Center for Energy Efficient Electronics Science

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Droplet Manipulation of Optoelectrowetting (OEW) Devices

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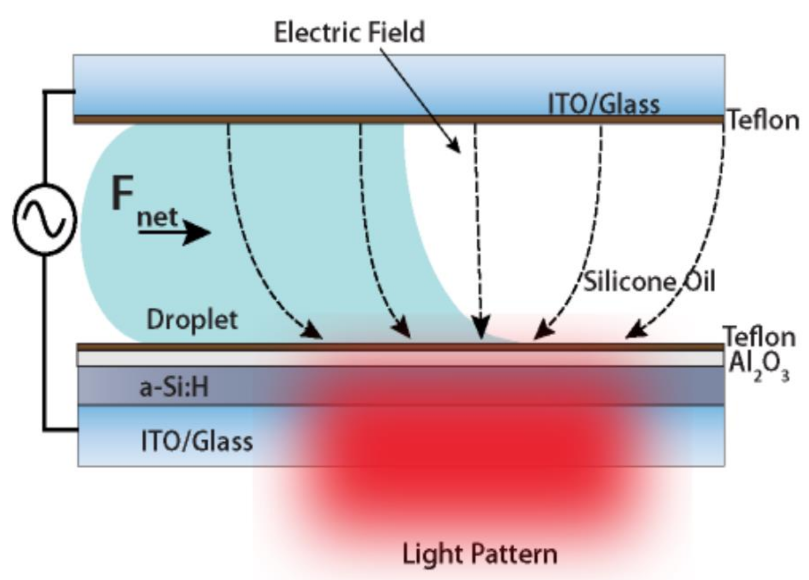
Abstract

Microfluidics, the science of manipulating small volumes (pL to uL) of liquids, benefits from the ability to perform large numbers of chemical and biological reactions in parallel. Digital microfluidics, compared to continuous-flow based microfluidics, benefits from individual sample addressing. We are developing a Light-Actuated Digital Microfluidics device based on the principle of Optoelectrowetting (OEW). Our device posses many advantages including real-time reconfigurable large-scale droplet control using low-intensity light sources.

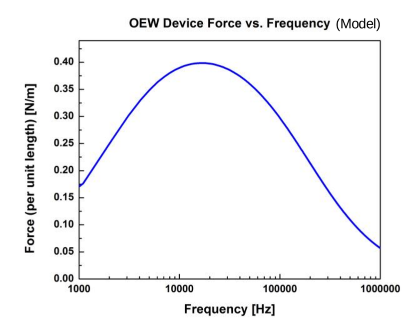
Motivation

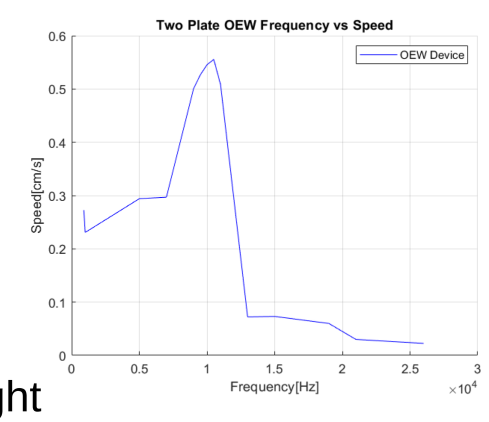
- Continuous-flow microfluidics is limited to channel restricted 1D fluid movement
- Electrowetting-on-Dielectric (EWOD) provides a platform for digital microfluidics based on surface electrodes but necessitates for complex addressing of electrodes for droplet actuation
- OEW benefits from low optical power required (<1.5W/cm^2), easily programmable and adjustable light patterns, easy fabrication methods

Device Operation



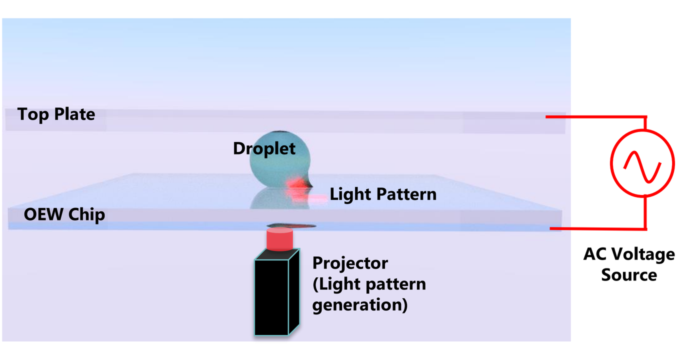
Device Top View





- Light generated from projector creates electron-hole pairs in a-Si
- Voltage drop switches from a-Si layer to oxide layer with incident light
- Light acts as surface electrodes to move droplets using electrowetting force

