ELECTRODEWETTING ON TRANSPARENT SUBSTRATE: DEVICE FABRICATION AND DEMONSTRATION

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ABSTRACT

Electrodewetting [1] is a newly discovered droplet manipulation mechanism that works in a manner opposite to the well-known electrowetting including electrowetting-on-dielectric (EWOD) [2]. When electrically actuated, the contact angle of a liquid on a solid surface would "increase" (i.e., electrodewetting) rather than decrease (i.e., electrowetting). This opposite effect of electrowetting allows digital microfluidic devices to work on a hydrophilic surface, i.e., free of the hydrophobic topcoat that has been the main drawback of electrowetting. In this paper, we detail the design and fabrication of electrodewetting "devices" and advance the technology to accommodate transparent substrates. To prove the feasibility of transparent devices, we achieve moving and splitting aqueous droplets along ITO electrodes on a glass wafer by electrodewetting with only ~5 V. The fabrication process is simple and compatible with today's LCD manufacturing process, indicating potential for low cost.

MOTIVATION

Since the introduction of EWOD [3,4], electrowetting has been utilized in a wide range of areas, including optical, biomedical, thermal, and electronics. The devices are useful if optically transparent for many applications, including biomedical where fluorescent and colorimetric detection are common [5-7] and optical which involves lenses, displays, and others [8-12]. Since the electrodewetting mechanism has been studied and demonstrated only on silicon (i.e., opaque) substrate [1], the fabrication technology needs to be advanced and expanded to realize transparent devices. In this paper, we report the development of transparent electrodewetting devices starting with an ITO-coated glass wafer.

FABRICATION

The concept of electrodewetting for digital microfluidics, schematically illustrated in Figure 1, was so far observed only on a conductive silicon (i.e., opaque) wafer [1], where the native oxide of silicon provides the strong hydrophilicity to assist the electrodewetting. Most common substrate for transparent devices is ITO electrodes on glass. However, since ITO is not hydrophilic enough to induce effective electrodewetting (unlike the conductive silicon with native oxide), in this paper we develop a fabrication method adequate for electrodewetting on ITO-coated glass substrate. Our results showed a PECVD-coated SiO_2 does work for electrodewetting when deposited to a thickness around 100 nm on patterned ITO electrodes, as shown in Figure 2.

Placed over neighboring electrodes, a water droplet can be translated by electrodewetting in a mirror fashion of the well-known electrowetting. As illustrated in Figure 3,

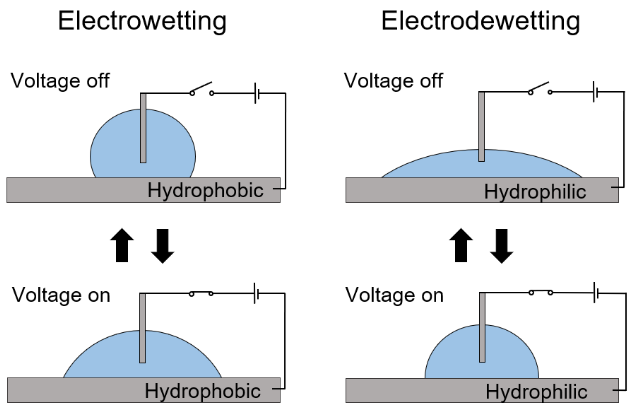

Figure 1: Electrowetting vs. electrodewetting. *The electrical switching of surface wettability is opposite to each other. Electrowetting (including EWOD) works the best on a hydrophobic surface. Since most materials are hydrophilic, electrowetting requires deposition of a hydrophobic topcoat. Electrodewetting mechanism works the best on a hydrophilic surface and does not require the hydrophobic topcoat.*

