PhD Thesis: Design and Development of Low Voltage Electrowetting Device with Droplet Position Sensing Scheme

Abstract

The thesis presents, design and development of an electrowetting device working at low voltage, with droplet position sensing scheme. In electrowetting device, wetting property of liquid droplet is altered by applying an electric potential to the actuating electrodes, and used for developing digital microfluidic (DMF) platform. These devices use an insulating film between the electrode and the liquid droplet to prevent electrolysis which plays a vital role to reduce the actuation voltage.

In this work, a nanocomposite thin film of Barium Strontium Titanate (BST) and Teflon®AF is synthesized, to use as an insulation layer in electrowetting-on-dielectric (EWOD) device for reducing actuation voltage. First, crystallized BST nanopowder is prepared by the sol-gel method, and after that, a nanocomposite is prepared by using Teflon®AF as matrix and BST as the filler material. The nanocomposite solution is spin-coated on a glass substrate and baked at 80 °C in open air. A thorough characterization of the film using X-ray Diffraction (XRD), Transmission Electron Microscopy (TEM), Energy-Dispersive X-ray (EDX), Selected-Area Electron Diffraction (SAED), Field Emission Scanning Electron Microscopy (FESEM) and Atomic-Force Microscopy (AFM) techniques show smooth, uniform and crack-free hydrophobic film (contact angle, CA $\approx 115 \pm 2^{\circ}$). The dielectric constant (ϵ_r) and breakdown voltage (V_{bd}) of the film are measured to be 9.1 ± 0.4 at 1 kHz and 1073 ± 76 V/μm respectively.

The synthesized BST-Teflon®AF nano-composite film is then used to fabricate several EWOD devices using conventional micro-fabrication technology. Experiments have been carried out for contact angle modulation and transport of the droplet to study the performance of the nanocomposite film as a hydrophobic and dielectric material. Further experiments have been carried out to investigate the effect of the different shapes and size of the actuating electrodes for droplet transport.

An electrical sensing scheme has been proposed to detect the position of the droplet during transport on the array of coplanar electrodes. Experimental results are provided, which shows that the direct output voltage linearly related to the position of the droplet during transport.

A Jigsaw electrode design is proposed for addressing inner electrodes in EWOD device consisting of a large two-dimensional (2-D) array of electrodes. The device has been fabricated, and droplet transport has been demonstrated experimentally. Algorithms have also been developed for transport, mixing and splitting of droplets for this new type of electrode design.

Keywords: Digital microfluidics (DMF), Electrowetting-on-dielectric (EWOD), Low voltage EWOD, Barium Strontium Titanate (BST), Nanocomposite, Droplet position sensor, Contact angle sensor, Two-dimensional (2-D) electrode array, Jigsaw electrode.