The Design and Analysis of Switchable and Stackable Reflective Color Filters

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Power consumption of display is one of the biggest concerns for portable electronic devices, and reflective color display with switchable and stackable color filters is a promising solution. However, this requires color filters have high brightness, high color saturation, large viewing angle and high contrast ratio. In this work, we meet those challenges by designing, fabricating and optimizing reflective color filters based on subwavelength resonant gratings. Here we report the analysis of the design and optimization, and the physics behind them.

First, to obtain high brightness, the reflectance of reflective filters should be close to 1, and with a broad bandwidth. Subwavelength resonant grating is employed as the reflective filters due to its unique optical properties. Grating material and structural parameters of filters are crucial to its performance. Through numerical simulation using finite-difference time domain (FDTD) method, the best material types, grating structure and structural parameters for reflective colors filters were obtained. Figure 1 shows the schematic diagram of resonant grating used, the SEM photo and measured spectrum of a blue filter.

Second, the reflection of resonant gratings is directly related to the index contrast, hence, the filters can be switched between colored and clear states via driving high index liquid into and out of the gratings. The mechanism behind this phenomenon was studied, and the gratings were optimized to obtain the largest possible contrast ratio. Using the blue filter as an example, figure 2a-e shows the simulated reflective spectra of 390 nm pitch resonant gratings with different width in different refractive index environments. With width of 140nm and refractive index of 1.8, a contrast ratio of 8:1 was obtained from the fabricated filters (figure 2f), which is comparable to the quality of newspapers.

Third, viewing angel is an important specification for reflective displays. The simulation results in Figure 3a shows the calculated angled reflection with respect to grating pillar sizes. The impact of grating materials on angle dependence is also studied, as shown in figure 3b and 3c. By optimizing the grating materials and structural parameters, reflective filters with large viewing angle were fabricated, and the physics behind it were analyzed.

Reference:

[1] H Liu, Y Yao, Y Wang and W Wu, "A full color reflective display system based on high contrast gratings", Journal of Vacuum Science & Technology B.

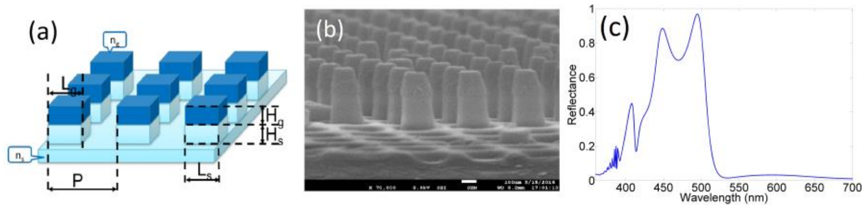

Figure 1: (a) Schematic diagram of 2-dimentional resonant grating, where each grating pillar consists of a top TiO_2 and a bottom SiO_2 layers. P, L_s, H_g and H_s denote the grating pitch, edge length of pillar, height of TiO_2 pillar and SiO_2 pillar, respectively. (b) SEM photo of blue filter. (c) Measured spectrum of blue filter.

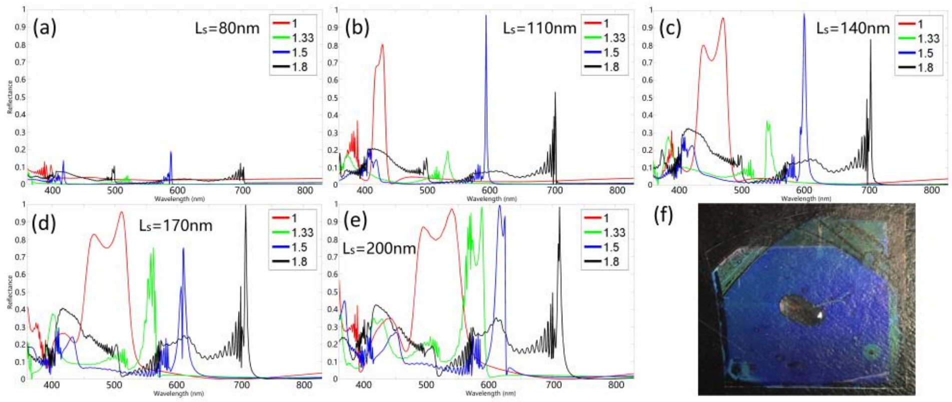

Figure 2: Simulated reflective spectra of same pitch (P=390nm) resonant gratings with different filling ratio (a) L_s=80nm (b) L_s=110nm (c) L_s=140nm (d) L_s=170nm (e) L_s=200nm in different refractive index environment (n=1, 1.33, 1.5, 1.8). (f) Photo of blue filter with a high index liquid (n=1.8). The area with the liquid is switched to the clear state.

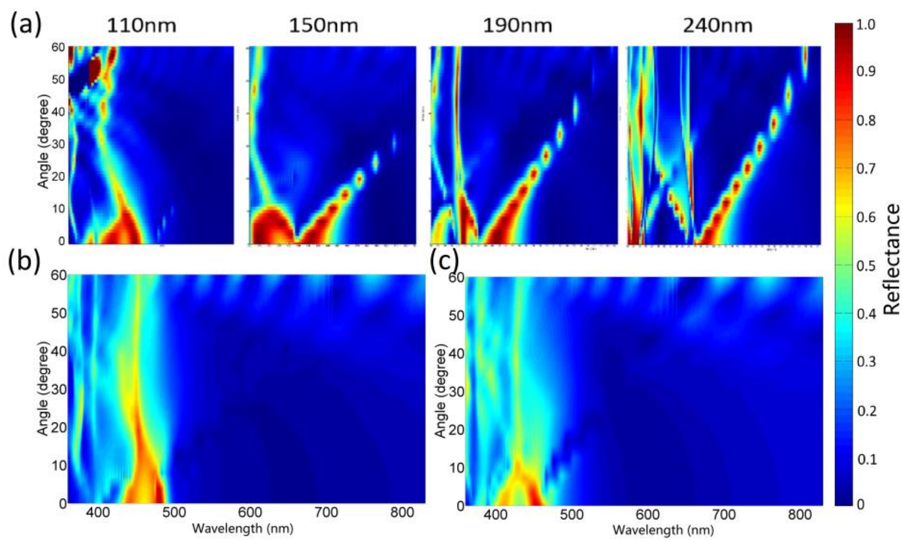

Figure 3: Simulations of reflective spectra over incident angles. (a) The dependence of reflectivity on incident angle and resonant gratings width when grating pitch (P=390nm) and material (top layer is TiO_2 and bottom layer is SiO_2) is fixed. (b) The best simulated result (grating pitch and width are 390nm and 140nm) when top layer material is TiO_2. (c) The best simulated result (grating pitch and width are 350nm and 150nm) when top layer material is Si_3N_4.