

Automated Droplet Manipulation through Electrowetting on Dielectric for DNA Synthesis

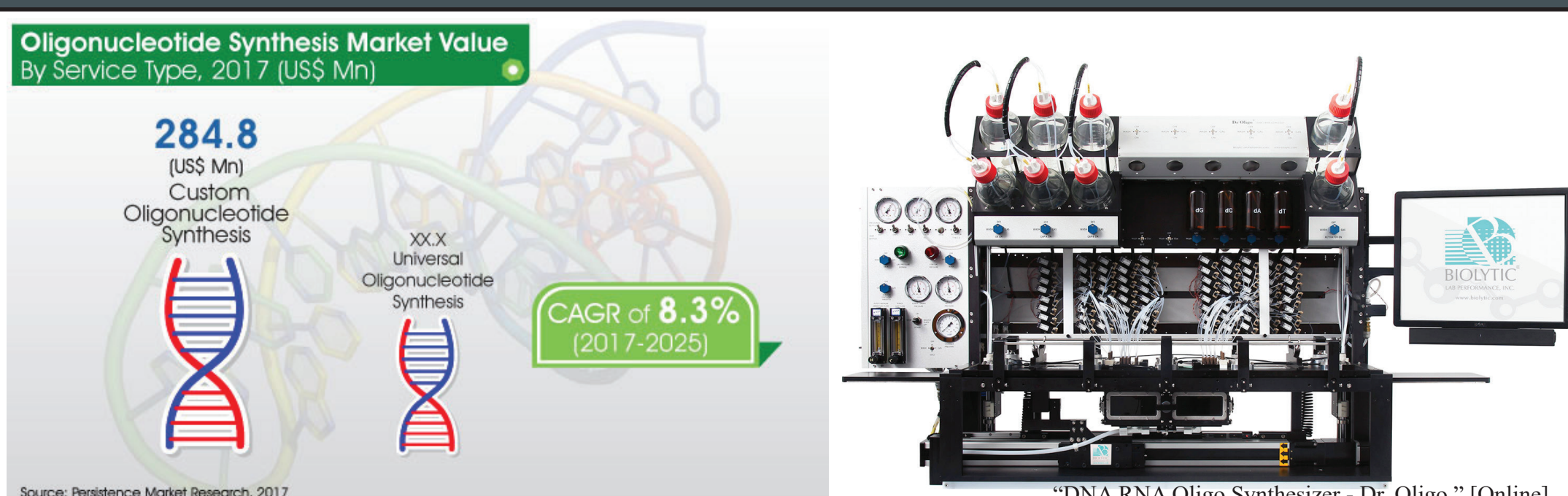
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Project Objectives

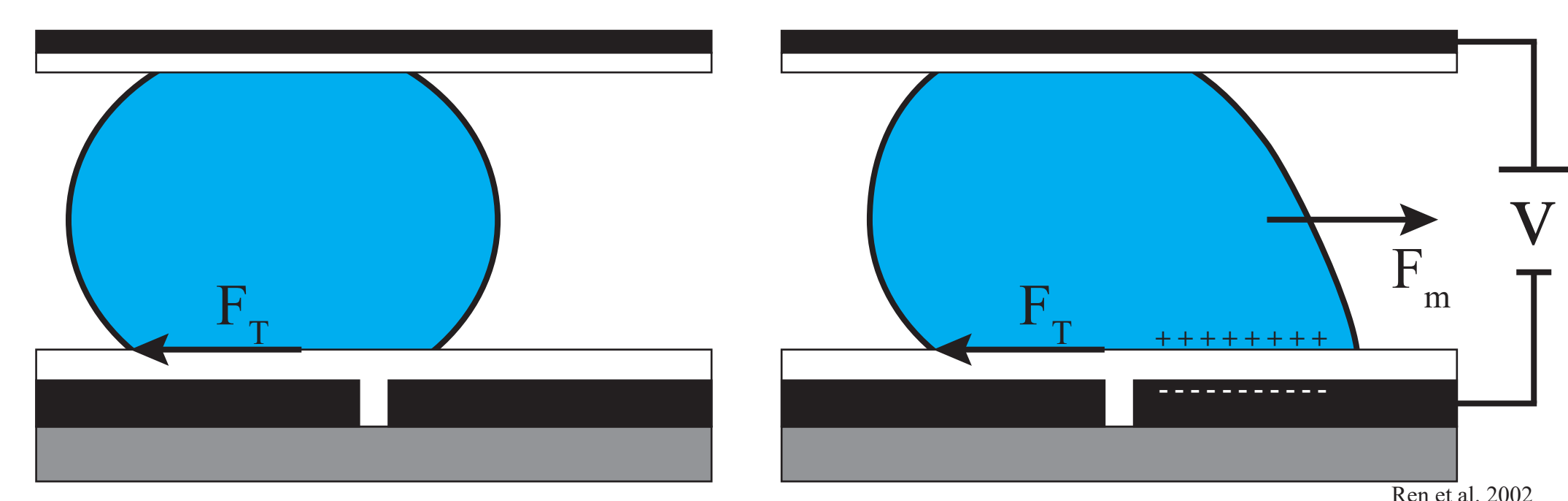
- Design an electrowetting on dielectric (EWOD) device that supports droplet manipulation and is also compatible with common cleanroom fabrication methods
- Perform and automate droplet manipulation with key functions such as droplet creation at reservoirs and merges at filters
- Characterize particle filtration performance