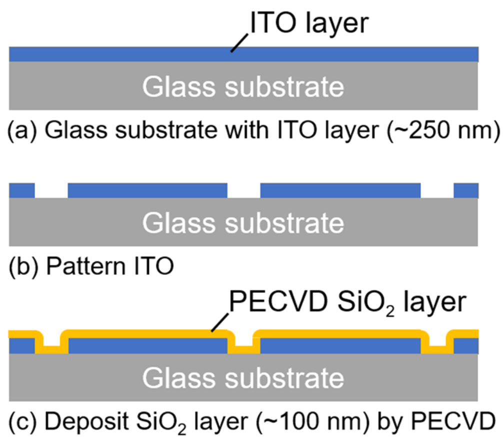

Figure 2: Fabrication process of transparent electrodewetting device. *(a) ITO-coated soda-lime glass as received; (b) Lithographic patterning of ITO; (c) Deposition of SiO_2 by PECVD.*

an external voltage is applied between two electrodes in a way the resulting electric field in the liquid makes the droplet dewetted on the left electrode but remain wetted on the right electrode. As result, the droplet is "repelled" (pushed) to the right. This is conceptually similar but opposite to the droplet translation by electrowetting, where the droplet is "attracted" (pulled) to one side. Once the device and actuation signals are tuned to increase the driving force, all four essential droplet microfluidics operations (i.e., generating, moving, splitting, and merging droplets) [13] can be achieved.

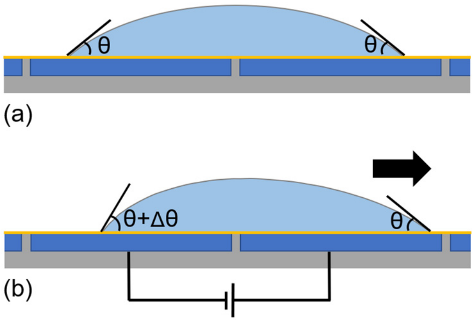

Figure 3: A droplet moved by electrodewetting over two SiO_2-covered ITO electrodes on glass. *(a) A droplet sits across two electrodes; (b) Electrodewetting on the left electrode repels the droplet to the right.*

RESULTS

Using DI-water containing surfactant on the device of Figure 2, we have observed droplets moving across multiple adjacent electrodes by sequentially applying ~5 V to the electrodes following the scheme of Figure 3. While the microfluidic actuation was confirmed, we have also found characteristics not observed with EWOD. One is the ability to translate and split droplets on an open device (i.e., no cover plate) in air. In contrast, on an open device in air, EWOD requires coplanar electrodes for droplet translation [14] and simply cannot achieve droplet splitting [13]. Figure 4 shows splitting a droplet on the developed electrodewetting device with no cover plate. This enhanced ability over EWOD in open configuration is understood by recognizing the electric field is stronger near the gap between the electrodes. However, we observed noticeably stronger tendency for satellite droplet to appear. The digital microfluidic operations on silicon and transparent device are presented with videos. Although a simple device layout was used in this proof-of-concept study, in future research we expect to design the electrode shapes that make use of the advantages and limit the drawbacks of electrodewetting compared with EWOD.

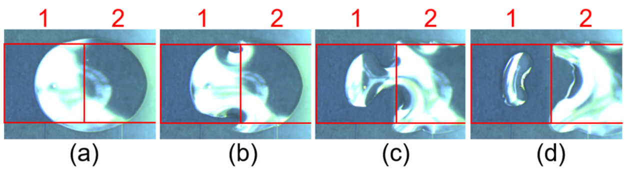

Figure 4: Sequential images showing a droplet of surfactant-containing DI water being split on the transparent device (with no cover plate) in air. *This type of droplet manipulation was not observed with EWOD. When voltage is applied between two electrodes, electric field inside the liquid is stronger near the gap between them. This field concentration leads to early dewetting near the gap on electrode 1 and assists cutting (a,b) but also causes asymmetric cutting (c,d).*

SUMMARY

We have achieved electrodewetting on a transparent device using a simple fabrication method. This method does not require high quality dielectric coating or hydrophobic topcoat and is compatible with the LCD manufacturing, suggesting a potential for fast development and low-cost product. Utilizing a simple device layout used for EWOD, we observed droplet translating and splitting on the transparent electrodewetting device in air with no cover plate.

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