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Demonstration of High Transmittance Color Filter Using Plasmonic Nanocavity Array (D2PA) Fabricated by Nanoimprint

Ruoming Peng, Yuxuan Wang, Qi Zhang, and Stephen Y. Chou*
Nanostructure Laboratory, Princeton University, Princeton, NJ 08544

For transmission color filters, high transmittance at desired wavelengths and long operating lifetime are the keys. The mainstay of today's CMOS imager, display and LED applications, dye-doped polymer thin-film filters, have transmittances of 40~70%; but short lifetime due to the polymer and dyes degradation. Subwavelength metallic (plasmonic) filters are stable, but usually transmit <40% of light[1,2]. Here, we designed, fabricated and demonstrated a new plasmonic color filter we invented, D2PA[3] (disk-coupled, dots-on-pillar, plasmonic, antenna-array), that has achieved 57%, 34% and 46% peak transmittance for red, green and blue, respectively, which, to our best knowledge, are the highest red and blue transmittance reported.

The D2PA comprises an array of dielectric nanopillars with a perforated continuous metal thin-film at the pillar feet, a metal disk on top of each pillar, metallic nanodots on pillar sidewall, and nanogaps between the metal components (Fig. 1). Metal disks completely block the light geometrical path for transmission, but, as we have discovered[4], light transmits through the D2PA much more than a D2PA with the disks removed (i.e. all holes open and unblocked)! Such giant extraordinary light transmission is due to the nanoplasmonic cavity antennas that are formed by the disks and the backplane of D2PA, which effectively couple light from one side to the other side. Optimized with FDTD, we selected pillar diameter of 100, 55, 105 nm; pillar height of 60, 60, 40 nm, and Ag thickness of 30, 30, 10 nm, respectively, for red, green and blue colors.

In fabrication, 200 nm pitch Cr disk array was first patterned on fused silica by nanoimprint, Cr evaporation and lift-off. Then the nanopillars were etched using RIE with the Cr disk mask. After removing the Cr disk mask, 30 nm thick Ag and 5 nm thick Au were deposited in normal direction to form the metallic top disks, metal film, and sparse nanodots on the pillar sidewall. The fabricated D2PA's pillar diameters, heights, and metal thicknesses for three primary colors were checked with SEM and found to match the above desired parameters (Fig. 2).

The filters' transmittance spectra, measured with a spectrometer and an unpolarized collimated white light, show that the peak transmittances for red, green and blue are 57%, 34% and 46% with FWHM of ~100 nm, ~100 nm and ~200 nm (Fig. 3), which are higher than the best red and blue plasmonic color filters reported[1,2]. Furthermore, the small FWHMs comparable to previous best results (~100 nm, ~100 nm, ~150 nm)[2] ensure minimum color cross-talk. The transmitted light images of filters taken with a camera in normal direction demonstrated good color uniformity over large area.

Compared with other transmission color filters, D2PA color filter has the advantages of (a) 4'' inch wafer fabrication capability with nanoimprint (b) high and wavelength tunable transmittance (c) the color filter is made of stable metal and dielectric material.

The new color filter, D2PA, with high transmittance, wavelength tunability, low color cross talk, and the nanoimprint fabrication process will have new applications in imaging and display.

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[3] Li WD, Ding F, Hu J, and Chou SY. *Opt. Exp*.19, 3925-3936, 2011
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*Chou@princeton.edu

Figures:

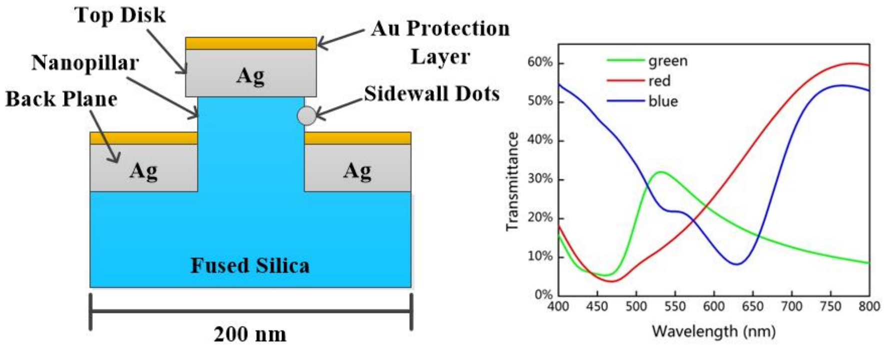

Figure 1. Plasmonic nanocavity scheme and the simulated transmittance results of three primary colors

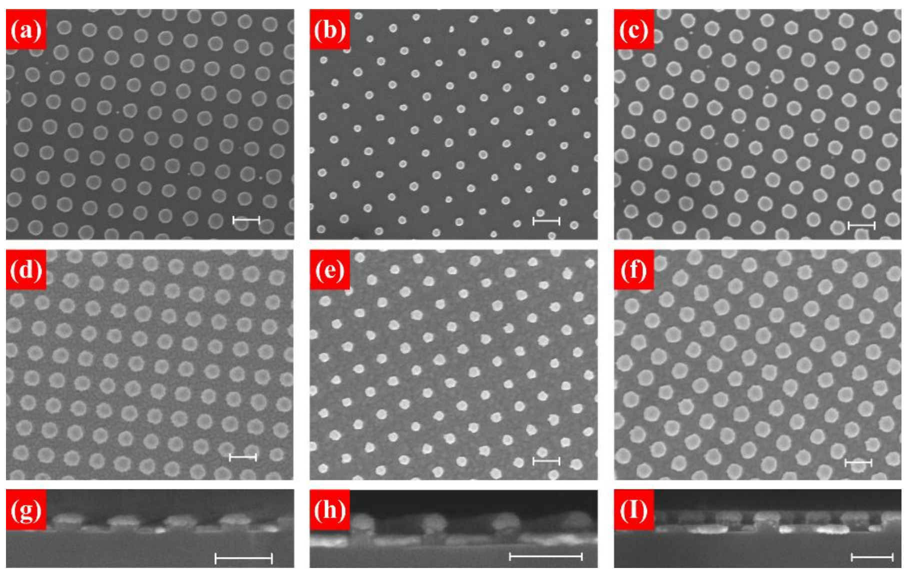

Figure 2 SEM pictures of nanopillar array and Ag D2PA color filter. (a)-(c) patterned nanopillar array on fused silica substrate corresponding to blue, green and red color (d)-(f) Ag D2PA corresponding to blue, green and red color. (g)- (I) Cross section view of (d)-(f) the scale bars are all 200 nm

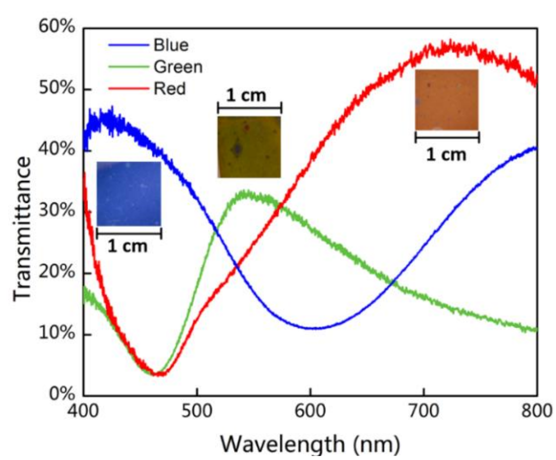

Figure 3 Optical image and transmittance spectra of blue, green and red color filters

*Chou@princeton.edu