Motivation



- Nucleotides are essential for biological applications such as genetic testing, research, and forensics
- Modern synthesis tools are large, expensive, exhibit high power consumption, and have prototyping difficulties
- EWOD devices can be small, cheap, low power, easy to prototype for various custom applications

Electrowetting Theory



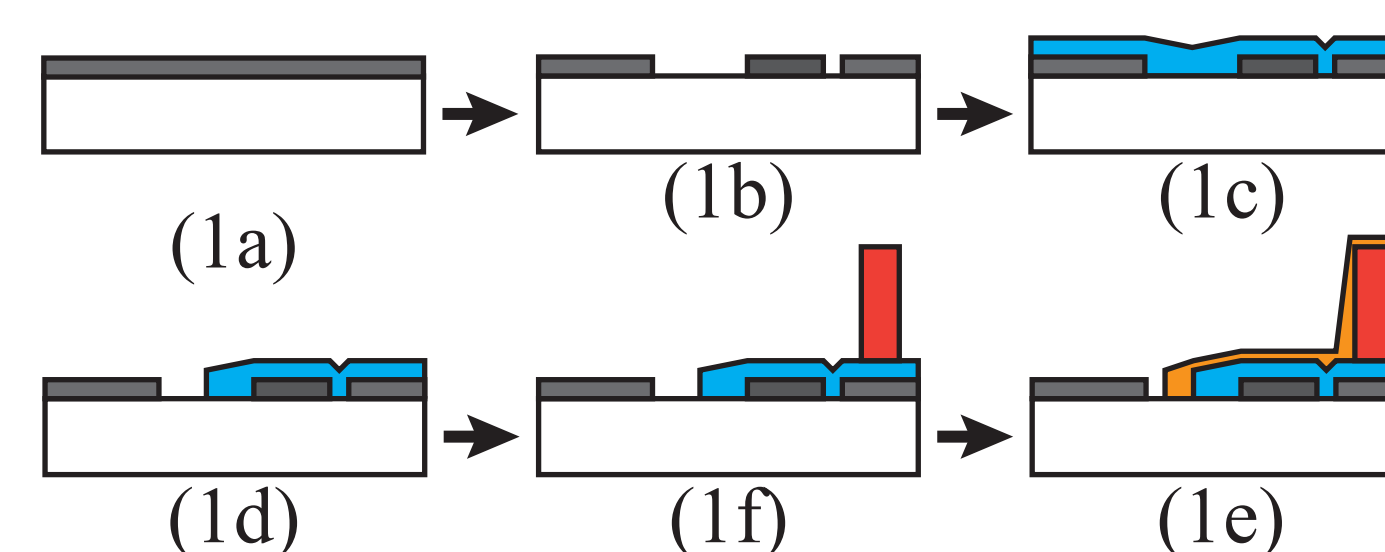
- Voltage is applied to actuation electrode
- Charge is induced in overlapping region of the droplet
- Electrostatic force deforms the droplet, reducing the liquid solid surface tension at the leading edge
- Surface tension gradient forces the droplet forward

