Metallic color filtering arrays manufactured by NanoImprint Lithography

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Nanostructured surfaces are widely expected to play a significant role in photonics, especially in wide-spread products like CMOS imaging sensors, solar cells, LED-based lightning and micro displays. Those expectations are related to two kinds of benefits: improvement of the conversion efficiency from photon to electron (solar cells, photo detectors and image sensors) or from electron to photon (lightning, displays); reduction of fabrication cost. Spectral filtering is used in several imaging or spectroscopic applications from the visible range to the IR range. It is already used in the visible range in CMOS sensors, where arrays of ~1µm^2 red, green, and blue polymer pads are integrated a few microns above the sensors, which requires several photolithographic steps and introduces a significant thickness in the devices with thus several limitations. One solution will is to realize all spectral filters using an in plane patterning of a single layer. Indeed, most of the spectral properties of λ or sub -λ structured layers scale more or less with the size of the patterning.

As shown by Ebbesenand [1], Getting [2], Xu [3] band pass filtering can be thus achieved in thin nanostructured metallic layer with a sub wavelength pattern. In this work the basic structure is a sub wavelength array of sub wavelength cross etched in an aluminum membrane. 3D FDTD (finite –difference time-domain) simulations were performed in the visible range for an aluminum membrane surrounded by air to optimize the nanostructures design to get blue, green and red filtering (figure 1). To address several issues related to filtering (metal layer thickness w.r.t. color filtering, wavelength dependency, incident angle dependency, polarization behavior), we have studied double-breasted rectangular hole array. Patterns were then manufactured with ebeam lithography with similar approaches than Optical Proximity Correction procedure used in optical lithography in order to manufacture such high resolution stamp (figure 2). Imprint and etching processes were then developed to manufactures 864 color filters (100x100 µm² each) on 200 mm wafer (figure 3).

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[1] Ebbesen TW., Lezec HJ., Ghaemi HF., Thio T., Wolff PA., Extraordinary optical transmission through sub-wavelength hole arrays, Nature 391, 667, 1998.
[2] Gétin S., Désières Y., Geoffroy Auvert M., Pellé C., Lartigue O., Poupinet P. and Frey L., Nanoplasmonic filters for image sensors, Proc. SPIE 7249, 724904, 2009.
[3] Xu T., Wu Y-K, Luo X., Guo LJ., Plasmonic nanoresonators for high resolution color filtering and spectral imaging, Nature Communicaiton 1, 59, 2010.

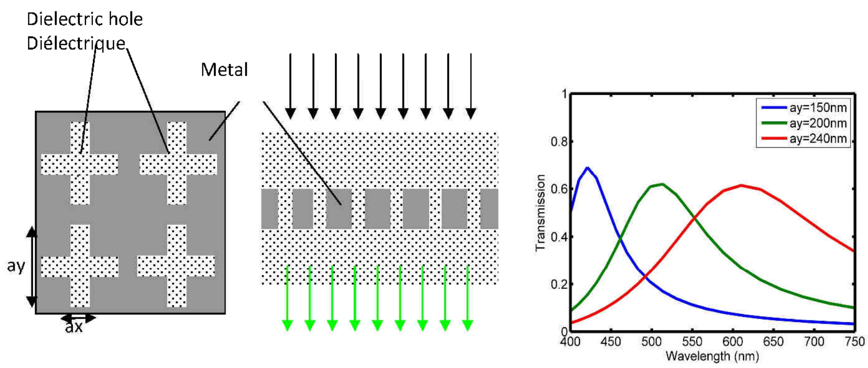

Figure 1: Diagram of symmetric cross holes array of in metal film (thickness h) and corresponding FDTD transmission spectra for normal incident plane wave for a 250nm period in aluminum (metal thickness is 40nm, ax = 60nm).

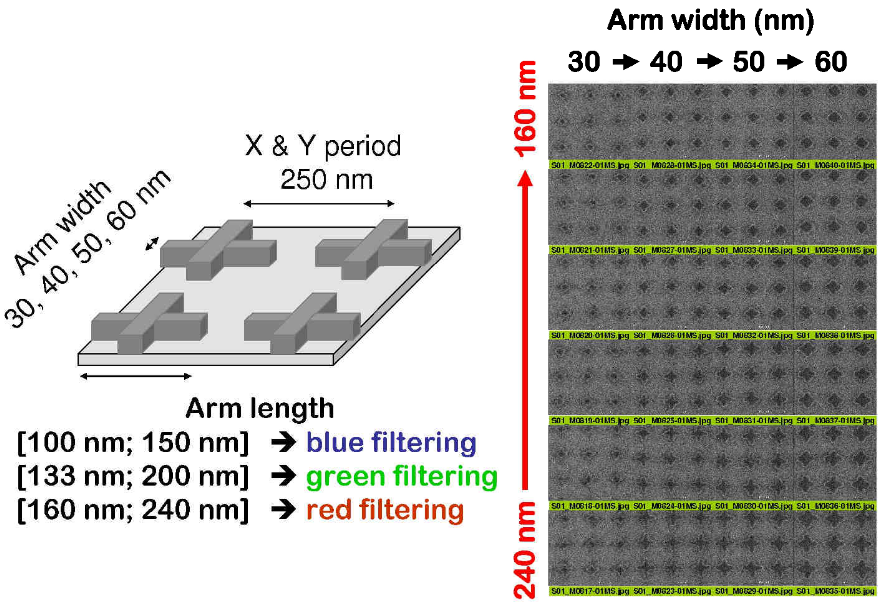

Figure 2: Pattern design for stamp manufacturing. SEM top view pictures of Si patterns for the 24 geometries variation for red color filtering function.

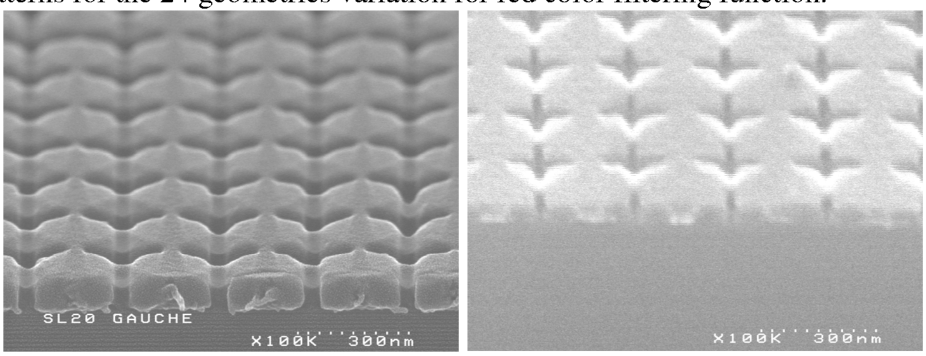

Figure 3: SEM cross section views of imprinted resist (left) with ultra low residual layer thickness and corresponding 40 nm thick Al etched layer (right).