Understanding the Physics of Droplet Electrocoalescence in a Microtrap

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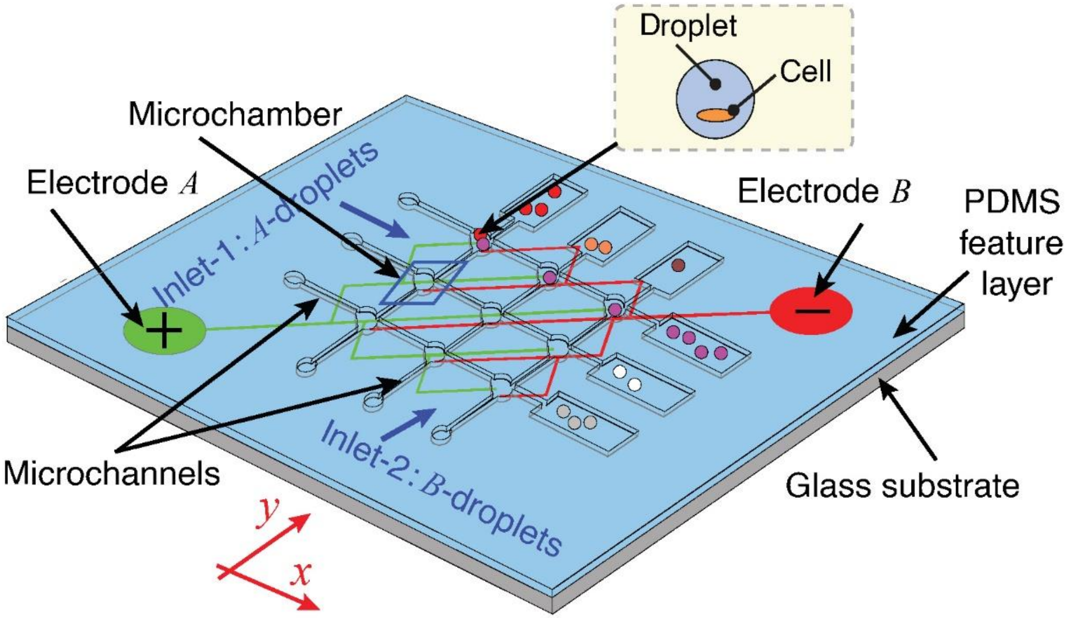
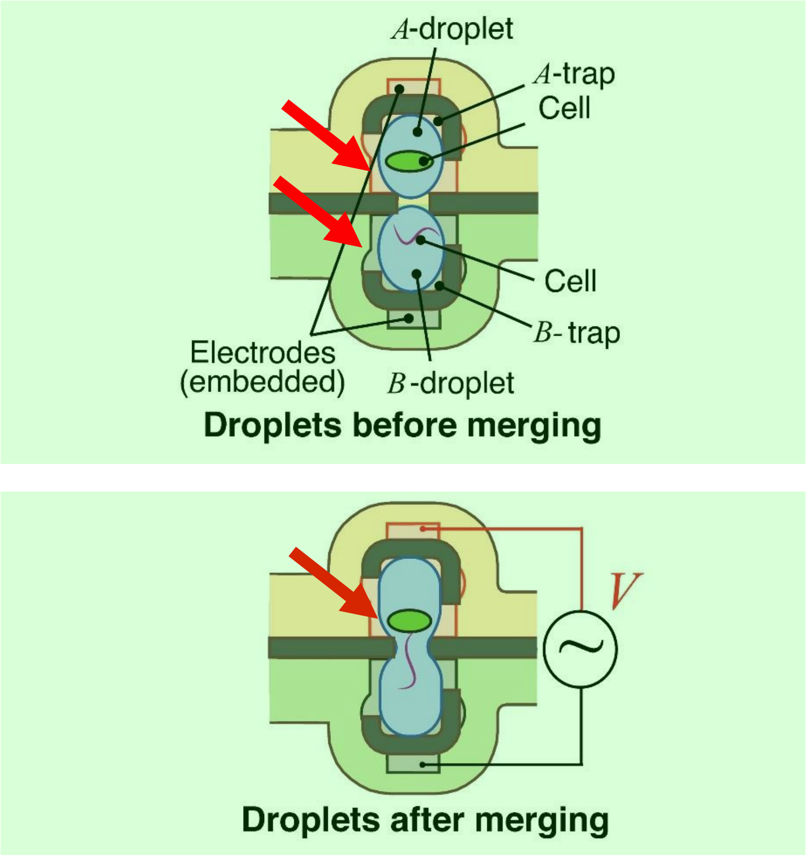
Overview and Objective



