ABSTRACT

There is increasing evidence that cellular responses in traditional macroscale culture platforms do not necessarily reflect how cells may behave in vivo. This discrepancy stems from the fact that biological cells, which are micron-sized, determine their cellular behaviours such as sub-cellular signalling, growth, differentiation and death, based on the various biophysical and biochemical cues. Improvisation to the traditional cell culture models is achieved through flows in microscale platform, which expands our ability to control the local cellular microenvironment while increasing the throughput of current methods. Flow of immiscible fluid phases of either with different chemical compositions (liquid/liquid) or with different physical states (gas/liquid) is gaining relevance to the microfluidic platform in biological applications. Much of the original motivation behind utilizing two-phase flows at microscale for the developments in biology also arose from various physiological processes which include gas exchange in human airways and blood capillaries in the form of laminar flows and organisation of cellular systems in both physiological and pathological conditions in the form of segmented liquid-gas flows.

The present study focuses on such two important facets of multiphase flows in biological paradigm - laminar flows and segregated flows of liquid-gas systems in microfluidic devices. First, the reaction-diffusion process of a two species system under laminar flow condition has been investigated. Utilising these flow conditions, a microfluidic static cell culture platform has been improvised for prolonged sustenance of adherent mammalian cells by formation of extended air-liquid interface through functionalizing inner surfaces of a Poly-Di-Methyl-Siloxane (PDMS) based microdevice. Second, a microfluidic platform has been developed for cell-bubble interaction in presence of the acoustic waves. An oscillating microbubble-cluster in the vicinity of a biological cell is shown to induce structural deformation in the cell membrane which alters the membrane permeability and finally forms resealable pores on the cell membrane. The fundamental basis for such complex interaction at the cell membrane surface has been demonstrated through the signal transduction on the cell surface using lipid rafts at the molecular level and through the alteration of the traction force that cell exerts on the substrate. These results may be of potential importance towards developing fundamental insights on acoustic force driven signal transduction in cells over bio-microfluidic scales.

Keywords: Microfluidics, Microchannel, Multiphase Flows, Advection, Diffusion, Dispersion, Cell Culture, Lab-on-a-Chip, Microbubble, Microrheology, Cell Membrane, Shear Stress, Sonoporation, FRAP, Lipid Raft, Focal Adhesion, Traction Force Microscopy.