Angle Independent Reflective Color Filters by Plasmonic-induced Light Funneling Effect

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Plasmonic color filters have gained considerable attention in recent years. The high efficiency and polarization dependence of plasmonic color could lead to lower cost and lower power consumption, which is of interest in the fields of CMOS image sensors and display panels. A variety of plasmonic color filtering effects have been demonstrated using nanostructures such as aperture perforated metal films[1], metal-insulator-metal (MIM) stacked arrays[2], and metallic resonant waveguide gratings[3]. However, most of the plasmonic color filtering effects are strongly angle dependent. This problem impedes the practical implementation on display panels and CMOS image sensors. To reduce the angle effect, one can exploit the localized surface plasmon resonance (LSPR) Nevertheless, LSPR usually works well at longer wavelengths, but is difficult to implement at visible wavelengths.

In this work, we propose a new scheme based on light funneling into nanoslits shown in Figure 1(a) to achieve angle robust reflective color filtering. The simulation results show that cyan, magenta, and yellow, three basic colors for subtractive color scheme (CMY scheme), can be achieved by changing the the slit depth (Figure 1(b)) or slit width (Figure 1(c)). Figure 1(d) shows calculated angle-resolved reflection spectrum results for period (P) of 210nm and slit width (W) of 60nm. This calculation shows that the main resonance dip remains around 660nm over a wide range of incident angles, confirming the angle-insensitive color filter design.

To fabricate the structure first an array of 60nm wide resist lines are defined on a fused silica substrate using ebeam lithography (EBL), which is followed by a nickel deposition and liftoff process. The sample is dry etched to fabricate 180nm high, 60nm wide silica line arrays. Afterwards, 220nm thick silver is sputtered over the silica grating. The final structure of the device is presented in Figure 2(a). The measurement is performed using a microscope interfaced with a spectrometer. Figure 2(b) shows the measured spectrum of the cyan, magenta, and yellow. The results show a good match with the simulation results in Figure 1(c). The reflection colors are also insensitive to the light incident angle, confirming the design principle.

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[2] H. J. Park, T. Xu, J. Y. Lee, A. Ledbetter, and L. J. Guo, Acs Nano 5, 7055 (2011).
[3] Nghia Nguyen-Huu, Y. Lo, and Y. Chen, Opt. Commun. 284, 2473 (2011).

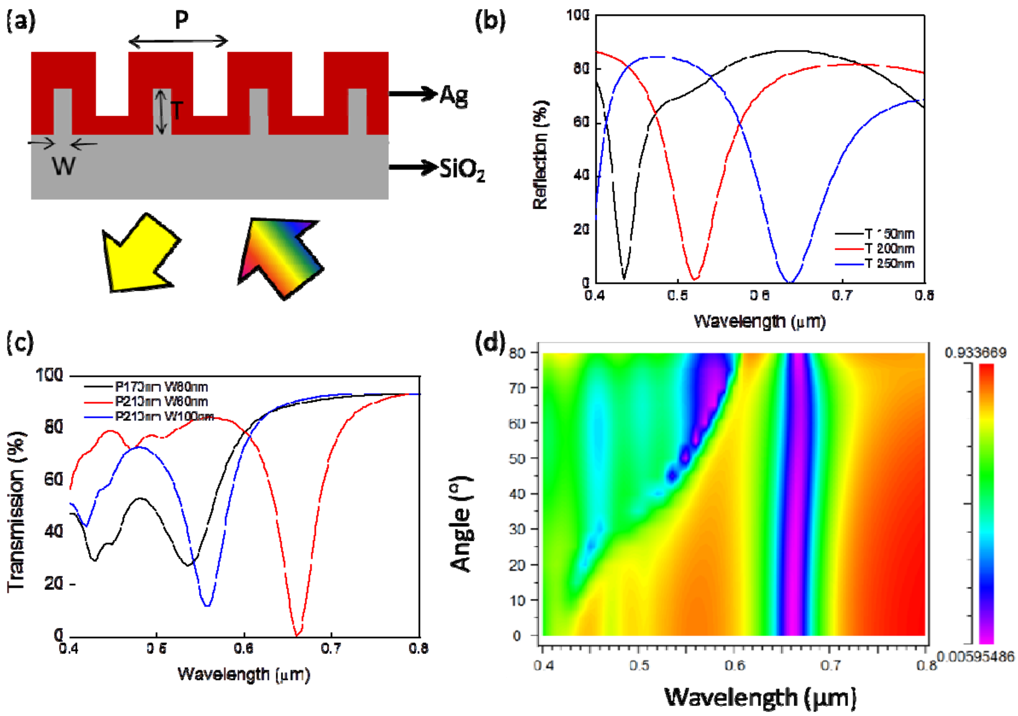

Figure 1 (a) design of angle insensitive color filter, W, P, and T indicate slit width, period, and thickness of metal perforated film, respectively. (b) The resonance dip shift with different T, which can achieve CMY color model (c) The resonance dip shift with various W at T = 180nm, which can achieve CMY color model. (d) Calculated angle-resolved reflection spectrum for P of 210nm and W of 60nm

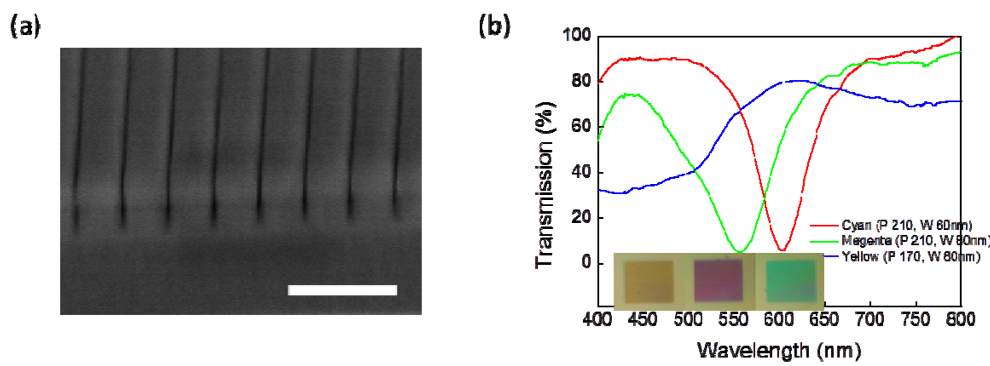

Figure 2 (a) final structure of the device and 500nm scale bar (b) measured spectrum of the cyan, magenta, and yellow, and their color images under a microscope