An example droplet-based microfluidic system for high-throughput screening of eukaryotic cells aimed to understand the complex, multidimensional, and dynamic biological processes

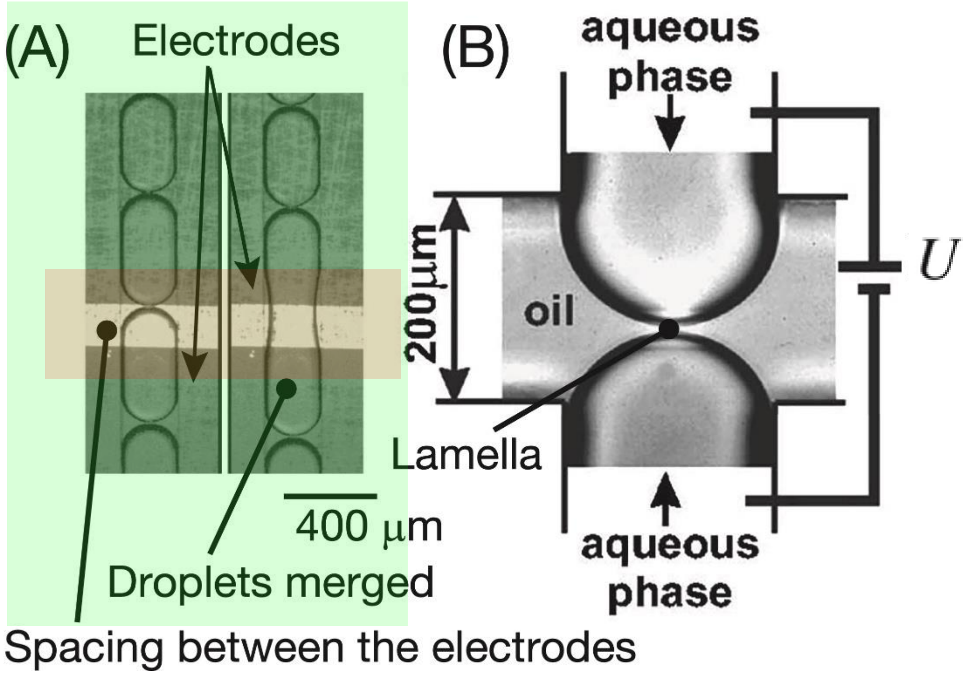


A schematic sketch of hydrodynamic microtraps for droplet electrocoalescence (top view)

Objective: To analyze the *effect of fluid surface tension* and *droplet gap* on the *aqueous droplet behavior in the hydrodynamic microtraps* through parametric studies

Droplet Electrocoalescence

Electrocoalescence is a phenomenon in which the droplets of same phase coalesce when an electric field is applied across a suspension of immiscible liquids.



Droplet electrocoalescence in a microchannel [1]

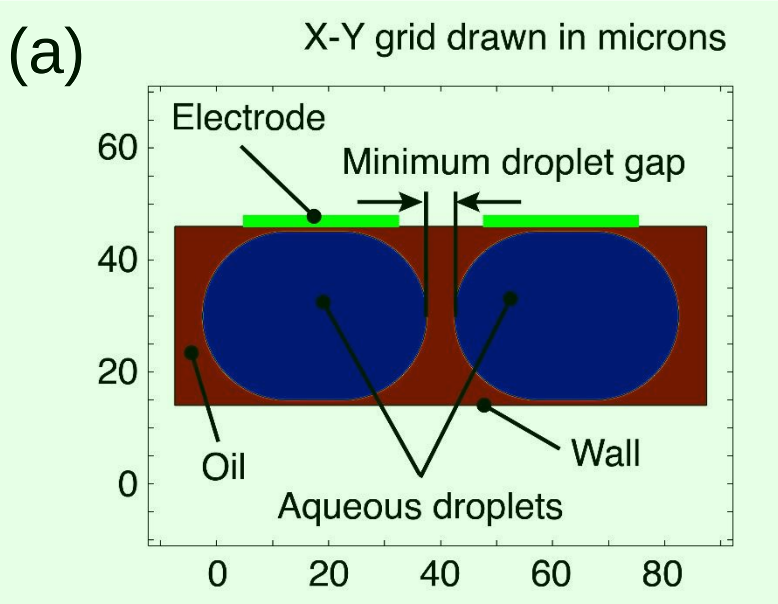
$$U = \sqrt{\frac{2\gamma}{\epsilon\epsilon_0 R}}\,d$$