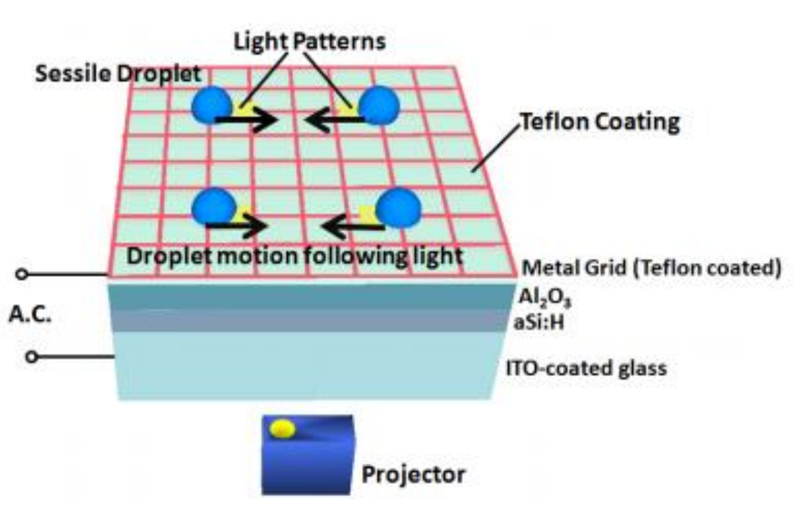
Experimental Setup

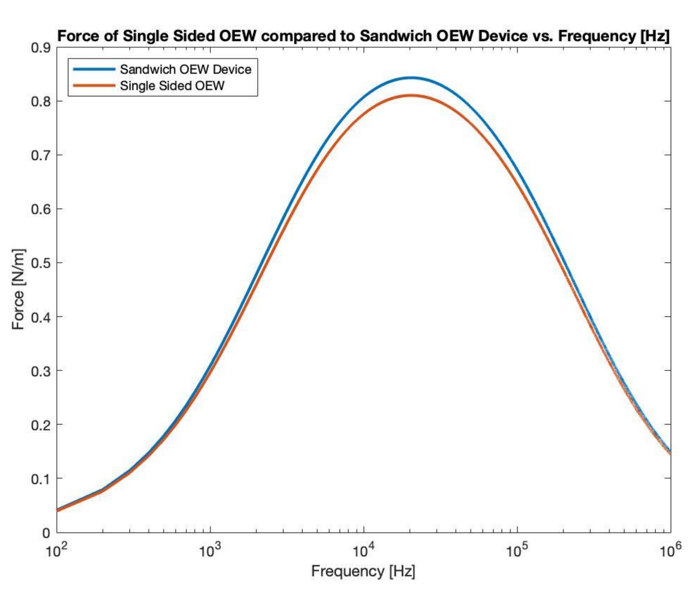


- pL to uL droplet manipulation
- Operates at 40V$_{pp}$ at 10kHz
- Force 100us uN/cm
- Low power (< 1.5W/cm^2) light source by a DLP-based projector
- Devices fabricated at the Marvell Nanolab at UC Berkeley

