ECEN 403H/URS project proposal

Faculty Advisor: Dr. Arum Han

Students: Erin Ingram & Omar Mahmood

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## Project Background and Description

Droplet microfluidics deals with the manipulation of discrete volumes of fluid as small as several ul through small microchannel devices and it has shown promise in many different biological and chemical applications, including cell biology, drug screening, and nucleic acid analysis applications. Among varieties of different droplet manipulation methods, the droplet generation is the first and most significant step. Two mechanisms are generally used to create the droplets (1) T-junction structure, where immiscible fluids (for example, water-in-oil) are mixed from two channels into a third containing the droplets. (2) flow-focusing structure where one fluid is introduced from two separate directions with a different fluid from another outlet to form the droplet. Encapsulation of viscoelastic fluids for droplet generation is common in applications like food engineering, cell lysis and droplet PCR. However, regardless of the generation structures, the viscoelasticity led to the problem of formation of satellite droplets during generation. These are undesired since they can negatively affect the precise manipulation of desired droplets. In addition, these droplets in biological applications are seen in the cross contamination between fluids during downstream processing. Such an example is in the case of library generation for bacterial and viral experiments where satellite droplets can merge with desired droplets containing sensitive organic compounds where mixing is not tolerated. The result is a set of false-positive or false-negative results which might require retesting and can be expensive as well as time consuming. To address these issues, a new method and system must be proposed to alleviate the problem by addressing the issue of satellite droplet generation. There are two possible solutions: torsional fracture to minimize the satellite droplet formation and size-based filtration of satellite droplets. Torsional fracture works on the principle of rotating the liquid bridge which induces shear and stress on the thinning neck. As the ends of the liquid spread, the neck begins to pinch off without the formation of a satellite droplet. Size-based filtration uses electric forces and spatial channels to help direct specific sized droplets to certain outlets to be processed and analyzed. The size-based filtration method can be further enhanced using interdigitated electrode (IDE) arrays. IDE arrays can more finely tune and control electric fields which allows the method to be more sensitive when attempting to spatially filter droplets by DEP force. As a relatively novel solution, the IDE bandpass filtration method has potential to usher in a breakthrough in the quality control of satellite droplet formation.

## Project Scope

1. Analyze droplet breakup and satellite droplet generation phenomena, which results in high error rate in droplet microfluidics operation by using commonly utilized droplet generator to generate water-in-oil emulsion droplets, take high-speed microscopic images, analyze the phenomenon under different flow speed and microchannel design conditions. Parameters of importance are channel dimensions, viscosity/surface tension of the fluids, and flow speed. Outcome is to analyze the size of desired droplets and collect data on presence of the undesired satellite droplets.
2. Design an improved droplet microfluidics channel with IDEs that can remove satellite droplets from the system to minimize operational failure. Points of interest include the dimensions of the channel and placement of IDE electrodes using electric field simulations to predict the forces and movement experienced by desired and satellite droplets.
3. Fabricate the device through at the Aggie Fabrication Facility
4. Conduct experimentation with the newly fabricated device
5. Apply the new system to microbial screening applications

## Deliverables (403 and 404)

**403** – The two students will individually create two different microfluidics channel designs. We will each start by fabricating our own channels and testing from satellite droplet formation to form a control group. Next we will individually apply different sized based filtrations, IDE arrays, and test for satellite droplet formation, and compare to the control group.

1. Investigate the existing problem: satellite droplet formation during generation (2 weeks, 9/16/22)
   1. Identify the correlation of the satellite droplet generation to regent chemical property such as aqueous viscosity, surface tension, flow speed and oil density (1 week, 9/9/22)
   2. Identify the correlation of the satellite droplet generation to device structure such as generation method, channel width and height (1 week, 9/16/22)
2. Design two microfluidic channels (2 weeks, 9/30/22)
   1. Finite element analysis, fluidic simulation for design validation
      1. Statistical analysis of the weighted correlation of each parameter
3. Fabricate the device designs (9 weeks, 12/2/22)
   1. Photolithography training and master mold fabrication (2 weeks, 10/14/22)
   2. 3D printing training and master mold fabrication (2 weeks, 10/28/22)
   3. Softlithography training and PDMS replica molding (2 weeks, 11/11/22)
   4. Metal deposition and wet etching training and IDE electrode fabrication (2 weeks, 11/25/22)
   5. Device integration, dry etching, hole punching and tubing connection (1 week, 12/2/22)

**404** – We will then take the best design specifications from each person’s creation and combine them to form an optimized design. This optimized design will be fabricated and we will apply the new system to microbial screening applications.

1. Collect high speed images for droplet generation – size and quantity of both main and satellite droplets (2 weeks, 2/3/23)
2. Fabricate new device based on best aspects of the two separate devices (2 weeks, 2/17/23)
3. Collect high speed images of droplet generation for new device - confirm it works correctly (2 weeks, 3/3/23)

1. Analyze the results and compare to prior literature (3 weeks, 3/24/23)
   1. Understand and use engineering statistical methods for data analysis
   2. Understand image processing using image software such as ImageJ and MATLAB
   3. Practice academic manuscript drafting for peer-reviewed journal publication
2. Apply new system to microbial screening applications (3 weeks, 4/14/23)

## References

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