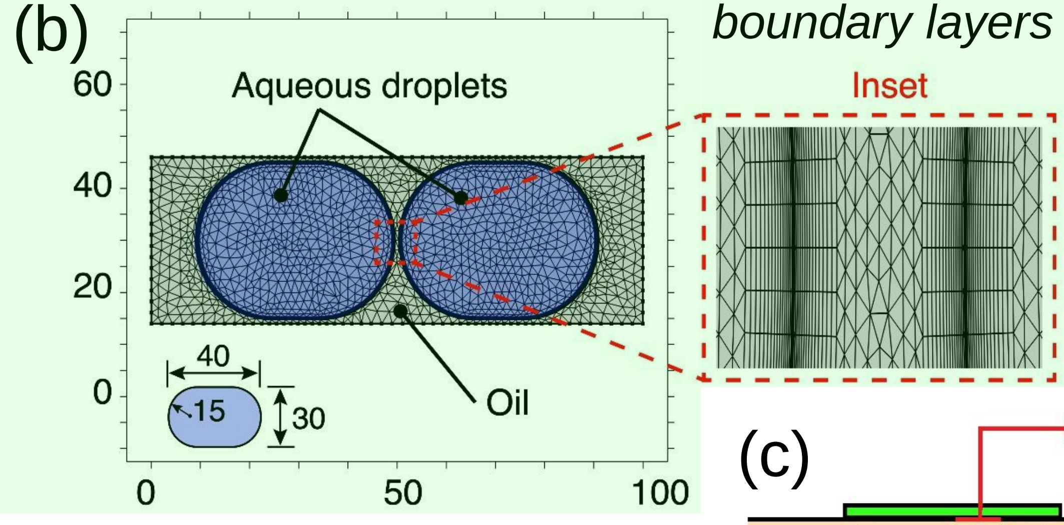
where,

- U - Voltage (V)
- γ - Surface tension (N/m)
- ϵ - Permittivity of oil
- ϵ_0 - Permittivity of vacuum
- R - Radius of the droplet
- d – Minimum gap between the droplets

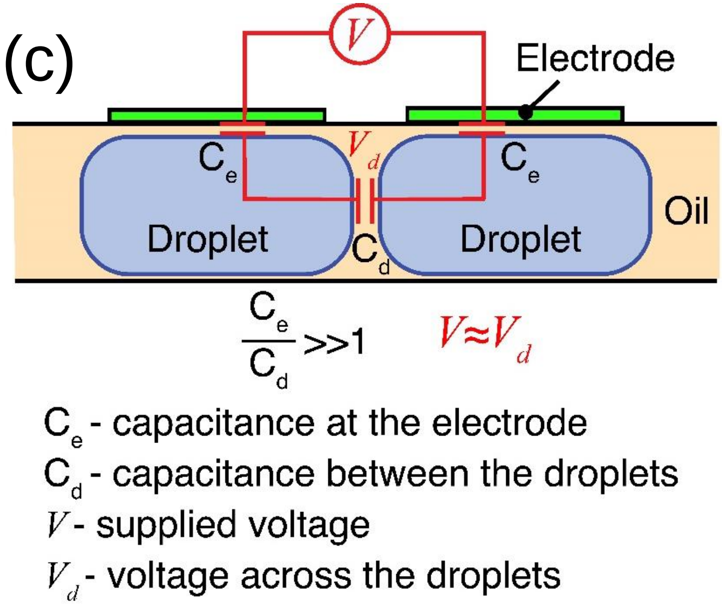
[1] C. Priest, S. Herminghaus, and R. Seemann, *“Controlled electrocoalescence in microfluidics: Targeting a single lamella,”* Appl. Phys. Lett. 89, 134101 (2006)