Single Sided OEW Device

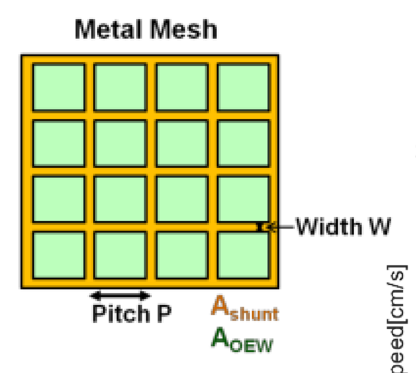
Single Sided Schematic

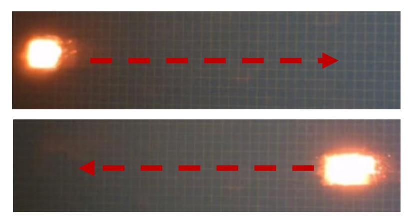




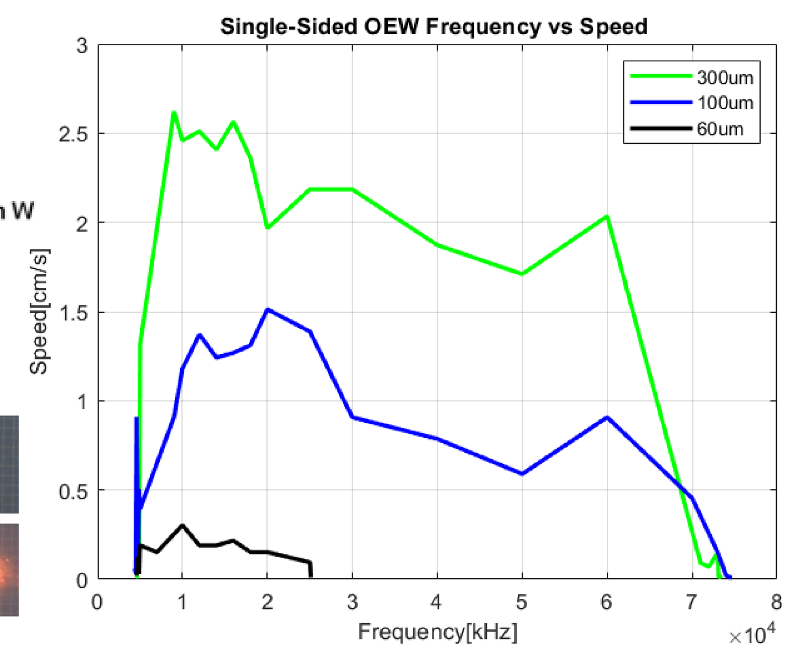
- Integrated ground mesh replaces need for top electrode from the conventional Sandwich OEW
- Metal grid introduces shunt path in OEW circuit reducing effective force on droplet
- Basic manipulations can be achieved with top speed of 2.9 cm/s at 40V$_{pp}$

