INTEGRATED MICROFLUIDIC DEVICE FOR DROPLET MANIPULATION

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Summary

Droplets based microfluidic systems have a big potential for the miniaturization of processes for bioanalysis. In the form of droplets, reagents are used in discrete volume, enabling high-throughput chemical reactions as well as single-cell encapsulation. Microreactors of this type can be manipulated and applied in bio-testing. In this work we present a platform for droplet generation and manipulation by using dielectrophoresis force. This platform is an integrated microfluidic device with a dielectrophoresis (DEP) chip. The microfluidic device generates microdroplets such as water in oil emulsion.

1. Introduction

Droplets in miniaturized microfluidic systems such as water in oil emulsion are promising for use as well-defined and confined microreactors[1]. The benefits of this system are a large reduction in the volume of reagent in each droplet, the small amount of samples required, and the miniaturization of the equipment itself, reduced cost and reaction time[2]. By reducing the volumes it is possible to enhance the speed of assay. Mixing of reagents in droplet has been proved to be achieved within few minutes and it is much easier in droplets than in continuous microflows. Multiple emulsions or structured drops can offer even more functionalities, such as cell encapsulation for targeted delivery or effective high-throughput screening, which requires a much higher degree of control, with access to individual droplets. Such control can be achieved using microfluidic technology[1], which enables the formation of uniform drops, the drop manipulation[3] and the mixing of small volumes. However, manipulation of drops in the microfluidic device is essential. This work aims at examining the possibility to manipulate the microdroplets by using dielectrophoresis force. Integrated microfluidic device with a DEP chip generates surfactant stabilized droplets using an inert oil as the continuous phase. The control circuit enables us to monitor *in situ* the change of motion direction of a droplet.

2. Experimental

Water in oil emulsion was generated using a T-junction droplet generator chip fabricated as described in the literature. The chip was inserted into the holder and connected to two syringe pumps using bare-fused silica capillaries. Two 250 μL glass syringes were filled with aqueous and continuous phases.

3. Results and discussion

Emulsion formation. We have tested different oil phases such as mineral and silicone oils; decane, dodecane and decalin. In order to stabilize an emulsion, we used a combination of surfactants selected on the basis of hydrophilic lipophilic balance (HLB) values. Hence we have chosen commercially available surfactants Span 80 and Triton X 100. According to the results of the previous studies[5], we investigated three different surfactant mixtures of Span 80 and Triton X 100 in decane. It was demonstrated that the ratio of Span 80 and Triton X 100 98:2 is optimal under the given conditions and these components were added into the emulsion. The studies permitted to determine conditions of emulsion formation. The samples of oil phase such as decane, dodecane, decalin, mineral oil and silicon oil were tested with a more suitable ratio Span 80-Triron X 100 found as mentioned above. The results are presented in the Fig. 1, from which we can derive that the system decalin/Span 80-Tritox X100 has no coalescence. This system is characterized by a stable emulsion for one month. It was chosen for future experiments. The size of water drops was controlled by adjusting flow rates of oil and water with syringe pumps. We have measured the droplet size using an optical microscope. The size of the generated droplets was in the range of 10–50 μm.

Droplet generation. In order to generate emulsion (w/o) we fabricated a microfluidic chip which was connected to microfluidic droplet generation system. Two syringe pumps were filled with continuous and aqueous phases. We conducted the emulsification using a T-junction geometry microfluidic device. The width of the nozzle in the device was 75±1 μm. All dimensions of the microchannels were maintained identical. In the emulsification process, we used the optimized values and ratios of the continuous and aqueous phases. Emulsion was collected by passing the outlet flow from the chipset to the array.

