Droplet-based microfluidics for smart emulsions and functional microparticles

Jianhong Xu

Tsinghua University, China, E-mail: xujianhong@tsinghua.edu.cn

Abstract

In recent decades, droplet-based microfluidics has arisen as a new and promising field of science and technology. The use of microfluidics to manufacture functional materials has piqued the curiosity of scientists and technologists from many backgrounds and vocations. This paper will present the author's research group's recent advances in multiphase flow control in droplet-based microfluidics and the creation of smart emulsions and functional materials with microfluidics. Multiphase microfluidics will be used to control multiphase flow with varied flow patterns. They've been used in the fabrication of innovative materials in a variety of sectors, including optics, biomedicine, controlled porous materials, and drug release.The rapid expansion in the production and widespread use of synthetic chemical compounds in industrial sectors has resulted in an increase in the number of new pollutants in environmental matrices (air, wastewater, water, sediment, and soil), posing a problem for regulatory bodies.Apart from that, exposure to new contaminants, particularly in water and wastewater, has steadily harmed the ecosystem. Various physical, chemical, and biological approaches for efficiently eliminating contaminants have been documented. Membrane separation, biological degradation, enhanced oxidation, and adsorption are some of the technologies used. According to recent improvements, the adsorption process is advantageous due to its widespread availability, cheaper cost, and recyclability. Particle adsorption materials become the key for implementing diverse adsorption applications in environment remediation employing fixed bed reactors, absorption columns, fluidized beds, and cyclone separators due to cost effectiveness, ease of construction, and easy modification of operating conditions. Most traditional approaches, on the other hand, have restrictions in terms of regulated forms, sizes, and compartments. Microfluidics, in comparison to traditional techniques, has increased and expanded the possibilities for synthesising highly regulated size microparticles with outstanding adsorption capacity and reusability. Engineers, physicists, chemists, microtechnologists, and biotechnologists are all involved in microfluidics. Two of the three geometric length scales in microfluidic devices are usually in the micrometre range. The micrometre length scale specifies the most visible yet crucial feature of microfluidic devices: their tiny size, which allows for tiny sample quantities, cheap cost, and quick analysis while maintaining excellent resolution and sensitivity. The flow within microfluidic devices tends to be laminar due to the length scale associated with them. Furthermore, microscale downsizing is characterised by a great surface area to volume ratio. As a result, in microfluidics, this advantageous feature plays a critical role in fluid flow control and manipulation. Recent advancements and improvements have the potential to make microfluidics technology widespread, resulting in microfluidic devices that are more functional, efficient, and cost effective than traditional methods.

Over the last 20 years, the development of microfluidic systems that allow for the creation of microdroplets inside microfluidic devices has gotten a lot of attention. The use of microfluidic devices in a wide range of biological and biomedical applications, including illness diagnostics, cell therapy, drug screening, single-cell analysis, and drug administration, has sparked interest. Liquid droplets distributed in a second immiscible fluid are beneficial, especially when droplet sizes and size distributions may be specified in the nanometers to millimetres range. In multiphase fluid systems, the microfluidic emulsification technique provides an alternative and adaptable technique to manufacture emulsions that are highly monodispersed and have high formation frequencies. Furthermore, the geometrical properties and flow characteristics of these microfluidics systems provide versatility in manufacturing complex structured emulsions, such as double-emulsions and multi-emulsions. As demonstrated in Figure 1, highly monodispersed single, double, or multi-emulsions may be utilised as a template to make micro- and nanoparticles with a variety of architectures and morphologies. In microfluidics, diverse particle forms, compartments, and microstructures are generated based on flow and geometrical features, as shown in Figure 1. As a result, the excellent features of a droplet-based microfluidic device have made it a very viable and appealing platform for producing functionalized monodisperse microparticles.

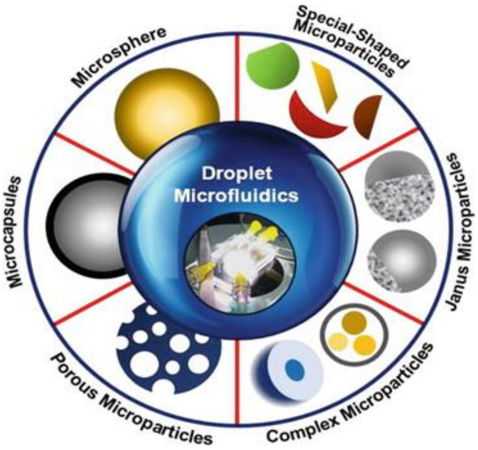

Figure 1.

Classification of various structures of microparticles produced by droplet-based microfluidics.

In order to create micro- or nanoparticles, a droplet formation analysis is required to comprehend device function and process control for a variety of applications. Other droplet manipulations, including as fusion, fission, mixing, and sorting with great accuracy and flexibility, are other important issues that have been the subject of much research. There are five ways to droplet manipulation based on the sources of the driving force involved: hydrodynamic stress, electro-hydrodynamics, thermos-capillary, magnetism, and acoustics. The use of hydrodynamic stress to manipulate droplets relative to the geometrical properties of microchannels is a simple and effective method. Various approaches have been used in the creation of droplets in microfluidics devices in this way of manipulation, including co-flowing mechanisms, flow-focusing mechanisms, and cross-flowing mechanisms. These methods allowed for the creation of dispersions with a variety of appealing characteristics, including control over droplet and particle size distribution.

Microfluidic devices have been developed throughout the years to generate particles for water cleanup. Zhao et al., for example, use microfluidics technology to produce graphene oxide microspheres for the elimination of perfluorooctane sulfonate. Using chitosan micro particles, Dong et al. investigated anionic dye adsorption. Stolaroff et al. also looked at the performance of microcapsules for CO2 adsorption and permeability. Until far, there have been few attempts to employ the microfluidic platform as a selection strategy for large-scale industrial wastewater treatment. Microfluidic platforms have a high cost and restricted capacity for high throughput manufacturing of microfluidic manufactured particles, which makes them feasible and high capacity. However, in order to achieve continuous processes, it is possible to run the production in parallel. Furthermore, basic microfluidic research is still in great need to bridge the gap between functional material synthesis and an industry viewpoint on microfluidic technologies' capabilities and prospective advantages.

Biography

Jianhong Xu has pursued his BSc and PhD from Tsinghua University in 2002 and 2007 respectively. He has continued his research in Tsinghua University as a Postdoctoral after graduation. He had finished his Postdoctoral program and became a Formal Faculty of the Department of Chemical Engineering, Tsinghua University. He had studied as a Visiting Scholar at Prof David Weitz lab in Harvard University during. Presently, his research areas are on the microstructured chemical system, multiphase microfluidic technology and functional materials synthesis. He has more than 100 peer-reviewed publications. He got the excellent young scientists fund from the national natural science foundation of China (NSFC). In 2016, he was awarded as young scholar of Chang Jiang scholars program of China of MOE.

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