Changing Pitch Size



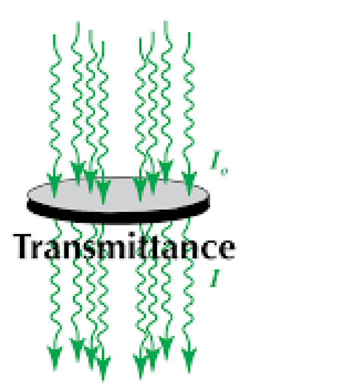


$speed = \frac{distance}{time}$

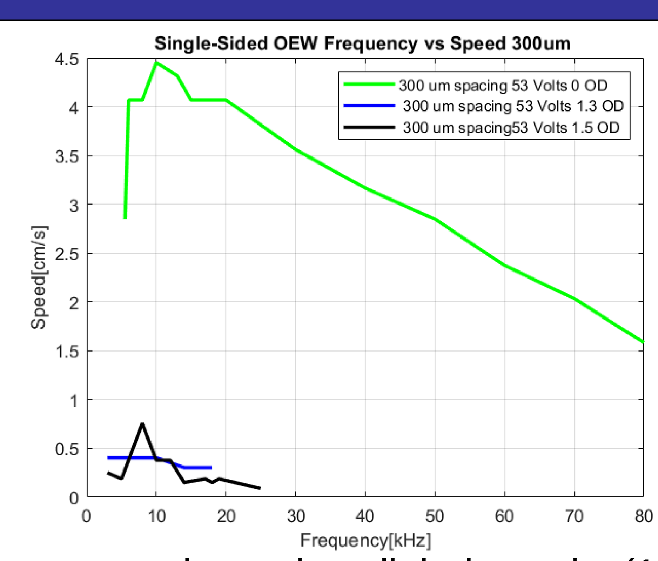


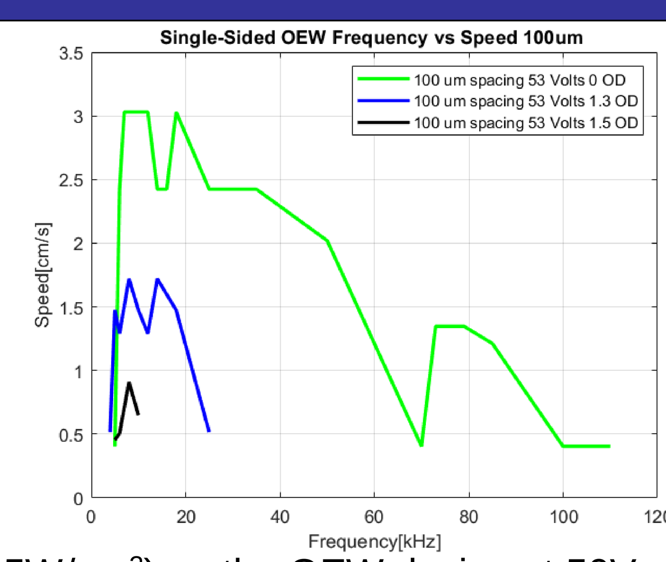
- Single sided devices were fabricated with varying Pitch dimensions: 60um, 100um, 300um
- Speeds of up to 2.6 cm/s achieved
- Peak speeds achieved at frequencies around 10kHz
- Devices with smaller Pitch to Metal Width ratios demonstrated faster droplet speeds

Changing Light Intensity



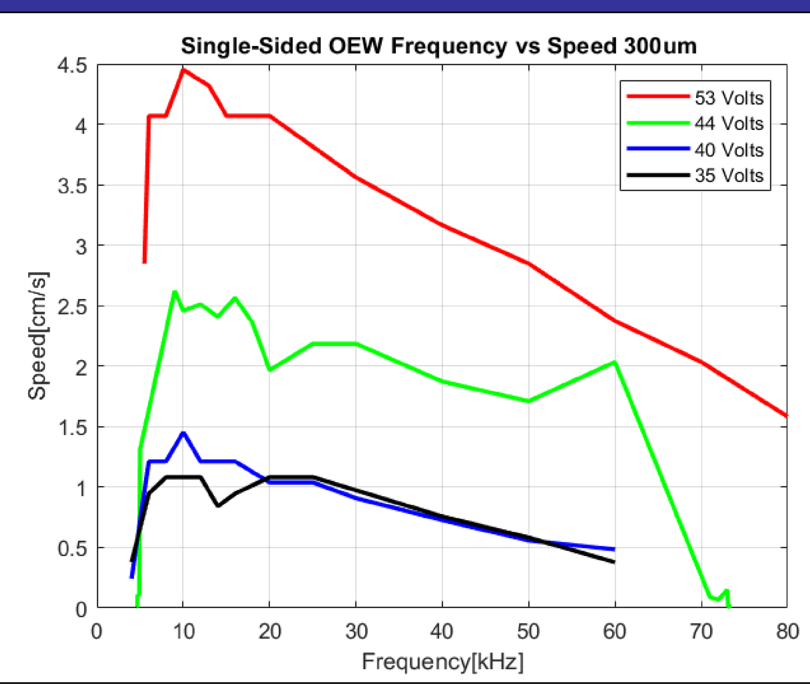
$\% \, Transmission = 10^{-OD} \times 100$





- Neutral density filters were used to reduce light intensity (1.5W/cm^2) on the OEW device at 50V$_{pp}$
- Droplet movement slowed as light intensity reduced
- Droplet movement was observed for 100% transmission to 3% transmission (0 OD to 1.3 OD)

Changing Voltage



- OEW device was tested with varying applied voltages at a light intensity of 1.5W/cm^2
- Minimum voltage required for droplet movement observed at 20V$_{pp}$
- Maximum voltage with droplet movement observed at 95V$_{pp}$

Summary

- OEW has the ability to manipulate droplets in 2D freely using arbitrarily sized electrodes
- Our single sided OEW benefits from being accessible from the top for various input & out configurations
- Our Speed vs. Frequency data confirms the OEW theoretical model
- Changes in applied frequency, light intensity and applied voltage characterized in order to optimize operating conditions

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