FLUORINATED SUPERHYDROPHOBIC SURFACES FOR DIGITAL MICROFLUIDIC DEVICES WITH ELECTROWETTING ON DIELECTRIC AND MAGNETIC ACTUATION

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ABSTRACT

Digital microfluidics (DMF) is a popular alternative to traditional in-channel microfluidics, which allows precise control of individual droplets. Most commonly used droplet manipulation methods for DMF are electrowetting on dielectric (EWOD) and magnetic actuation. Both methods require high surface hydrophobicity to facilitate droplet movement, and often superhydrophobic surfaces are used to further enhance droplet actuation. This study systematically examines EWOD and magnetic actuation on natural, commercial and custom-synthesized superhydrophobic surfaces for droplet-based microfluidic platforms.

KEYWORDS: Superhydrophobic surface, Fluorinated nanoparticles, Electrowetting-on-dielectric, Magnetic actuation

INTRODUCTION

EWOD is a commonly used method of droplet manipulation on DMF devices, where the droplet is moved by a reduction in surface contact angle (CA) due to an applied potential (Figure 1). [1]

Alternatively, magnetic actuation on DMF platforms provides a low cost method for droplet manipulation where the only requirements are a hydrophobic surface, magnetic particles and an applied magnetic field. [2] Hydrophobic surfaces are commonly used in DMF as EWOD benefits from larger initial CA, as lower voltages are required to cause controlled droplet movement.[3] Furthermore superhydrophobic surfaces (CA >150°, roll off angle <10°) provide low friction, where aqueous droplets containing paramagnetic particles can be precisely and reproducibly actuated to a desired location. Superhydrophobic surfaces are created through the micro/nanoscale patterning of hydrophobic materials.

EXPERIMENTAL

In this paper we systematically study EWOD and magnetic-based droplet actuation on a natural surface (Colocassia leaf), commercially available superhydrophobic coatings, and custom synthesized nanoparticle based surfaces. Both commercial and synthesized surfaces are based upon fluorinated silica nanoparticles (5-150 nm) sprayed directly on a glass substrate or polymeric binder for added stability. These surfaces offer a robust and cost effective alternative to lithographic surface fabrication methods. The superhydrophobicity of custom synthesized surfaces can be tailored through the size of the nanoparticles and degree of fluorination. The superhydrophobicity of the surfaces is characterized by scanning electron microscopy (SEM) (Figure 2) as well as atomic force microscopy (AFM), and evaluated using both CA and roll-off angle measurements.
RESULTS AND DISCUSSION

The synthesis procedure of fluorinated silica nanoparticles allows to optimize surface chemistry and particle size for enhanced EWOD actuation. Figure 3 illustrates that both the initial contact angle (V=0) and contact angle change (after an applied voltage) increase with an increase in surface fluorination.

![Figure 3: The effect of the degree of fluorination on the initial contact angle (●) (at V=0) and the contact angle change (○) under an applied potential of 150 V.](image)

To examine magnetic actuation on superhydrophobic surfaces, the effect of different droplet size, solvent composition, concentration of magnetic particles and magnetic field strength is extensively studied. Figure 4 shows an example where the concentration of magnetic particles and roll off angle is examined. With no applied magnetic field, droplets roll off at angles less than 1°, regardless of the particle concentration. However, with an applied magnetic field roll-off angle increases as more particles are added to the droplet. Concentrations of the magnetic particle above 10 mg/mL allow to inverted the surface without droplet rolling off. The droplet is held on the surface upside down as long as magnetic field is applied, and it is possible to actuate the droplet under an inverted superhydrophobic surface by moving the magnet along the top of inverted surface (Figure 4 inset).
Figure 4: Roll-off angles of water droplets (20 μL) on a commercial surface against concentration of suspended magnetic particles without (●) and with (●) applied magnetic field. Above 10mg/mL the droplet can be inverted (inset image).

As an extension, droplets can be anchored on reduced hydrophobicity, nitrocellulose-based spots (CA 58°). Anchored droplets can be supplied with reagent to conduct sample dilution, colorimetric and cellular assays through chemical titrations (Figure 5).

CONCLUSION
A systematic study examined EWOD and magnetic actuation on natural, commercial and custom synthesized superhydrophobic surfaces for droplet-based microfluidic platforms. The silica nanoparticle-based coatings can be simply sprayed onto a number of substrate materials (i.e. plastic, glass and metals) enabling facile device fabrication. Furthermore optimized surface chemistry and particle size enables EWOD and magnetic actuation performance to be enhanced.

REFERENCES

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