Solar Energy Harvesting Photonic Color Filters

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Color filters are widely used in all color displays. The commonly used colorant can transmit certain colors while completely absorbing light of other wavelengths. The absorbed energy is inevitably wasted. If such energy can be utilized to generate electrical power instead, innovative energy-efficient electronic media can be envisioned. In this context, we introduce a new color filter concept that can harvest the absorbed light to generate electric power as a PV cell while preserving the color filtering function.

Our energy-generating photonic color filters are capable of filtering white light into individual colors across the entire visible band, and simultaneously scavenge the absorbed light to generate electrical power that are otherwise wasted. Especially, we focused on the reflectance type color filtering devices, which can work under bright ambient light; and even better under direct sun light. Recently, optical resonance effects in nanostructures such as nanoslits have been exploited for color filter application [1]. Our dual-function devices are based on photonic nanostructure with metallic nanogratings shown in Figure 1, which are fabricated by nanoimprint lithography (NIL)-based processes allowing large area format, as semi-transparent electrode, and organic photovoltaic (OPV) cell structure for power generation. Therefore, this approach also can take the unique advantages of OPV, such as low cost, easy fabrication, and compatibility with flexible substrates over a large area.

Since the reflective type color filters act similar to the color paint, i.e. absorbing some colors corresponding to specific wavelengths but reflecting the others, we focused on the CMY color scheme (cyan, magenta and yellow) in this work. The reflection spectra of designed CMY color filters showed expected color filtering behavior, and the experimentally measured spectra were well-matched with the simulation results (Figure 3). Furthermore, photovoltaic function was achieved for all three color filters that were characterized under AM 1.5 G simulated sun light (at 100 mW cm^{-2} intensity) as shown in Figure 2. This unique energy-generating property is expected not only to point a new direction toward energy-efficient electronic media, but also to suggest alternative application of OPVs.

[1] T. Xu, Y.-K. Wu, and X.-G. Luo and L. J. Guo, "Plasmonic nano-resonators for color filtering and spectral imaging," *Nat. Commun*. **1**, 59 (2010).

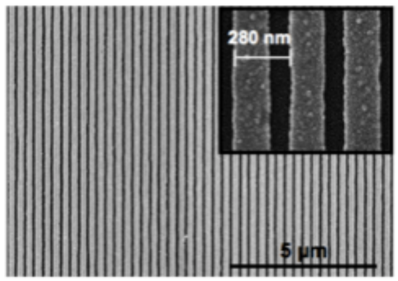


Figure 1: SEM image of metallic nanogratings for magenta colored dual-function device: 280 nm period and 200nm line width.

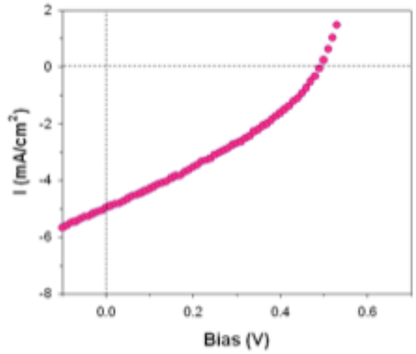
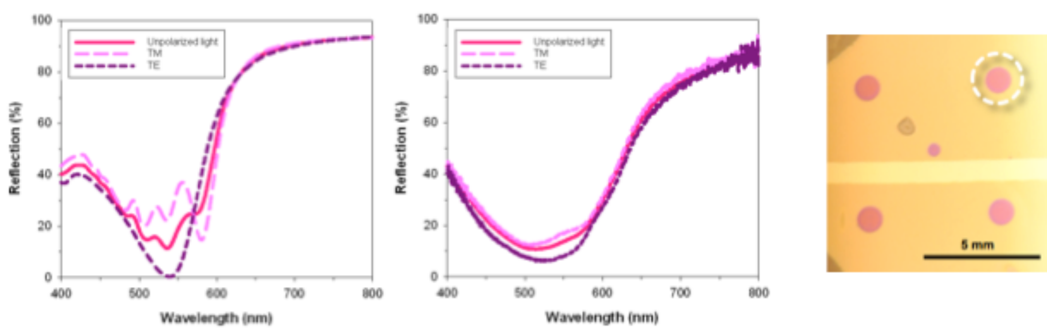


Figure 2: Photovoltaic property of magenta colored dual-function device: Current density versus bias voltage characteristics measured at AM 1.5 G with a light intensity of 100 mW cm^{-2}.



(a) (b) (c)

Figure 3: Color filtering behaviors of magenta colored dual-function device: The reflection spectrum for various polarization states calculated by rigorous coupled wave analysis (RCWA) simulation (a) and by experiment (b). (c) Photographs of dual-function devices having 1 mm diameter circular shape showing expected magenta color.