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Title

In Polish: Pasywne systemy mikroprzepływowe do oznaczeń analitycznych

In English: Passive microfluidic systems for development of analytical assays

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Droplet microfluidics is an interdisciplinary field of science dealing with production, manipulation and use of the droplets at the microscale. Droplets are produced in microchannels of engineered cartridges called microfluidic devices. Architecture of microfluidic device, a way the microchannels are placed in the microfluidic device, greatly influences the size of the generated droplets and uniformity of their sizes.

Inside each of the droplet of the emulsion a number of operations can be carried out, for example conducting the chemical reaction or culturing cells. Large number of compartments offered by emulsions allows performing assays with many repetitions. Emulsions are useful in analytical schemes such as nucleic acid amplification or drug toxicity screening. Droplet microfluidics revolutionized the field of bioanalytics, allowing performing assays previously unattainable due to technical limitations of number of compartments. Example of such assay is sequencing genomes of single cells in large bacterial populations. Droplets required for analytical methods should be monodisperse – uniform in size – to provide the emulsion stability and allow direct comparison of results from distinct droplets. Passive droplet microfluidic techniques offer tightly monodisperse emulsion, though at quite low throughput (droplets production rate). The intuitive solution is to increase the flow rate of the emulsified liquid in order to increase the throughput. However, increasing the flow rate of the to-be-dispersed (droplet) phase in standard passive droplet generating junctions results in changing the emulsion size and uniformity.

The aim of this dissertation was optimization of passive droplet microfluidic architectures in order to i) decouple the produced droplet volume from the flow rate of the droplet phase, ii) increase the throughput of the device, and iii) explore possibility of producing complex emulsions using step emulsificator. The expected outcome was creation of an emulsificator that would produce monodisperse emulsions useful for development of analytical assays in wide range of flow rates.

The dissertation consists of three main sections: introduction, results, and literature. First four chapters offer introduction to the subject of the dissertation. Chapter 1 introduces emulsions and their properties. Chapter 2 provides description of the droplet microfluidics, with emphasis on passive droplet generation schemes. In Chapter 3 research objectives of my dissertation are revealed. Chapter 4 includes description of the materials and methods used in the described experiments. Chapters 5-7 describe selected experimental results of the projects I researched. In Chapter 5 I described how to decouple droplet volume from flow rate of the droplet phase in step emulsificator. In Chapter 6 I present how I upscaled the production of monodisperse emulsions from the step emulsificators by modifying the microfluidic device architecture. In Chapter 7 I describe passive production of double emulsions in the microfluidic device. Chapter 8 concludes the dissertation with the summary, conclusion and perspectives of use of developed step emulsificators in development of analytical schemes.