$$F_m = \frac{\epsilon_0 \epsilon_R}{2d} V^2 - F_T$$

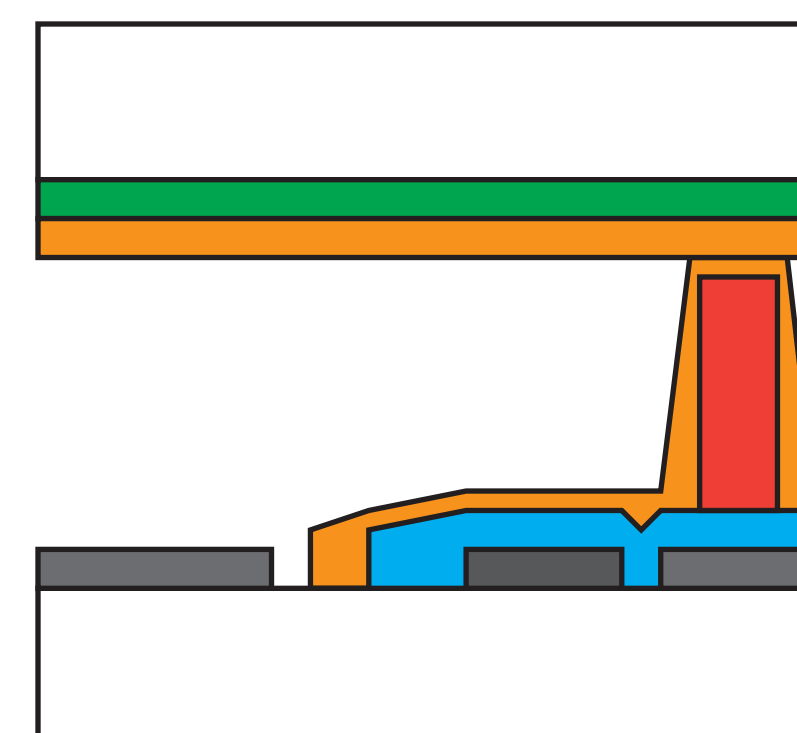
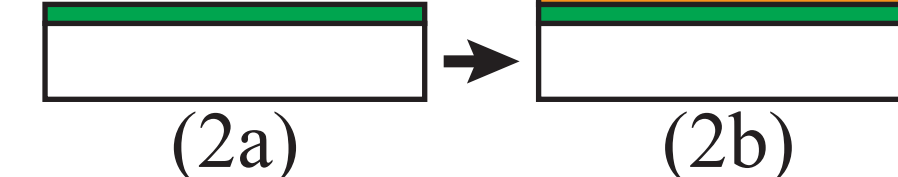
F_m : external force per unit length, ϵ_0 : permittivity of free space, ϵ_R : relative permittivity of the entire film stack, d : gap distance between the top and bottom electrodes, V : applied voltage, and F_T : threshold initiation force

