Switchable and Stackable Color Filters for a full-color Reflective Display

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Reflective displays have been of great interest for decades, and are attracting more and more attentions with the popularity of wearable devices due to their unique properties like low power consumption, outdoor readability and print-like quality. Many progresses have been made towards a full-color reflective display via different approaches, such as, electrophoretic display, cholesteric liquid-crystal display, MEMES-based reflective display, electrochromic display, and electro-wetting display. However, most of the approaches adopted a single-layer architecture, arranging the subpixels in parallel, because the filling ratio of each subpixel is only 33% the optical efficiency is limited to a poor value of 33%. (Figure 1a)

In this work, a tri-layer display architecture operating in RGB additive mode is proposed, as shown in Figure 1(a), theoretically, the optical efficiency can reach 100%. Blue, green and red reflective color filters are designed and fabricated for this tri-layer device, and the filters can be switched between colored and clear states. For example, the blue filter reflects blue light in its colored state and becomes transparent in its clear state. Two-dimensional subwavelength dielectric gratings are employed as the color filters, and the schematic diagram is shown in Figure 1(b). The reflection of the filters originates from the resonances inside the gratings, and the reflection spectra can be well engineered. Photos of blue, green and red reflective color filters as well as the corresponding SEM images are shown in Figure 1(c) and (d). As can be seen from the photos, red, green and blue filters are obviously demonstrated, and the color is constant over the entire filter for each of them. The calculated and measured reflection spectra and the corresponding gamut are shown in Figure 1(e), (f). The filters can be switched between colored and clear states by driving high-index liquid in and out of the filters via electro-wetting. Photos of the three filters in their clears states are shown in Figure 1(g). To demonstrate the performance of stacked color filters, the blue, green and red filters are stacked as illustrated in Figure 2(a), then the stack is placed on a black (anodized Aluminum) surface, and high-index liquid can be injected to switch one or more filters into their clear states. All eight combinations of the three filters' states are studied, and some photos are shown in Figure 2(d)-(k), as well as the measured spectra of the stacked filters. For example, when the green filter is switched to its clear state, the overlapping area shows a purple color, which is the sum of blue and red, as shown in Figure 2(j). In total, red, blue, green, cyan, magenta, yellow, white and black are obtained by injecting high index liquid at different interfaces. To our knowledge, this was for the first time that stackable and switchable filters were demonstrated, and this opened a path to a practical full-color reflective display by employing stacked-layer architectures. In addition, grey scales of colors (using a green filter as an example) have been demonstrated by a green filter with changing coverage percentage at each pixels. The photo of the green filter (to show grey scales of color) and stacking with a blue filter (to show color reconstruction) are shown in Figure 2(c). Last, the demonstrate of integration with a conventional transmissive display is shown in Figure 2(b), wherein stacked filters in clear states is placed on top of the screen of a mobile device, and the text from the device is shown through the transparent filter stack, this proves the feasibility of the proposed revolutionary hybrid display.

