3-D IMAGING OF MOVING DROPLETS FOR MICROFLUIDICS USING OPTICAL COHERENCE TOMOGRAPHY

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We report the use of optical coherence tomography (OCT), a 3-D imaging technique, to visualize microdroplets in an electrowetting-based microfluidic device. Vertical cross-sections of stationary and moving microdroplets are imaged to measure static and dynamic contact angle changes and flow profiles inside the microdroplet during transport. The contact angle information is useful to study important electrowetting phenomena such as contact angle saturation and hysteresis.

Electrowetting refers to the electrical modulation of the interfacial tension between a conducting liquid phase and a solid electrode, the science of which is not understood completely due to lack of good visualization tools [1][2]. Current visualization techniques have been limited to observation using CCD cameras [3][4]. This technique, though sufficient for observation from the top, can pose severe constraints on materials and system design for imaging from the side, and does not provide 3-D tomographical information.

OCT is an emerging real-time, *in-situ*, and non-invasive imaging technique based on low-coherence interferometry [5]. Though most of its applications have been for cross-sectional tissue imaging in biological systems, OCT has recently been used to image flow patterns in continuous flow microfluidic systems [6]. Unlike CCD cameras, OCT obtains tomographical images of the droplets just from the top circumventing the design constraints mentioned before.

The schematic of the electrowetting system is shown in Figure 1. The details of the OCT setup are described in [5] and the system specifications are listed in Table 1. Droplets of skim milk and an aqueous solution of 1μm polystyrene beads (polybead) are used, since OCT relies on the light scattered by the liquids. All images and videos are captured at the center of the droplet though in principle any cross-section of the droplet can be visualized.

Figure 2 shows OCT images of a 400nL polybead droplet where the static contact angle increases with applied voltage and saturates beyond 60V. Saturation of contact angles at higher voltages is a very important contact angle phenomenon in the fundamental study of electrowetting. Using OCT, this phenomenon can be visualized very clearly at different voltages and cross-sections. Figure 3 shows snapshots of a 500nL skim milk droplet as it moves across two 1mm electrodes. The changes in the dynamic advancing and receding contact angles from the images can be used to study the effect of contact angle hysteresis on the electrowetting droplet transport. Flow profiles inside the droplet are obtained by imaging a moving 500nL KCl droplet (0.1M) loaded with a small volume (<50nL) of the polybeads. Figure 4 shows the droplet as it moves across two electrodes. Complete flow reversibility is evident from the images, corroborating the observations in [3].

OCT can be a very useful technique in visualizing droplets in an electrowetting system for static and dynamic contact angle information for studying contact angle hysteresis and saturation. Flow profiles inside a droplet can also be visualized which can be further extended to study droplet mixing. The initial results yielded qualitative information on the utility of OCT to image droplets. Further analysis is required to obtain quantitative information.

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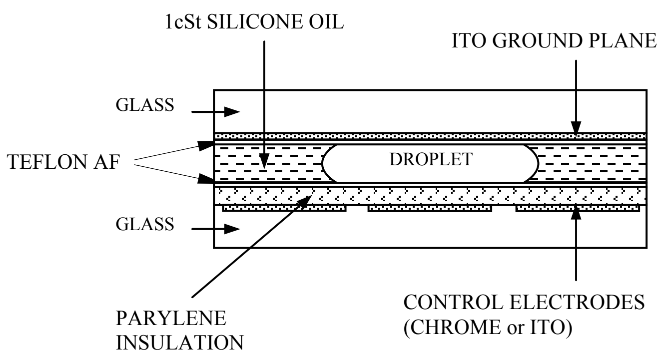

Figure 1 – Schematic of the electrowetting setup

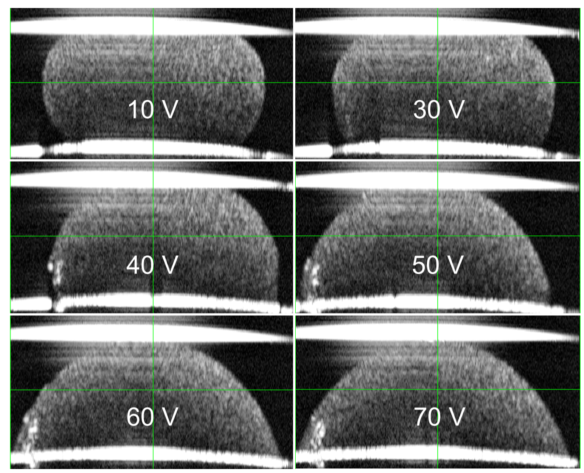

Figure 2 – Change in contact angle vs. voltage

Axial / vertical resolution	20µm
Lateral / horizontal resolution	20µm
Axial scan range (vertical field of view)	1.5mm
Lateral scan range (horizontal field of view)	1mm (static expts) 2mm (dynamic expts)

Table 1 – Specifications of the OCT setup used in the experiments described in this paper

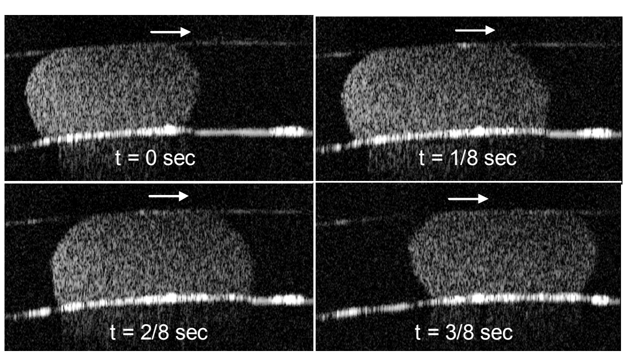

Figure 3 - OCT cross-section image of a moving droplet

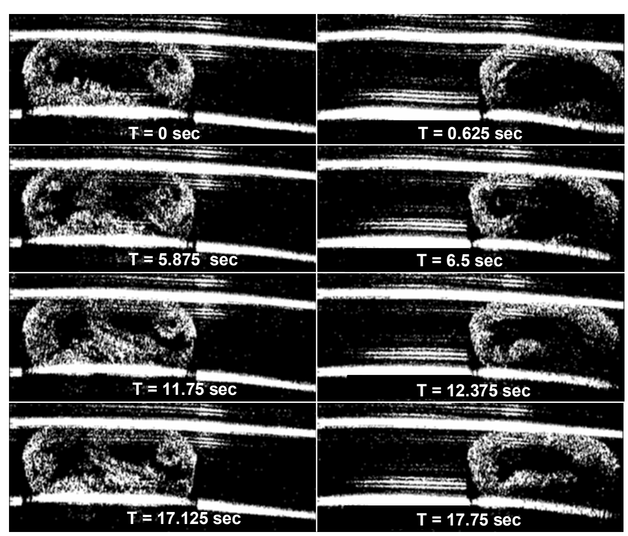

Figure 4 - Flows patterns inside a moving droplet