ABSTRACT

Recent advancements in microfluidics have greatly influenced biological and technological domain by providing researchers precise control over fluid flow dynamics in micro level, mass transport phenomenon and cellular microenvironments. Among numerous approaches, three-dimensional (3D) printing— specifically Digital Light Processing (DLP)—has emerged as an effective tool for rapid prototyping of complex microfluidic designs with high resolution, design flexibility, and less fabrication duration. This thesis centers on the design, fabrication, characterization, and application of DLP-printed microfluidic devices for diverse biological applications, illustrating its adaptability of this fabrication approach towards numerous scenarios. In the first objective, a DLP-printed microfluidic device fabricated using a commercially available photopolymer resin was utilized to study the growth of *Escherichia coli* in the presence of two media and fluid flow dynamics inside the channels was studied. Along with bacterial culture and biofilm formation experiments, computational fluid dynamics (CFD) simulations were performed to investigate the velocity profiles, shear stress distribution, and bacterial trajectories. And, hence confirming the appropriateness of the printed devices for microbiological research and analysis. The second objective informs the utilization of the 3D-printed microfluidic device to environmental application, where it was utilized to facilitate bacterial biofilm formation for the biodegradation of petroleum hydrocarbons present in petroleum sludge using a novel bacterial consortia. The regulated microenvironment promoted biofilm growth and increased interaction between microorganisms and hydrocarbons, illustrating the potential of microfluidics for studying and improving bioremediation phenomenon. In the third objective, a flow-focusing 3D-printed microfluidic device fabricated using a lab-developed photo resin was designed to generate Janus droplets encapsulating two different kinds of cells. Biopolymers such as alginate and fucoidan were used to form compartmentalized droplets that mimic the native liver microarchitecture. CFD simulations were conducted to investigate the compartmentalization and the concentration of cells within the droplet, providing elucidating the correlation between platform geometry, flow parameters, and droplet generation. Lastly, the fourth objective showcases the amalgamation of a DLP-printed microfluidic device with a blue laser-scribed graphene (BLSG) substrate to establish a hybrid platform for cell culture and impedance measurement applications. The integration of LIG is a step ahead towards development of a 3D conductive and biocompatible surface in the microfluidic platform which promotes cell adhesion and proliferation while providing opportunities for real-time impedance measurement. Collectively, this thesis demonstrates the extensive utility of the DLP printing as an all-rounder, cost-effective and scalable technique for developing multifunctional microfluidic devices. It proves the extensive applicability of 3D-printed microfluidic devices in the biological and environmental avenues, where the experimental investigations are complimented with CFD analysis across microbial culture, biodegradation studies, droplet-based three dimensional cell encapsulation, and advanced cell culture systems.

Keywords: 3D-Printed Microfluidics, Digital Light Processing (DLP), Bacterial Adhesion, Bioremediation, Micro-sinusoid mimic, Janus hydrogel