Simulation Setup





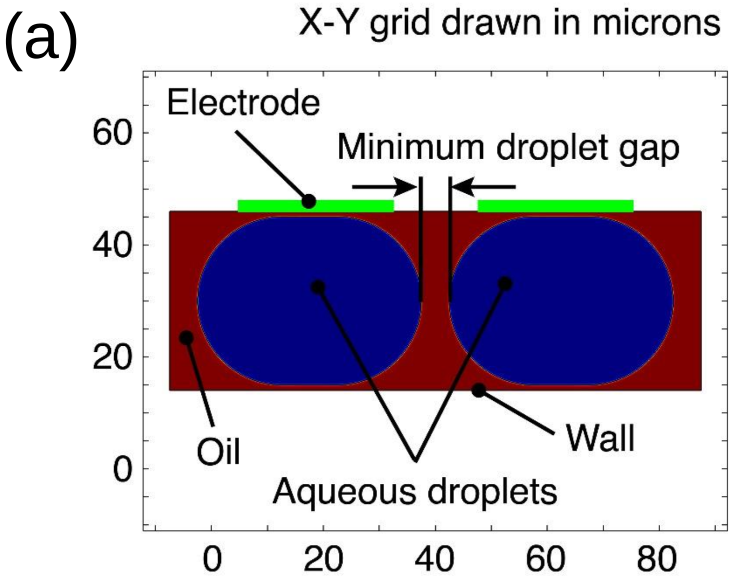
Representative mesh with refined boundary layers at the droplet interface

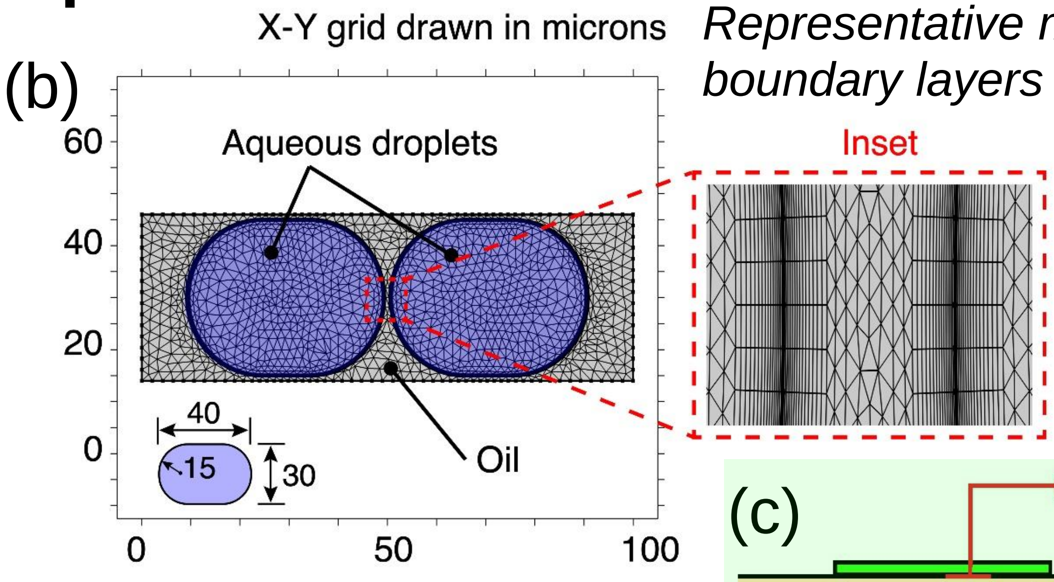


Electrical circuit diagram of droplets-electrode setup for DC actuation voltages

COMSOL physics	Laminar flow, phase field, and electrostatics
Materials	Water/Oil (contact angle=180°)
Surface tension coefficient	(0.0025–0.04) N/m
Droplet gap	(0.4–1.66) µm
Meshing	Extremely Fine/Free Triangular
Supplied Voltage	8 V

Simulation Setup





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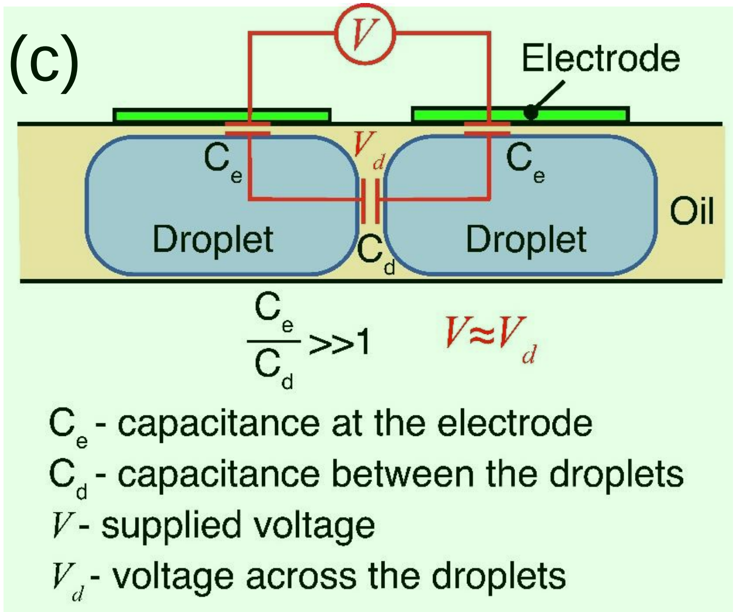

