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RESEARCH PAPER

Control of secondary flow in concentrically traveling flow on centrifugal microfluidics

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Abstract This paper reports a fundamental study of the stripe laminar flow pattern on a centrifugal microfluidic device with the goal of realizing a sedimentation-based, continuous mode particle separation technique. Microfluidic channels were designed with a concentrically integrated microchannel, and the patterning of the flow in the channel was investigated. A significant secondary flow was observed as a preliminary result. We conclude that the origin of this secondary flow was not the Dean force, because it was observed in a straight microchannel, but was not observed in curved channel during the spinning of the system at rest. The transition of the pattern was investigated using a simulation and experiment, and the flow pattern's dependence on the rotational speed was determined, which suggested that the origin of the secondary flow was the Coriolis force. The significance of the secondary flow was controlled by adjusting the rotational speed of the disk, and the flow rate and laminar flow patterns were controlled by the stripe flow pattern.

1 Introduction

A continuous mode particle separation method that uses the transportation of particles by microscale laminar flow in a microfluidic device has been proposed (Pamme 2007; Petersson et al. 2007; Tsutsui and Ho 2009). In these applications, the lateral migration of particles is induced by an external force, which is applied across the flow direction. If there is specific interaction between the applied force and the particles, the particles selectively migrate and separate from the suspension flow to a clean medium flow by their selective interaction with the external force. To enhance the selectivity, a specific marker is important. The specificity of an immune reaction is typically used because of its high specificity. In this way, an antibody labeled with a magnetic particle is suspended in a cell suspension and incubated to bind the magnetic particle to a target cell (Xia et al. 2006). The magnetic force is utilized to drive the particles in a microchannel. On the other hand, other markers such as size (Yamada et al. 2004), or size and density (Huh et al. 2007; Morijiri et al. 2011), have also been intensively researched. These markers are intrinsic to the particles; therefore, they can be used for label-free separation methods. Because no target labeling is required, these kinds of separation methods are likely to have positive aspects, with fewer problems affecting the process downstream, even though the selectivity is relatively lower than the labeling method. In the case of using density as a marker, centrifugal force can be applied to drive the migration. Because centrifugal separation has traditionally been widely used in the field of biochemistry, its reliability is well established (Pertoft 2000). Centrifugal microfluidics can be used for both liquid pumping and the sedimentation of particles by applying a centrifugal force in a microfluidic system on a spinning disk (Ducrée et al. 2007; Duffy et al. 1999; Haeberle et al. 2007; Madou et al. 2001; Ukita et al. 2012). Because centrifugal microfluidics does not require complicated systems, it has the potential to realize simple systems, the parallel driving of a system, and the accurate control of artificial gravity and liquid pumping. Centrifugal microfluidics have been applied to the sedimentation of

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