302d On-Chip Generation and Manipulation of Emulsion Droplets for Microfluidic Single Cell Assay Devices

Prasanna K. Thwar, Mark A. Burns, and Jennifer J. Linderman

Single cell assays require spatially isolating a single cell and moving small volumes of liquid reagents to and from the cell. We are developing an emulsion droplet-based technique to probe a single cell over long periods of time. This technique is based on encapsulating a single cell in a water-in-oil emulsion droplet and actively manipulating it using dielectrophoresis. Compared to other microfluidic techniques for single cell analysis, this technique has unique advantages in precisely metering and delivering small volumes of reagents. This could potentially be useful in developing assays for cellular signal transduction, high content assays for screening drug targets and pharmacological and toxicological analyses. In this talk, we will present experimental data on two of the component tools of the technique – droplet generation and droplet trapping and manipulation.

We have designed PDMS-based channel geometries to generate monodisperse water-in-oil emulsion droplets of size 30-50 μm. The droplets are formed by creating Rayleigh-Plateau instability at the junction of the water and oil phases and are stabilized by surfactants dispersed in the oil phase. We found that the size of the droplets can be easily controlled by regulating the flow rates of the two different phases.

We have also developed an AC dielectrophoresis-based method to trap single or multiple droplets at a specific location. In this method, 5-10 V_{p-p} applied to quadrupolar electrodes creates a virtual energetic trap where the droplet is levitated. By applying a four-phase voltage to the quadrupolar electrodes, we can rotate the trapped droplet and can facilitate mixing inside the droplet. We are currently investigating dielectrophoresis-based methods to facilitate droplet fusion and fission. The integration of all these tools on a single microfluidic chip would provide a total analysis system for single cell analysis.