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Validation of our Electrocoalescence Model

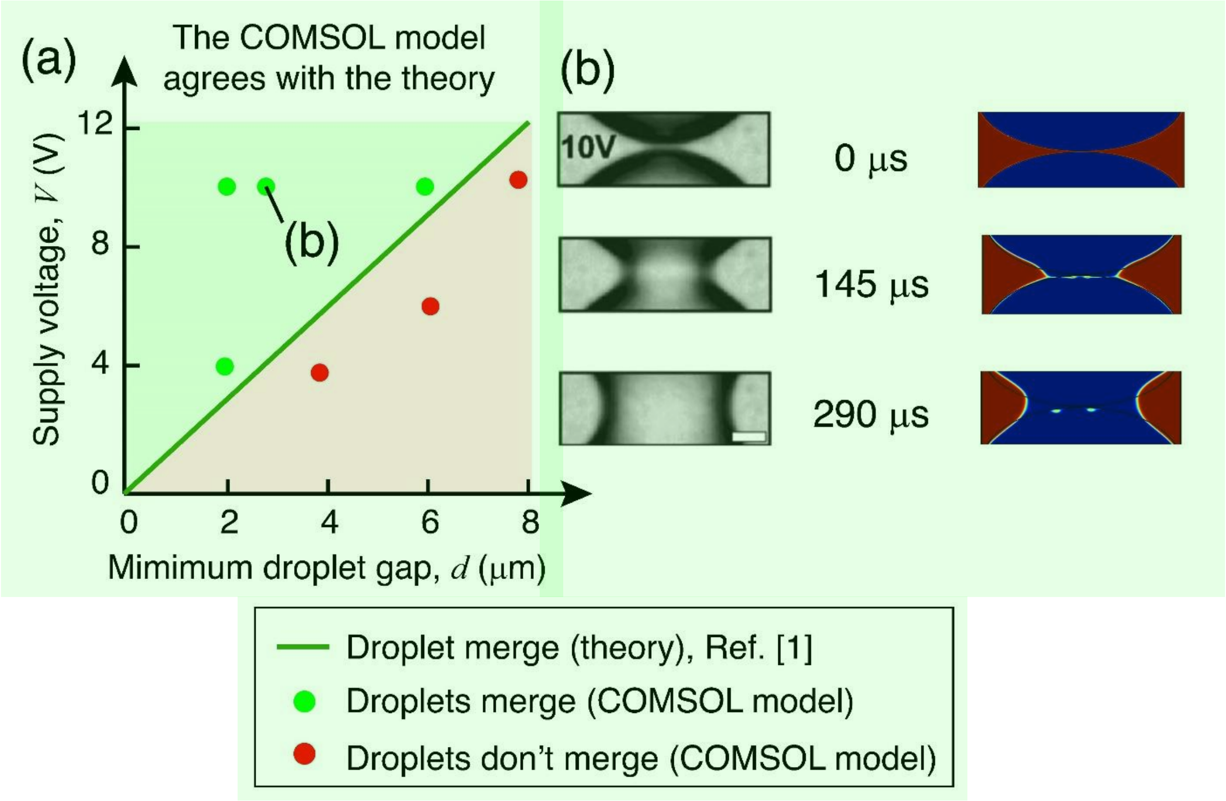

Table 1: Comparison of droplet coalescence results obtained from our COMSOL model versus the existing date from literature [1]

Time (μs)	Droplet bridge width (μm) [1]	Droplet bridge width; our COMSOL model (μm)
0	0	0
145	80	74
290	120	114

Less than 10% error

Validation of the model using an experiment data available in the literature [1]