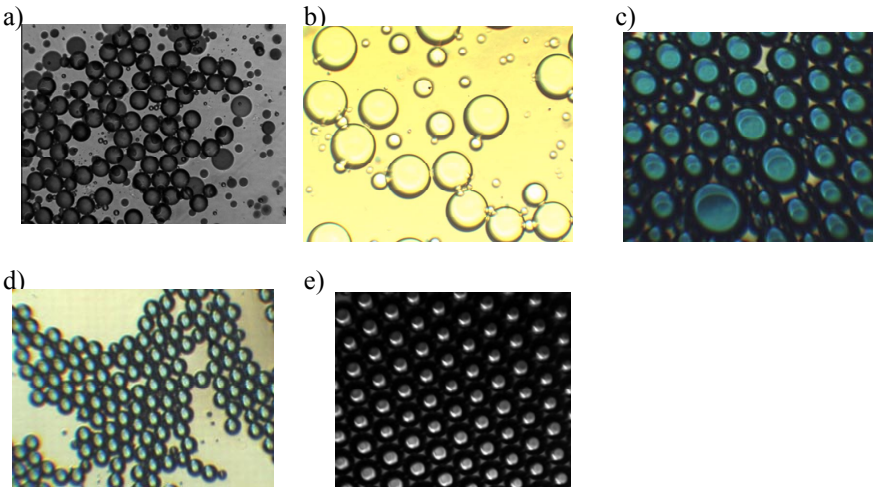

Fig. 1. **Optical micrographs of (a) mineral oil; (b) silicon oil; (c) decan; (d) dodecan; (e) decalin water in oil emulsion in the aqueous phase**

Droplet manipulation. The emulsion was collected onto the array (Fig. 2) and covered with an ITO-glass using parafilm "M" as a spacer. We applied AC voltage 25V at frequency ranging from 50 Hz to 1 MHz across the electrodes. Under these conditions we observed positive dielectrophoresis of water droplets. Droplets were attracted to the edges of electrodes, where the gradient of the electric field is the highest. We have also observed coalescence of droplets induced by AC current. This undesirable phenomenon needs to be avoided. One of possible ways to prevent it is to have sufficient distances between droplets. This could be achieved by using inlet capillary for the emulsion and pulling droplets one by one directly from the capillary. Then the droplets will be manipulated separately.

4. Conclusions

The described platform – a microfluidic device with an integrated dielectrophoresis chip for droplet manipulation – is an essential component for high-throughput bioassay. The generated droplets were placed onto the electrode array where directions of their motion could be influenced through the DEP force. The manipulation flexibility can be further increased by using higher fields, thinner electrodes or different layout of the electrode array. Applying this system for the future work involves single cell encapsulation and detection by optical and mass spectrometric means[4].

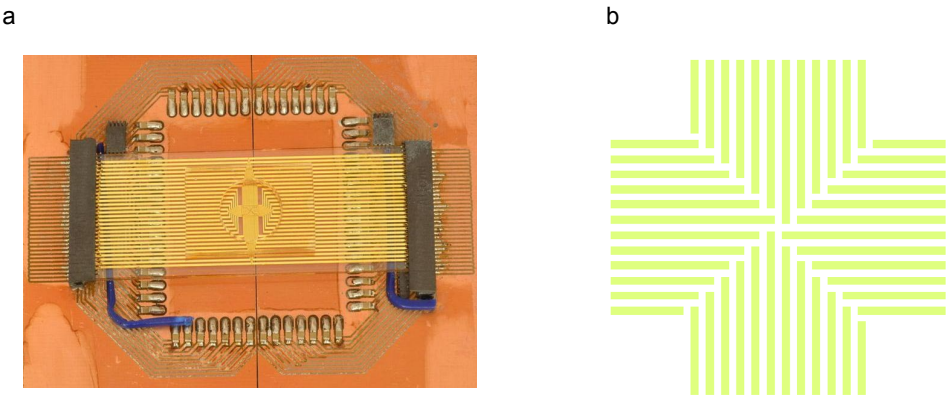

Fig. 2. **a) Schematic top view of the microelectrode array connected to the generator; b) layout of the four-segment microelectrode array which enables inducing motion perpendicular to the electrodes**

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