Device Fabrication

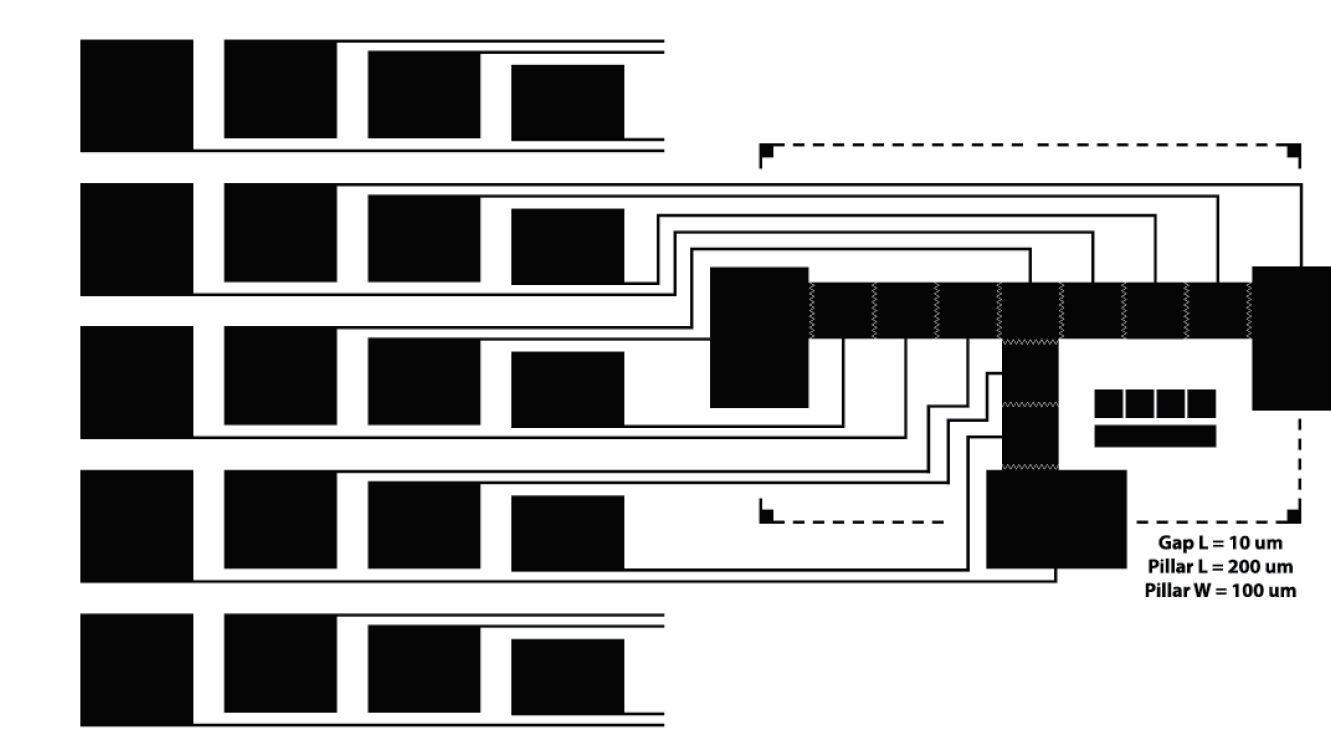
- Device Fabrication
 - Al electrode PVD
 - Electrode patterning
 - SiO₂ insulator CVD
 - Insulator patterning
 - SU-8 filter lithography
 - Teflon coating