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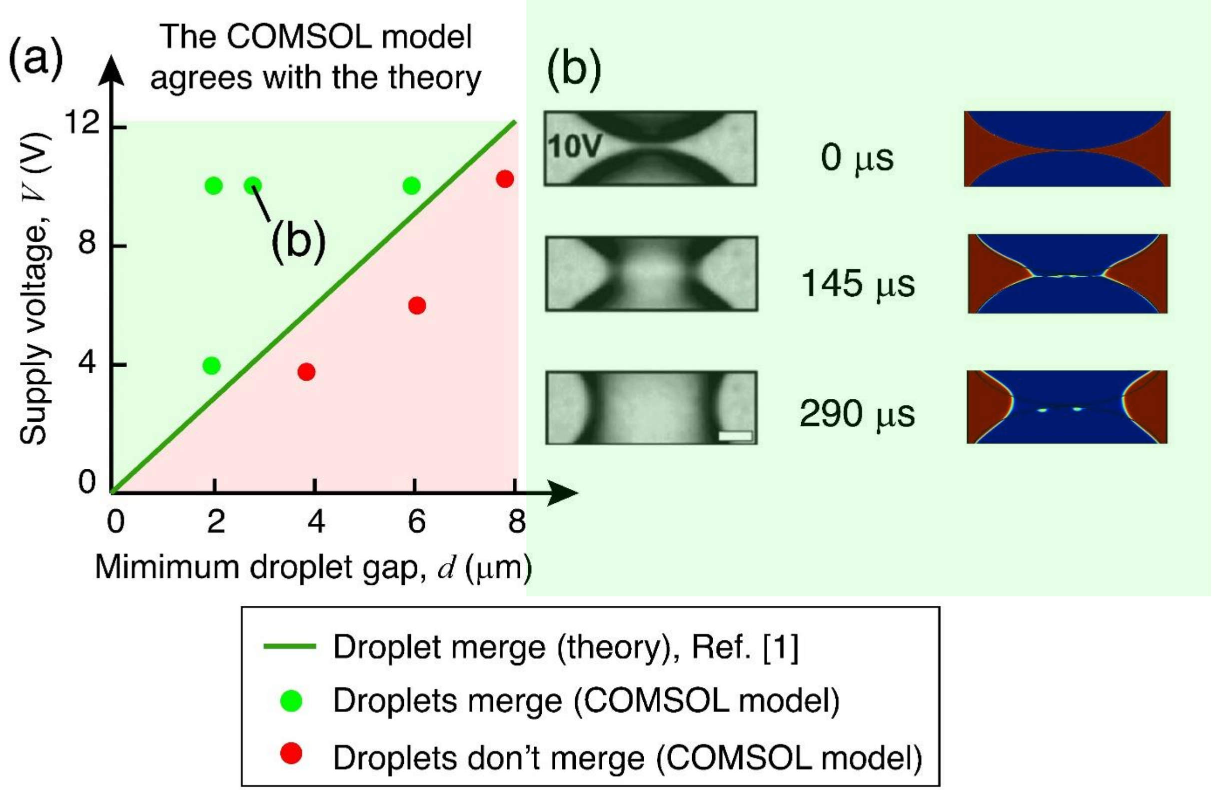

