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RESEARCH PAPER

Spindle-shaped microfluidic chamber with uniform perfusion flows

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Abstract The reaction chamber is important due to its wide applications. Based on the idea of the bionics, a novel spindle-shaped chamber (S-chamber) for microfluidics was designed to provide uniform flow and eliminate stagnant corners for microchannels. The computational fluid dynamics simulation results demonstrate that these S-chambers have a better performance compared to the conventional diamond-shaped chambers. An S-chamber with the optimized shape, which consists of a rectangle reaction region interfaced to the inlet/outlet channel through an expansion region with smooth arc edges, was fabricated by micromolding of polydimethylsiloxane. This S-chamber was fixed into a microreactor and mounted horizontally on a synthesizer for biochemical reactions. Solvent perfusion experiments and synthetic optimization experiments for in situ synthesis of peptide nucleic acids microarray were performed. The experimental results indicate that the newly designed and fabricated S-chamber provides excellent homogeneous perfusion flows. This type of S-chamber is designed for the most convenient fixation in the horizontal direction, without the need to consider the complicated effect caused by other housing directions. It has a wide application for cell culturing, microarray synthesis, gene hybridization, and many other microfluidic system-based techniques requiring uniform flow conditions.

1 Introduction

The development of microfluidic technology enables a wide variety of microchambers to be designed to perform biological and biochemical experiments due to its ability for increasing accuracy, throughput, and efficiency as well as reducing the cost and labor (Cho et al. 2011; Vinuselvi et al. 2011). The flow characteristics inside the channels of a microscale system vary from those of a macroscale system since microscale systems show a larger surface-to-volume ratio, resulting in more interactions between the flow and the channel surface. The flow condition of a chamber is a crucial factor which directly impacts the experiments conducted in the chamber. For example, in a cell culture chamber, a uniform flow condition is required to provide even shear stress and homogenous supply of the nutrients to the cells in different parts of the chamber (Petronis et al. 2006). For microarray hybridization experiments, because the hybridization kinetics are diffusion dependent (Adey et al. 2002), a reaction chamber providing uniform flow conditions is able to achieve uniform signal intensity across the microarray, leading to a more accurate measurement. Most importantly, many synthesis assays (e.g., for the synthesis of DNA chips) performed in reaction chambers require the exchange of reagents, so that different reagents can be delivered into and pushed out of the chambers successively. Non-uniform flow chambers with poor exchange of reagents may induce non-desired reactions due to the cross-contamination of the reagents.

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