World Academy of Science, Engineering and Technology
International Journal of Biomedical and Biological Engineering
Vol:18, No:05, 2024

Optimization of Geometric Parameters of Microfluidic Channels for Flow-Based Studies

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Abstract : Microfluidic devices have emerged as indispensable tools across various scientific disciplines, offering precise control and manipulation of fluids at the microscale. Their efficacy in flow-based research, spanning engineering, chemistry, and biology, relies heavily on the geometric design of microfluidic channels. This work introduces a novel approach to optimise these channels through Response Surface Methodology (RSM), departing from the conventional practice of addressing one parameter at a time. Traditionally, optimising microfluidic channels involved isolated adjustments to individual parameters, limiting the comprehensive understanding of their combined effects. In contrast, our approach considers the simultaneous impact of multiple parameters, employing RSM to efficiently explore the complex design space. The outcome is an innovative microfluidic channel that consumes an optimal sample volume and minimises flow time, enhancing overall efficiency. The relevance of geometric parameter optimization in microfluidic channels extends significantly in biomedical engineering. The flow characteristics of porous materials within these channels depend on many factors, including fluid viscosity, environmental conditions (such as temperature and humidity), and specific design parameters like sample volume, channel width, channel length, and substrate porosity. This intricate interplay directly influences the performance and efficacy of microfluidic devices, which, if not optimized, can lead to increased costs and errors in disease testing and analysis. In the context of biomedical applications, the proposed approach addresses the critical need for precision in fluid flow. it mitigate manufacturing costs associated with trial-and-error methodologies by optimising multiple geometric parameters concurrently. The resulting microfluidic channels offer enhanced performance and contribute to a streamlined, cost-effective process for testing and analyzing diseases. A key highlight of our methodology is its consideration of the interconnected nature of geometric parameters. For instance, the volume of the sample, when optimized alongside channel width, length, and substrate porosity, creates a synergistic effect that minimizes errors and maximizes efficiency. This holistic optimization approach ensures that microfluidic devices operate at their peak performance, delivering reliable results in disease testing. A key highlight of our methodology is its consideration of the interconnected nature of geometric parameters. For instance, the volume of the sample, when optimized alongside channel width, length, and substrate porosity, creates a synergistic effect that minimizes errors and maximizes efficiency. This holistic optimization approach ensures that microfluidic devices operate at their peak performance, delivering reliable results in disease testing. A key highlight of our methodology is its consideration of the interconnected nature of geometric parameters. For instance, the volume of the sample, when optimized alongside channel width, length, and substrate porosity, creates a synergistic effect that minimizes errors and maximizes efficiency. This holistic optimization approach ensures that microfluidic devices operate at their peak performance, delivering reliable results in disease testing.

Keywords : microfluidic device, minitab, statistical optimization, response surface methodology
Conference Title : ICMN 2024 : International Conference on Microfluidics and Nanofluidics
Conference Location : Singapore, Singapore
Conference Dates : May 02-03, 2024

Open Science Index, Biomedical and Biological Engineering Vol:18, No:05, 2024 publications.waset.org/abstracts/182141.pdf