of a ramp like structure to improve the capture rate of a microfluidic structure. If the geometry parameters are adjusted appropriately, it will be possible to use the ramp in pump-driven structures.

Reference

[1] A. Weddemann et al., Positioning system for particles in microfluidic structures, Microfluidics and Nanofluidics, 7, 849-855 (2009).

Figures used in the abstract

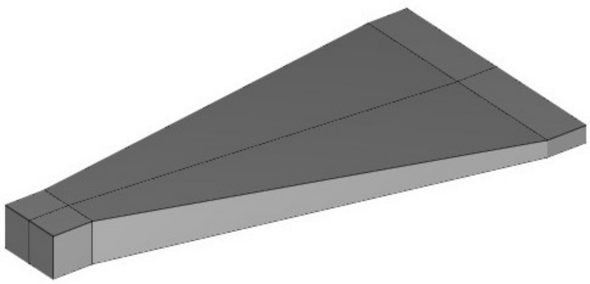

Figure 1: COMSOL model of a ramp like structure.

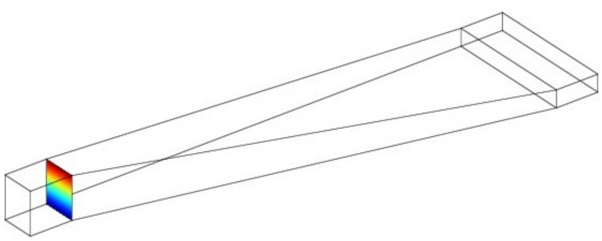

Figure 2: Simulation model: boundary conditions at the inlet.

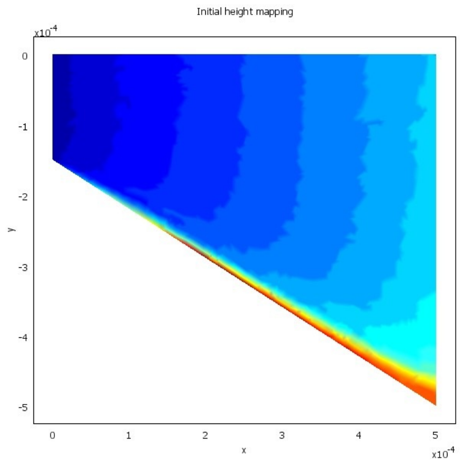

Figure 3: Solution for the landing positions. Blue denotes particles from the ground of the inlet, red ones are from the top.