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Understanding the Physics of Droplet Electrocoalescence in a Microtrap

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This work details a parametric study for merging microscale water droplets, using an electric field, in a microfluidic device. This device, titled TAP (Trapping and Assisted Pairing) is a cell handling platform for conducting cell-cell (plant cell-microbe) interaction studies for identifying symbiotic/parasitic relationships and to help plant biologists devise approaches to maximize the symbiotic functions and minimize the parasitic functions. This work stems from the big picture idea of smart and sustainable agricultural practices to meet the future global crop production demands in the era of ecosystem degradation and climate change. TAP leverages droplet microfluidics to efficiently electrocoalesce multiple pairs of droplets — one set of droplets containing individual plant cells and another set of droplets containing individual microbes — to initiate multiple cell-microbe interactions. As a first step, through numerical simulations we analyzed the physics of droplet merging and conducted a parametric study to analyze the effect of droplet/fluid properties and droplet gap on their behavior. This study resulted in the generation of a preliminary design-chart – a plot of the droplet fate (merged or non-merged) vs minimum droplet gap d – for a fixed actuation voltage (8 V) and fixed electrode gap (10 microns). We found that for successful merging of the aqueous droplets, the magnitude of the electric field strength $E=V/d$ must be about 4.45 MV/m for γ =0.0025 N/m and about 17.8 MV/m for γ =0.04 N/m. These observations are in good agreement with the existing literature.