Dispensing thin liquid films using dielectrophoresis

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This paper describes a novel system using liquid dielectrophoresis to dispense thin films of viscous, insulating liquid onto rolls and substrates. The scheme provides precise control of volume flow from picoliters to nanoliters per second per electrode pair. The basic structure, shown in Fig. 1, consists of two coplanar electrode strips patterned in evaporated metal on an insulating substrate. A thin coating of a low-surface energy material covering the electrodes prevents liquid from spreading in an uncontrolled manner. This DEP microfluidic system is generally similar to droplet dispensers for aqueous liquids [1], but here the liquid is far more viscous, has much lower surface tension, lower dielectric constant, and negligible electrical conductivity.

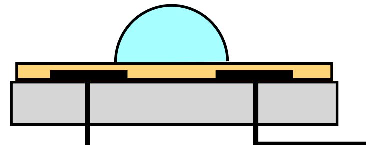

Fig. 1. Basic coplanar structure of electrodes forms a non-uniform E field that creates new hydrostatic liquid equilibrium with semicircular cross-section. Raising voltage increases both semicircular radius and max. flow rate.

Fig. 2. Selected video frames of liquid motion immediately after applying voltage. Starting from the liquid reservoir at right, the finger travels to the left. The liquid is 50 cS silicone oil. Electrode width = 90 μm; gap = 30 μm; voltage = 625 V-rms; frequency = 100 Hz.

When voltage is applied, a non-uniform electric field created by the electrodes leads to a new hydrostatic equilibrium configuration that the liquid tries to fill. It does so by forming a finger that extends from the liquid reservoir and moves down the length of the electrodes to the other end of the structure. See Fig. 2. If liquid is withdrawn from the end, for example, by transferring it continuously to a receiving surface, the liquid flow is sustained. This steady flow can be adjusted continuously by changing the voltage, which modulates the cross-sectional area of the finger. Using arrays of co-planar electrodes, the narrow liquid finger is replaced by a thin film that moves along parallel to the electrodes. See Fig. 3.

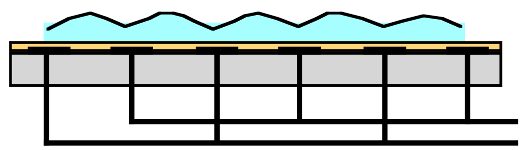

Fig. 3. Cross-section of liquid film created by array of parallel electrode strips.

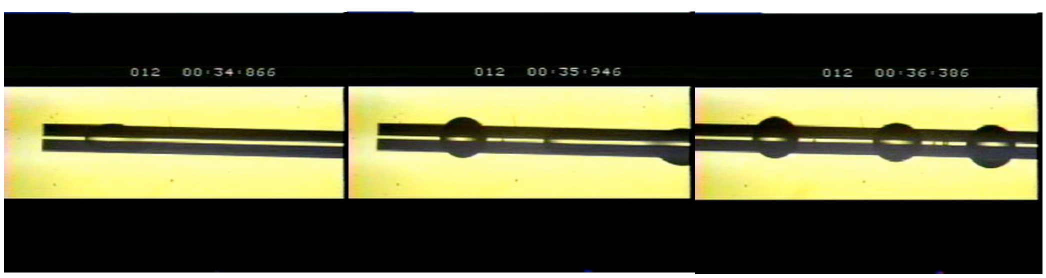

Fig. 4. Selected video frames showing capillary induced break-up of liquid finger into droplets. Near the end of the structure, surface tension simultaneously draws the finger from left to right back to the liquid reservoir, but instability proceeds more quickly.

Voltage termination disrupts the flow equilibrium by allowing capillary instability to break up the liquid finger into droplets along the structure. See Fig. 4. Droplet formation interrupts fluid communication and stops the flow within ~10^2 milliseconds. When voltage is reapplied with the droplets disposed along the length, fluid communication and flow are restored within ~10 milliseconds.

Reference

[1] R Ahmed and TB Jones, "Dispensing picoliter droplets on substrates using dielectrophoresis," J. Electrostatics, in press.

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