Electrically switchable structural color using electrowetting on superhydrophobic surface

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Reflective display requires no internal light source, which makes it consume much less power, moreover, it also has some unique properties, such as printing-like looking and readability under sunlight. Those make reflective display a much better solution than transmissive display for a number of applications, such as e-book reader, signage, electronic shelf-labels and display for wearable devices. We proposed a full color reflective display design based on stacked "color mirrors", which could exhibit high brightness with large color gamut area, and better than newspaper contrast [1]. Those "color mirrors" are implemented using structural color based on 2-D high contrast gratings (HCGs). The electrical modulation/switching of the structural color is achieved by changing the index contrast between the grating and its surrounding driven by the electrowetting process (figure 1a&b). Figure 1c, d&e show the red, green and blue mirrors and their reflection spectra in ON and OFF states. Figure 1f, g&h show the photos of comparisons for ON and OFF states.

The HCG based structural colors were fabricated by combining interference lithography and nanoimprint lithography (NIL), and a Teflon layer was spin-coated on the surface of HCGs as the hydrophobic layer required in electrowetting process. Fabricated structural colors are shown in figure 2.

In the electrowetting process, the liquid movement is driven by the contact angle change under electrical field. While it is a well-studied process, to realize the modulations of structural colors, there are still some challenges haven't been solved. For example, high index liquid, which is not conductive, instead of water is needed to modulate/switch the structural colors. Most reported studies on electrowetting have been focused on water, and there is no reported study of electrowetting with non-conductive liquid. In addition, while moving liquid on a flat surface has been well studied, in our application the surface has nanostructures, which makes it superhydrophobic (figure 3), that gives us unique challenges. For example, electrowetting on superhydrophobic surface, the transition is irreversible. As the result, we have to drive the liquid by a pair of electrodes instead of relying on wetting and dewetting of the surface (figure 4).

We successfully achieved droplet moving in centimeter scale, which is much beyond the need for high reflective display in nanoscale. That proved the feasibility of electrically switchable full color reflective display using electrowetting.

References:

1. He Liu, Yuanrui Li, Yuhan Yao, Yifei Wang, and Wei Wu. Full color reflective display based on high contrast gratings. EIPBN 2016.

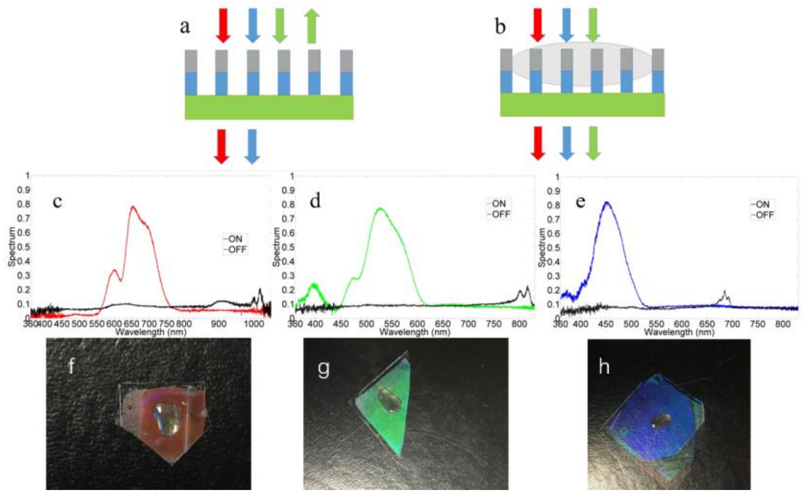

Figure 1 (a&b) Schematic of the switching mechanism of color mirrors (using green color as an example). (a) Green mirror will be transparent for red and blue light and reflective for green light (ON state). (b) The mirror will be transparent for all three color lights (OFF state), which the high index liquid is driven in. Experimental reflection spectra of red (c) green (d) and blue (e) mirrors in ON state (color lines) and OFF state (black lines). (f, g&h) Photos of the comparisons for ON and OFF states. When the high index liquid is driven in, the mirrors turn into transparent (from ON state to OFF state) and show black (the color for background).

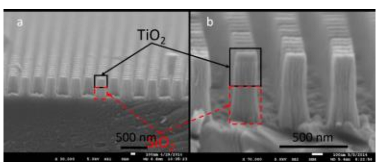

Figure 2 (a) SEM image of the 2D subwavelength grating reflecting blue light. (b) SEM image of the 2D subwavelength grating reflecting green light.

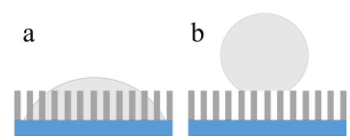

Figure 3 Droplets wetting on patterned surfaces. (a)Wenzel state with enhanced solid–liquid interfacial area.
(b) Cassie–Baxter state with entrapped air underneath the droplet.

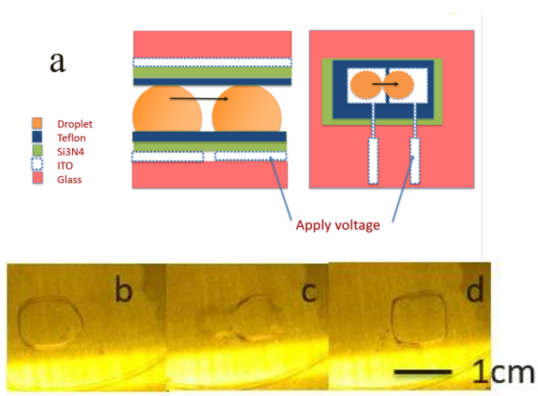

Figure 4 (a) Schematics, cross-section on the left and top view on the right, of the cell used to demonstrated Droplet moves to the area which has been applied potential. (b) At first, droplet was above the left electrode. The electrodes are invisible. (c) When we applied the potential on the right electrode, the droplet moved the right side. (d) Droplet stops on the area above the right electrode. The whole process will be finished within 0.2s.