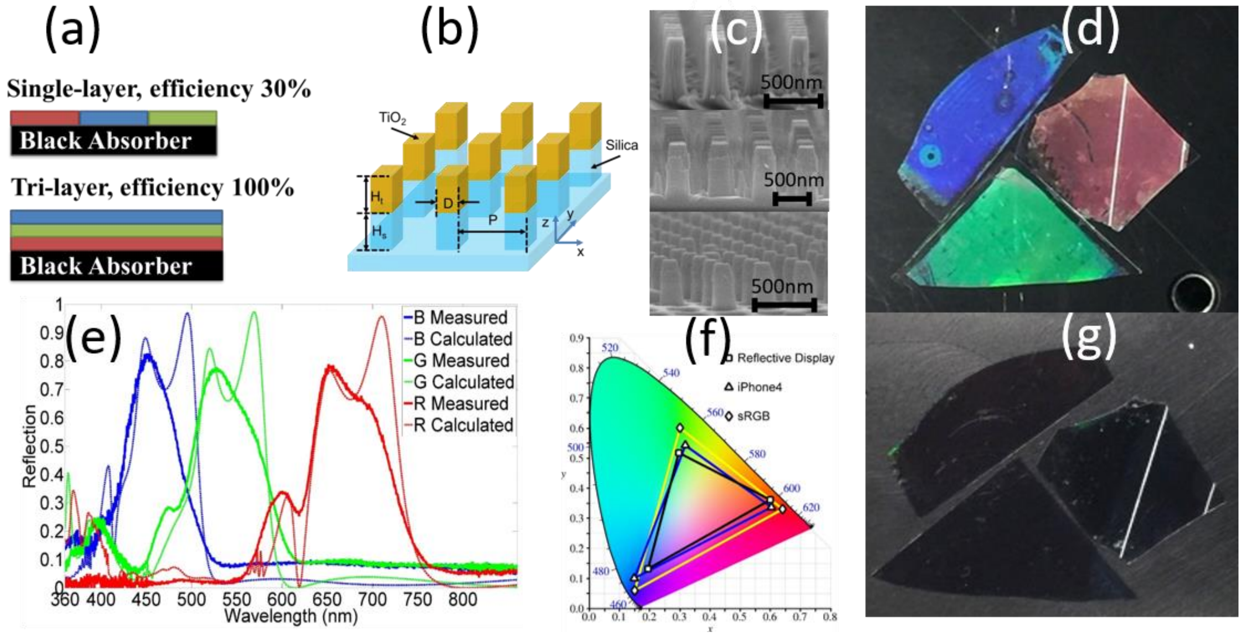

Figure 1 Reflective color filters based on resonant gratings. (a) Single-layer and tri-layer display architectures. (b) Schematic diagram of a resonant grating. (c) SEM images of fabricate blue, green and red filters. (d) Photos of the filters in colored states. (e) Measured and Calculated reflection spectra of the filters. (f) Gamut of the filters. (g) Photos of the filters in clear states.

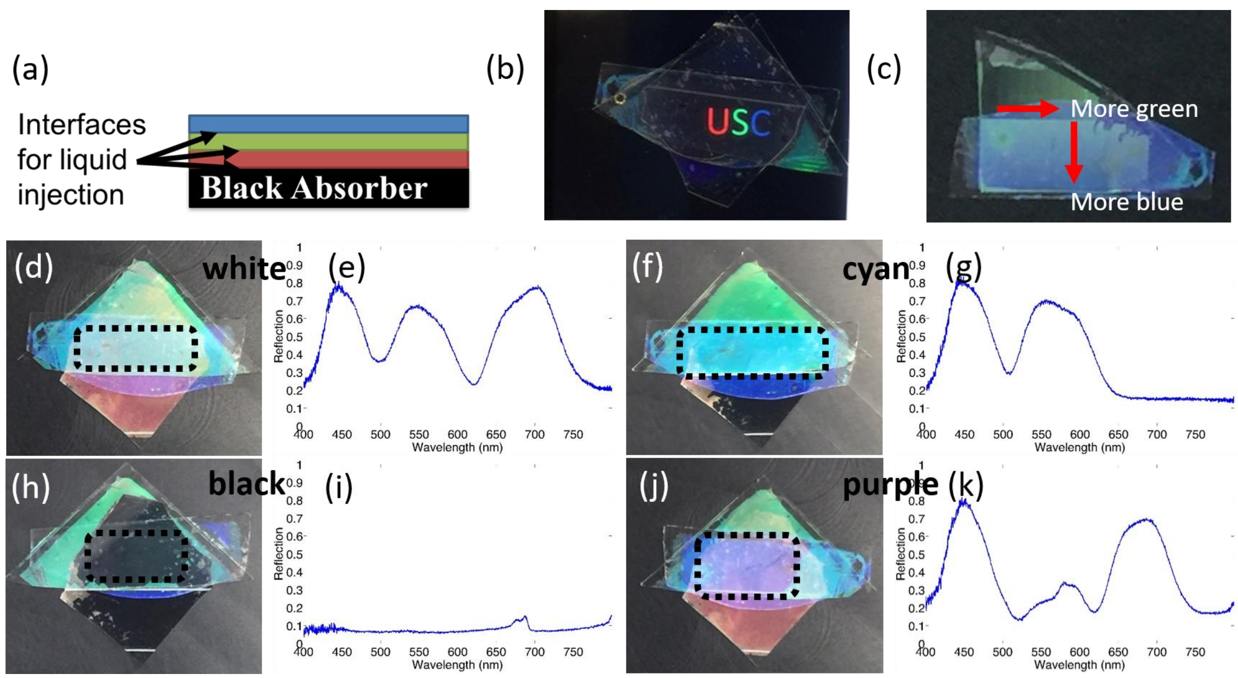

Figure 2 Stacked filters. (a) Schematic diagram of the filter stack. (b) Filter stack in transparent state on top of a transmissive display. (c) Blue filter on top of a green one with changing gray scales. (d)-(k) The construction of different colors, as well as the corresponding measured reflection spectra. One or more filters are switched to clear states in the filter stack, and different combinations generate different colors.