- Top Plate Fabrication
 - ITO PVD
 - Teflon coating

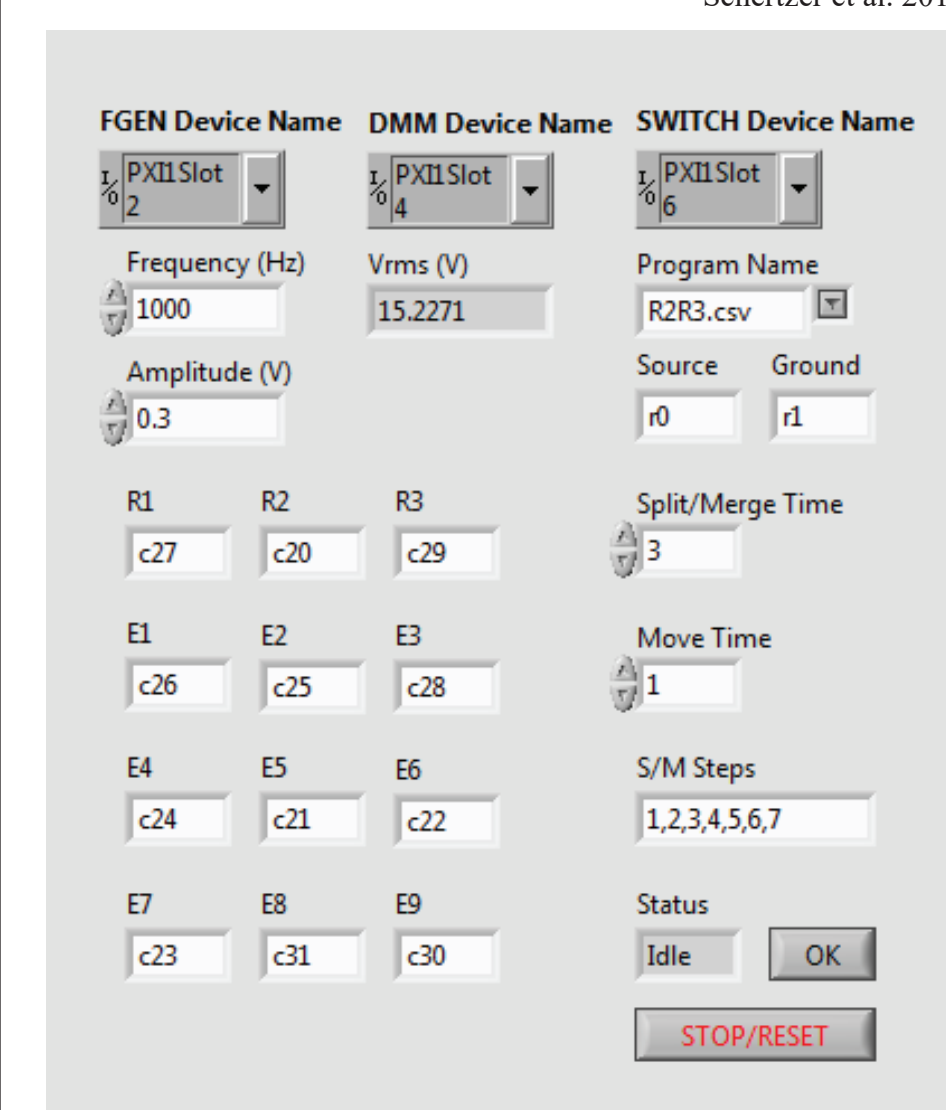
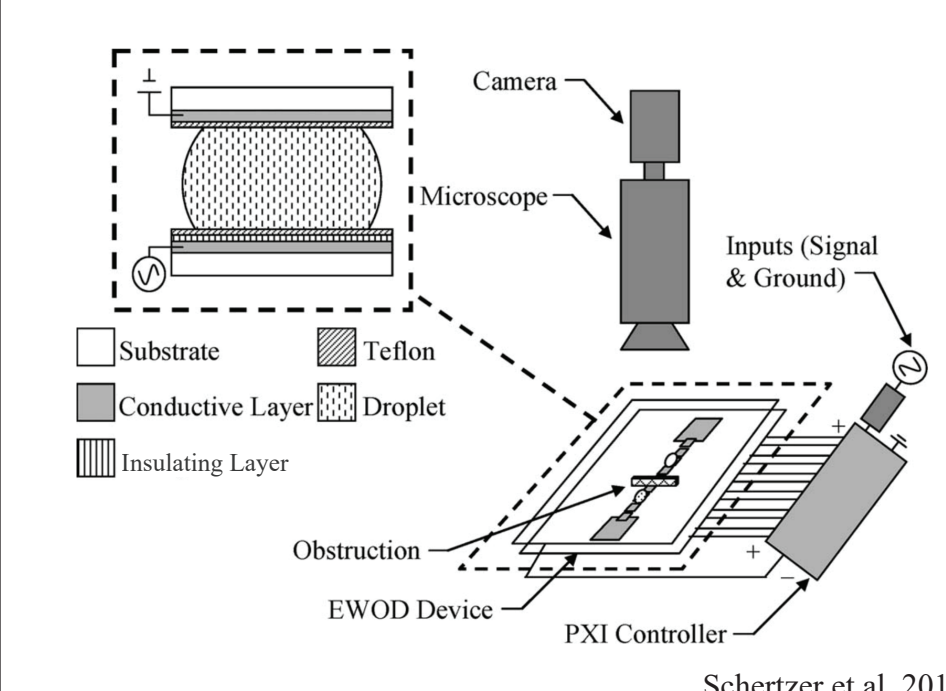