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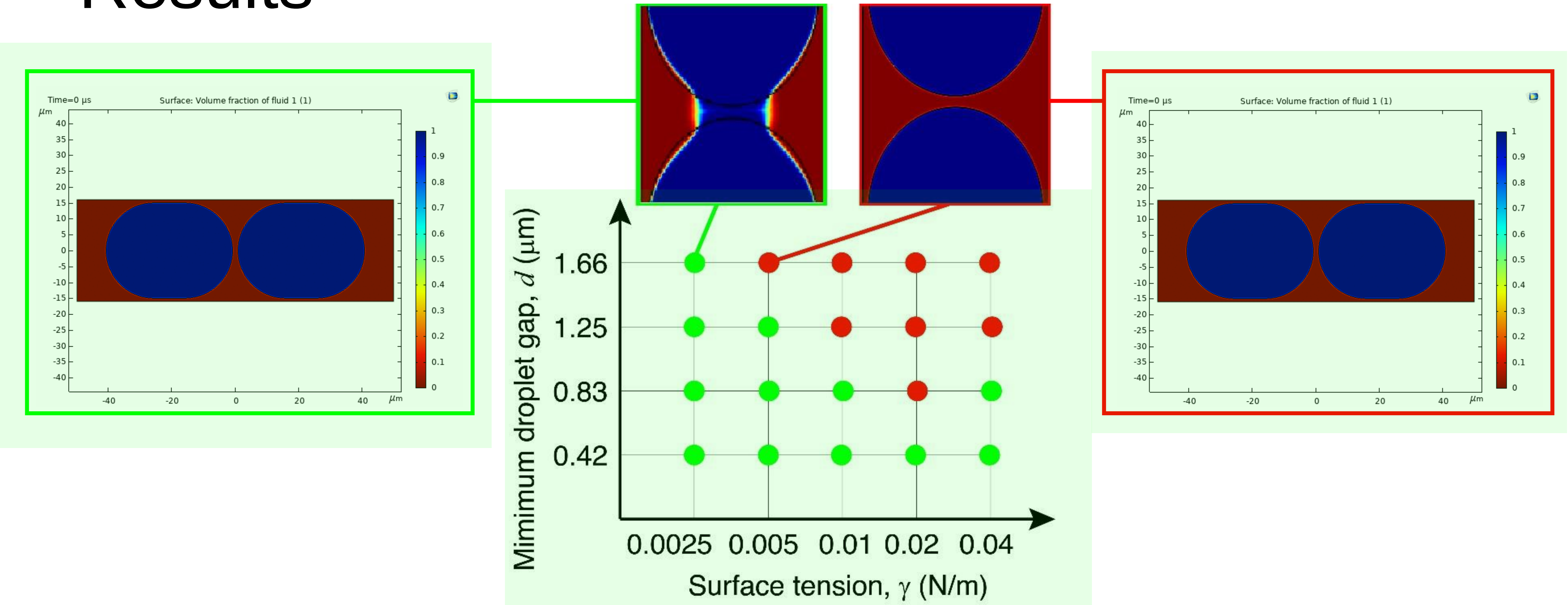
Results



A preliminary design chart

For successful coalescence of the aqueous droplets, a higher fluid (oil/water) surface tension γ necessitates a higher supply voltage V

