Plasmonic color filter based on metal-insulator-metal resonators

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Transmissive optical filters are widely utilized in applications such as LCD panels. However, conventional optical filters using pigment dispersion to produce RGB colors are manufactured by four separate processes, which not only complicate the manufacturing but also waste a lot of chemical materials in the process. Moreover, the transmissions of these components for RGB color are also relatively low (~30%) and therefore energy inefficient. Clearly there is a need for a new paradigm in color filter technology that can produce optical filters in the visible range with higher transmission efficiency and reduce the manufacturing complexity.

In recent years, metal-insulator-metal (MIM) resonators are of considerable interest for nanophotonics applications due to their capacity of subwavelength spatial mode confinement. In this work, a modified MIM resonator structure is proposed to realize the color filtering function. Figure 1(a) shows the schematic of the proposed structure, which consists of a periodic aluminum/ zinc selenide/ aluminum (Al/ZnSe/Al) stack array on a transparent film. The subwavelength periodic structure can efficiently couple the incident light into specific plasmon modes of the MIM stack and then scatter them to the far field. By tuning the stack period and the dielectric layer thickness, we can control the transmission peak to cover the visible wavelength range. Figure 1(b) shows the transmission spectra of color filters for blue, green and red colors designed by using the Finite Difference Time Domain (FDTD) method.

To prove the design principle, we fabricated the color filters using focus ion beam (FIB) lithography. First, an Al/ZnSe/Al/MgF_2 multilayer stack was sequentially deposited using e-beam evaporation. The subwavelength periodic patterns were fabricated by FIB under 30kV accelerating voltage and a beam current of 50 pA. Figure 2(a) is the optical image of 10 μm size color pixels fabricated using this method that show five distinctive colors. Figure 2(b) is the measured spectrum of the green color filter, showing a peak transmission of ~60% at 535nm. The spectrum matches well with the simulation result. Importantly, our structure achieved several orders of magnitude higher transmission than the previously reported.[1]

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[1] Diest, K., Dionne, J.A., Spain, M., Atwater, H.A. *Nano Lett.* **9**, 2579-2583 (2009).

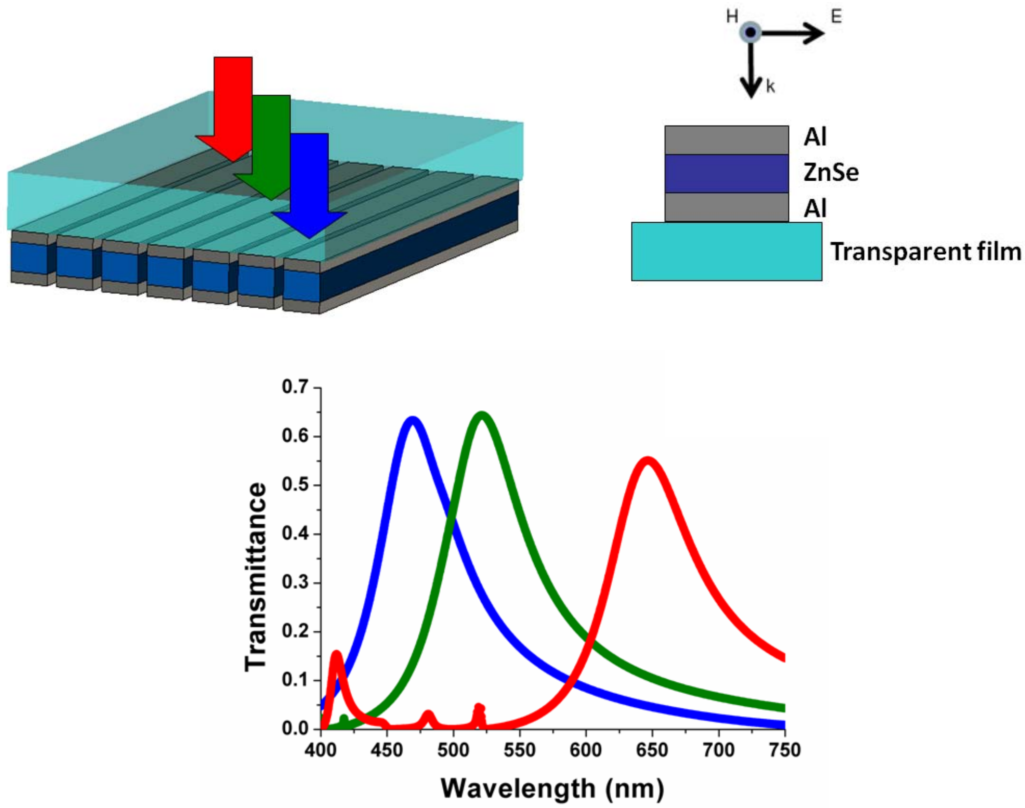

Fig. 1. (a) Schematic of the proposed color filter structure based on metal-insulator-metal stack. (b) Simulated TM transmittance for the MIM stack with different structural parameters to produce blue, green and red spectra.

Fig. 2 (a) Photograph image of fabricated color filter pixels with five distinct colors (Scale bar 10μm). (b) Measured TM spectrum of the green filter. Insets show the micrograph image of the green color filter and the cross-section SEM of the patterned MIM stack (scale bar 100nm).