Popular Scientific Summary

The field of microfluidics is a research field that manipulates very small volumes of fluids, most often liquids. As the name implies, this is performed in the microscale where *micro* is a prefix for a millionth part. The devices for microfluidics have channels that are in sizes of a few to hundreds of micrometers (million part of a meter). Microfluidics emerged in the beginning of the 1980s, for development and applications in inkjet printers, but later applications for other fields, such as physics, chemistry, biochemistry, nanotechnology and biotechnology emerged.

One subfield of microfluidics is droplet microfluidics, which manipulates dispersed droplets, or packages, of one fluid encapsulated inside another continuous fluid. The two fluids have to be immiscible, meaning that they will not form a homogeneous mixture and a distinct interface will form between the fluids. This is comparable with water droplets in oil, the two liquids will not form a homogeneous mix but a visible boundary will form between them. In droplet microfluidics these droplets have volumes ranging from microliters down to picoliters and the droplets can be used in assays for biological or chemical experiments. Example, if two or more solutions are to be mixed or cells are to be analysed in a specific solution, they can be fused into droplets and due to the small volumes full mixing occurs fast and analysis of the assays can be done immediately.

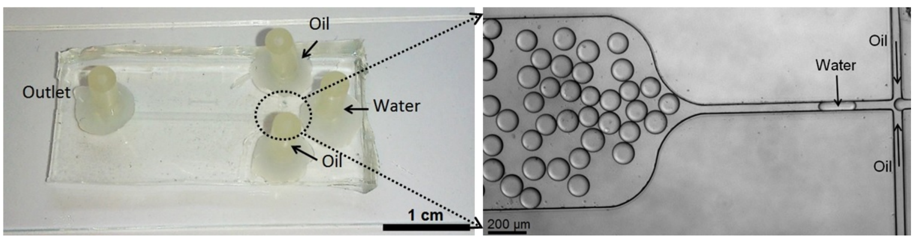

Figure 1: A microfluidic device (left) fabricated in this MSc work for droplet generation. 4x magnified picture of the cross-jucntion (right) of a fabricated device, showing the incoming oil and water.

The major advantages of using droplets or small packages of one fluid encapsulated inside another are that each droplet work as isolated reactors and that each droplet can be analysed separately, which opens up for serial and parallel reactions. These advantages increase the through-put compared to traditionally assays but also lowers the waste, lowers costs (due to small volumes of solutions required) and lowers the risk of handling errors. Droplet microfluidics has therefore a big potential for medical research, diagnostics, single cells analysis, gene therapy, polymer emulsions and many more.

In a MSc Thesis work at the Faculty of Engineering, LTH, at Lund University, have droplet generating devices been fabricated, to examine how a few parameters affect the droplet formation. One fabricated device for generating droplets can be seen in figure 1, where a silicone rubber (PDMS) has been moulded and bonded to a glass slide. The rubber is moulded after a stamp, called a *master*, which yields an inverse replica when detached from the master that results in channels when bonded to a glass slide. Two approaches for achieving droplets were tested - T-junction and flow-focusing geometries. In both approaches is a dispersed fluid injected into a continuous fluid. In the experiments water was used as the dispersed fluid and an oil, an hydrofluoroether (HFE), as the continuous fluid. For water-in-oil droplets, the oil has to wet the channel walls thus the surface of the walls has to be modified to be hydrophobic. To stabilize the droplets (so that they do not coalesce with each other) surfactants are added to the oil. A surfactant is a compound that arranges along the interface between the two immiscible fluids and stabilizes the droplets but also lowers the surface tension between the two fluids.

In the experiments were different flow rates and flow rate ratios of the two fluids tested, as well as different surfactant concentrations and how the channel dimensions affect the size of the droplets. The device is positioned under a microscope with a mounted camera where the droplet generation can be observed and recorded. The fluids are injected into the device by syringes driven by syringe pumps. Generation of water-in-oil droplets can be seen in figure 2, where monodisperse droplets of approx. 0.9 nanoliters are continuously generated.

The experiments showed that the ratio between the fluids' flow rates govern the size of the droplets; if the ratio is defined as $\frac{Q_{water}}{Q_{oil}}$ lower values will result in smaller droplets and bigger values will result in bigger droplets. Additional, while keeping the flow rate ratio constant an increased total flow rate of the fluids resulted in smaller droplets. Next, different concentrations of added surfactants affected the droplet size - with higher concentrations the droplet diameter decreased. This is due to the decreasing surface tension between the fluids with increasing surfactant concentration. The tested

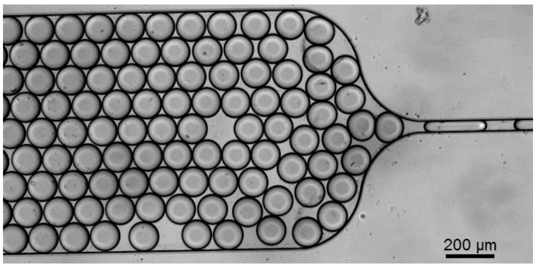

Figure 2: Dropelt generation in a microfluidic device. Here are water droplets generated in oil. Scale bar is 200 μm.

concentrations were 1, 2 and 4 % (volume/volume) of added surfactants to the oil. If no surfactants were added the droplets weren't stable and coalescence occurred when droplets encountered each other. Lastly, the channel dimension have shown to govern the droplet size. With smaller dimension smaller droplets are generated compared to wider channels. This due to the higher flow rates in the smaller channels that increases the shear rate in the system. With bigger shear rates smaller droplets are formed.

There are many parameters that one has to consider before any applications involving droplets are designed and fabricated. E.g. if the aim is to generate small droplets with low volumes (e.g. in single cell analysis) the channel dimensions has to be small or if larger droplets are desired wider channels could be used. Then can the flow rates of the fluids be determined as well as a suitable surfactant concentration.