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Editorial

Droplet-Based Microfluidics as a Potential Platform for Point-of-Care Diagnostics

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Editorial

Point-of-Care (POC) devices are widely used in the clinical tests for detection of certain diseases like blood glucose levels, pregnancy tests, Ketonacids etc. One of the key benefits of POC devices is that analyses can be done in minutes rather than much longer times, typically hours needed in conventional analytical labs. POC devices must be able to detect early stage biomarkers for certain diseases and help with monitoring the diseases. Robust, sensitive, cheaper and easy to handle POC devices are required in order to get access to the clinical market.

Miniaturization of microfluidic devices has become practical with the development of microfabrication technologies and these microfluidic devices have been developed for miniaturizing chemical and biological assays, with key advantages such as reduced amounts of samples and reagents, cost effectiveness, robustness and sensitive assays [1]. These systems have the ability to be used for high throughput, parallel and automated analytical analyses.

Continuous microfluidics involves laminar flow of minute quantities of miscible fluid streams in microfluidic devices. Numerous such microfluidic devices were developed to scale down the amount of reagents from millilitres or microliters to nanoliters and study chemical reactions or synthesize materials in a short interval of time. However, it has number of disadvantages such as slow and weak mixing in microchannels, Taylor dispersion of the analytes and sample loss or contamination of biomolecules on the surface of the channel walls. Parabolic velocity profile of two miscible fluids shows that the velocity of fluidic flow is zero on the surface of the channel walls (non-slippery boundary conditions) and the highest in the middle of the channel [2]. This effect introduces Taylor dispersion that leads to spreading of sample and signal smearing along the channel.

Droplet-based microfluidics has immerged as an alternative technique to encapsulate biomolecules or analytes of interest into a discrete droplet and perform analysis with these 'digital' units [2]. Nanoliters to femtoliters sized discrete droplets are generated in a microchannel by pinching off continuous aqueous stream with an immiscible carrier phase. Mixing in droplets is fast as compared to continuous microflows because of the high surface area to volume ratio and shorter diffusion distances between molecules. Analytes of interest are compartmentalized into droplet plugs and the carrier phase prevents the sample from contact with the surface wall and hence, eliminates sample loss on the surface wall. Carrier phase also prevents leakage of the molecules and cross-contamination between droplets. Thus in droplet microfluidics each droplet acts as a separate microreactor and multiple of them (as many as millions) can be transported and analysed in a single device [3], whereas in continuous microfluidics, it requires separate microchannel for each sample, or complicated fluidic controls because of contamination and dilution problems.

Reactions in droplets offer robust mixing, shorter distances between molecules for faster diffusion, mass and heat transfer, reduced hazardous material exposure and requirement of small quantities of precious and expensive reagents [4]. Fast mixing in microfluidic systems is required to study chemical kinetics of chemical and important biological reactions. Mixing in droplets is enhanced by circulating flow and chaotic advection. Flow is produced by touching the droplets with solid channel walls which generates circulating flow in half of the droplets. Due to the flat rectangular cross channel, the two halves of the droplet remain unmixed while the fluids within each half are mixed [5]. Chaotic advection is required to improve the mixing between the two halves which is generated by fabricating bends and turns in the microfluidic channels [2]. This type of geometry introduces stretching and folding of the fluid halves inside the droplets and advance mixing. Serpentine microchannels are also designed to increase chaotic advection inside the droplets; at the turn in the microchannel, each halves of the fluids experience unequal recirculating flows. This unequal flow introduces motion in asymmetrical plane along the walls of the microchannel and mix thoroughly across each halves [6]. Sharp bends increase stretching and folding events inside droplets and reorient the droplets to promote mixing.

Multiple reactions can be performed within droplets by changing reaction conditions such as temperature, concentration or catalysts. Droplets can also be stored for longer times in microchannels without evaporation of the reagents and transported whenever required for detections or further reactions. For the reactions to be performed in microchannels, conditions such as controlled reagent addition, mixing and reaction times, and analysis must be similar with the macroscale reactions. High throughput reactions also require accurate indexing of the droplets and analysis in a shorter time [7].

However, the use of microfluidic based devices is still very limited for clinical diagnostics. POC device must be able to provide high sensitivity for detection and more importantly high throughput for the clinical analyses.

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