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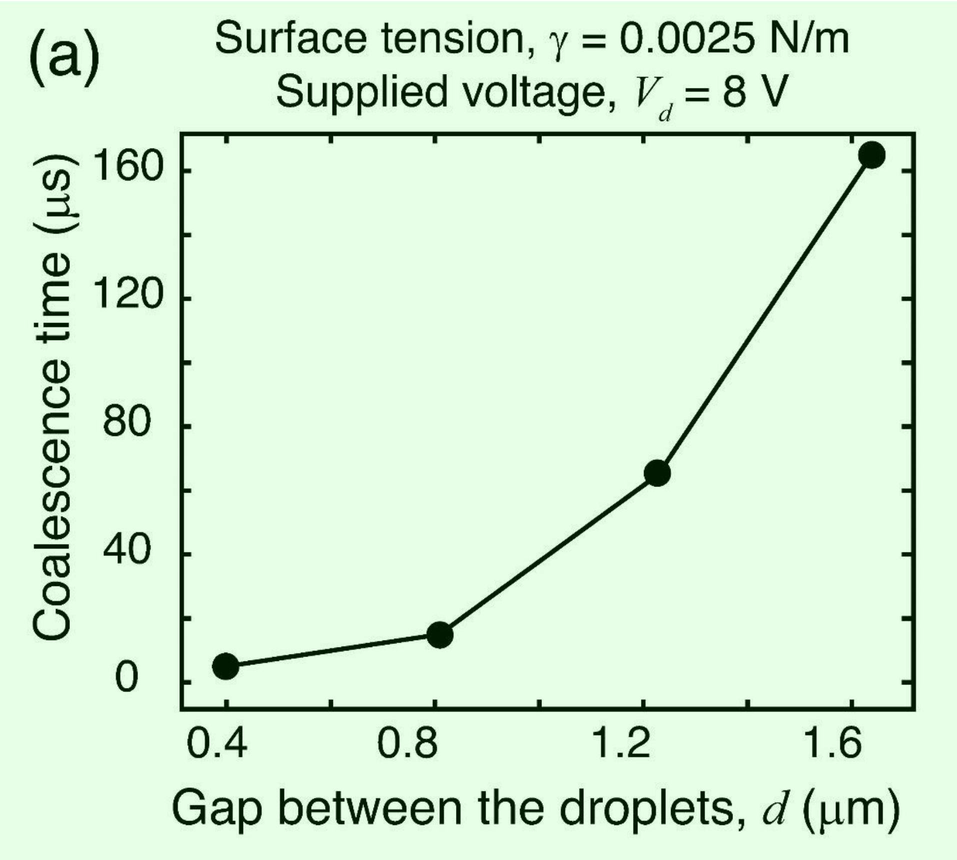
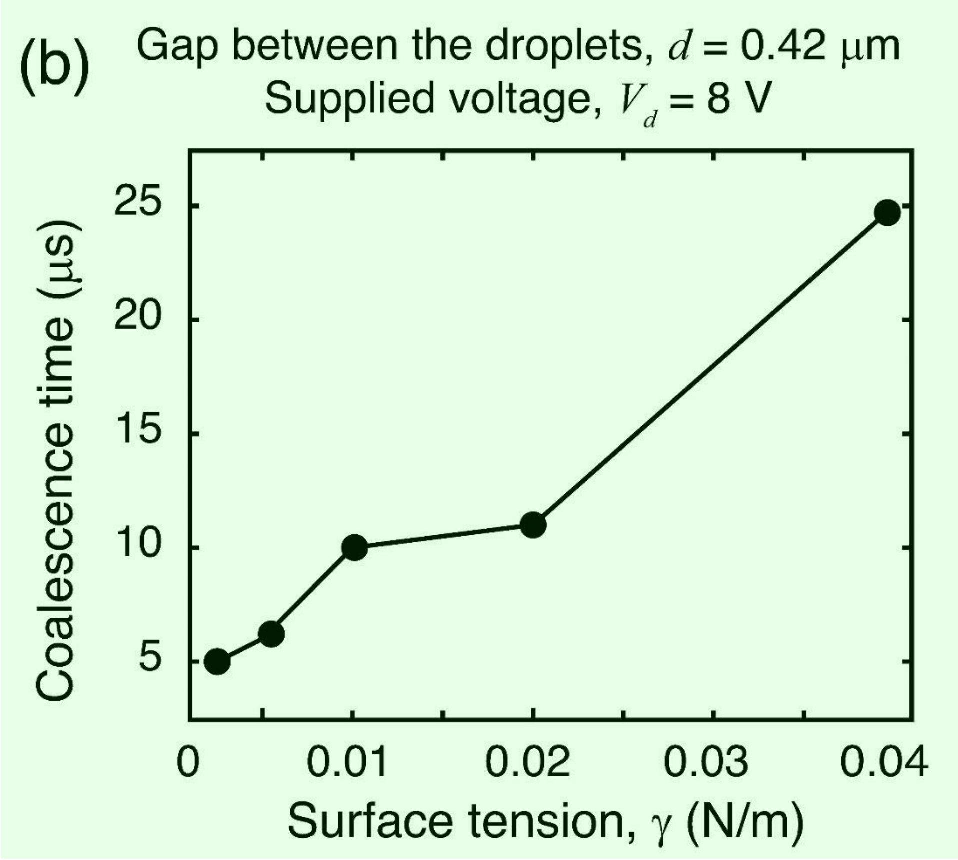
Results (2)





There is a direct relationship between surface tension/droplet gap and coalescence time.

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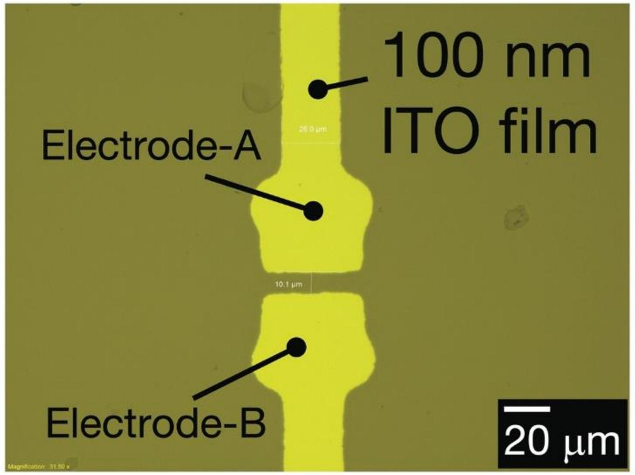
Future Work

The COMSOL Multiphysics model presented here will be fully validated with experiments for different fluid properties, droplet gaps, and supplied voltages.



Representative image of electrodes obtained using a stereomicroscope

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