Device cross section

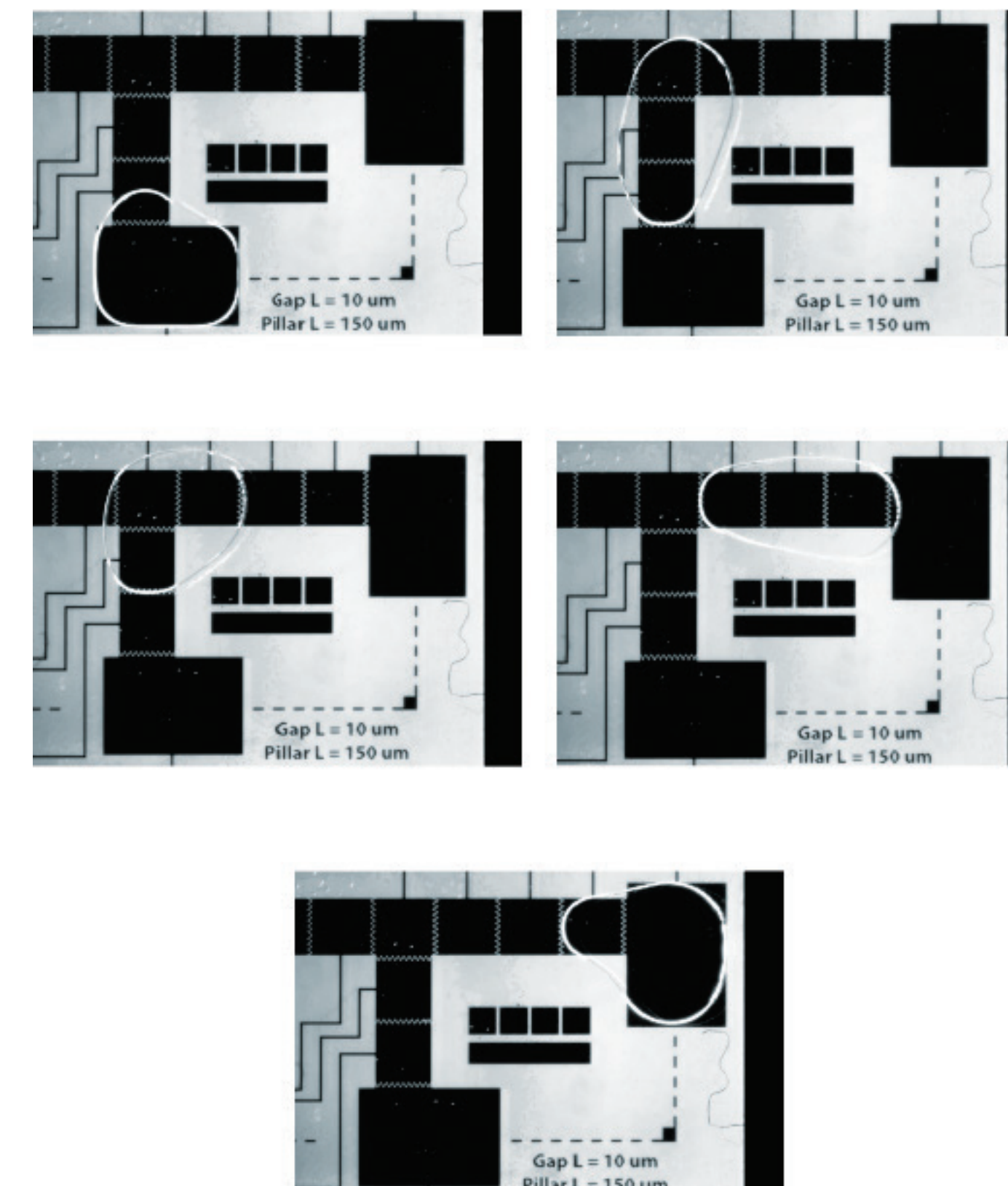


Top-down view of electrode design

Automated Droplet Manipulation

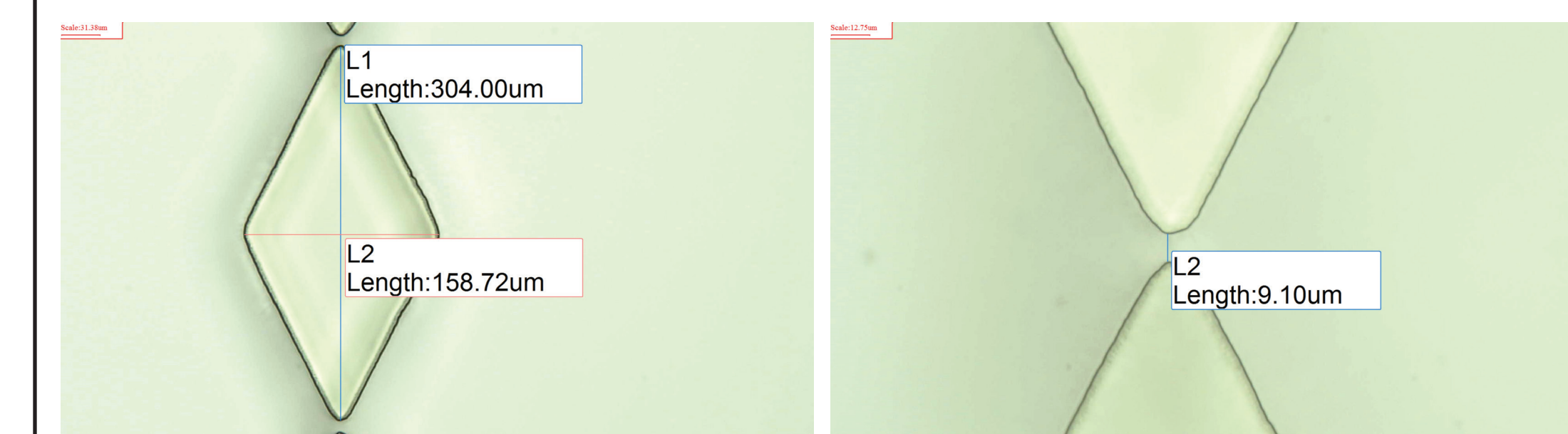


Comprehensive LabVIEW program was created for fully automated manipulation of droplets on device

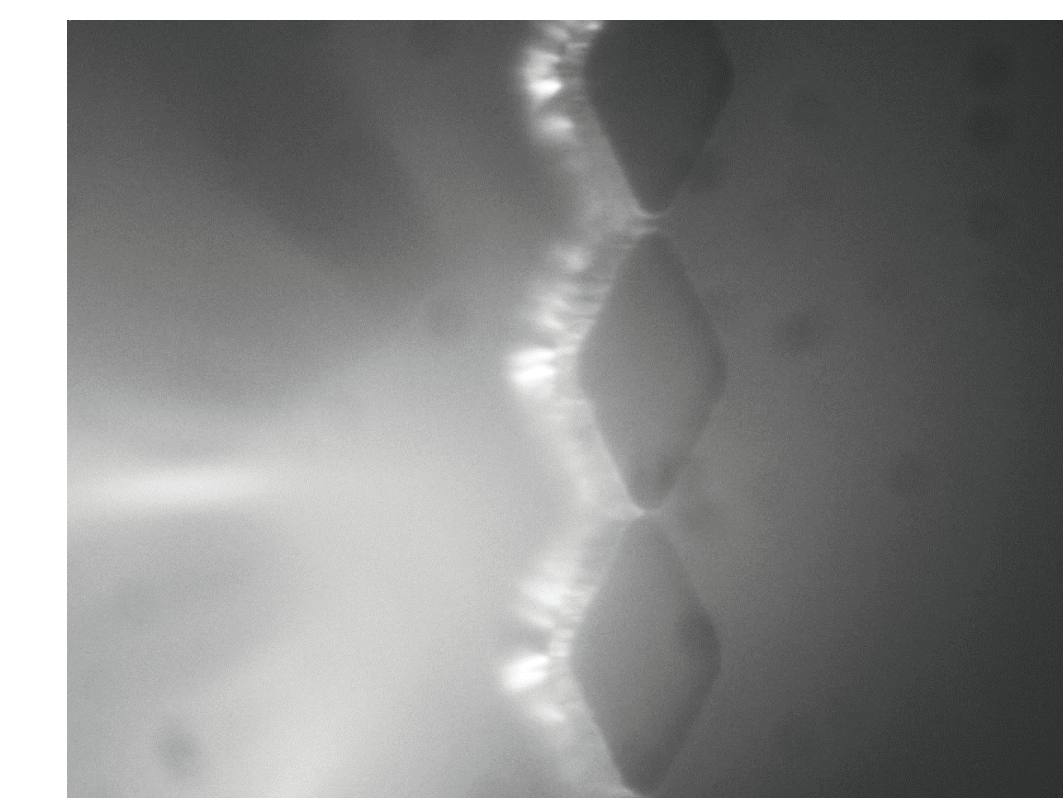


- Electrowetting actuation conducted using 1 μ L of DI water with an applied potential of ~ 38 V_{rms}
- Droplets were easily manipulated for various movement programs

Filter Fabrication



- SU-8 mechanical filters are fabricated using photolithography
- Filters are mechanically robust with a very small gap to be able to separate biological particles from carrier droplet
- Similar electrowetting actuation across device is ensured using filters as stand-offs



118 μ m thick pillars with ~ 4 μ m gap

Conclusions

- All the necessary components for a complete DNA synthesis EWOD platform was designed, fabricated, and tested for functionality
- While large droplets were easily able to be moved, small droplets could not be created from fluid at the reservoirs
- A better understanding of the droplet movement dynamics will improve future iterations in device design and automation development
- Automated functions such as droplet creation and merges must be perfected before filtration characterization

Acknowledgements

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