MEMS Cantilever Controlled Plasmonic Colors for Sustainable Optical Displays

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Abstract: We show a cost-effective, CMOS compatible, fast, and full range electrically controlled RGB color display by combining transmission based plasmonic metasurfaces with MEMS (Microelectromechanical systems) technology, using only two common materials: Aluminum and silicon oxide.

The optical display industry is facing serious concerns about long-term sustainability, due to the difficulty of recycling display units because of the large of variety of materials contained within [1]. Here we combine plasmonic metasurfaces and MEMS technology to generate transmission type dynamic structural colors using only two common and easily recyclable materials: Aluminum and silicon oxide (glass) [2]. The colors are generated by optical transmission based plasmonic metasurfaces consisting of aluminum nanohole arrays, and the relative transmission/brightness of each color subpixel is modulated by a MEMS cantilever made of aluminum and silicon oxide fabricated on top of the metasurface. By using the nanohole array itself as the actuation electrode for the cantilever, application of a bias between the two then causes electrostatic forces to pull the cantilever down and close off light transmission through the plasmonic array, see Fig. 1.a. By modulating the actuation voltage, we show how it is directly possible to modulate the overall brightness of each pixel by changing its average transmission in time via fast modulation, changing the relative transmission of a color subpixel freely from 35% to 100%. Our method allows for fabrication of large cantilever arrays with high packing density (see Fig. 1.b), and we demonstrate the generation of a full range RGB color subpixels based on three different aluminum nanohole array, Fig. 1.c and d.

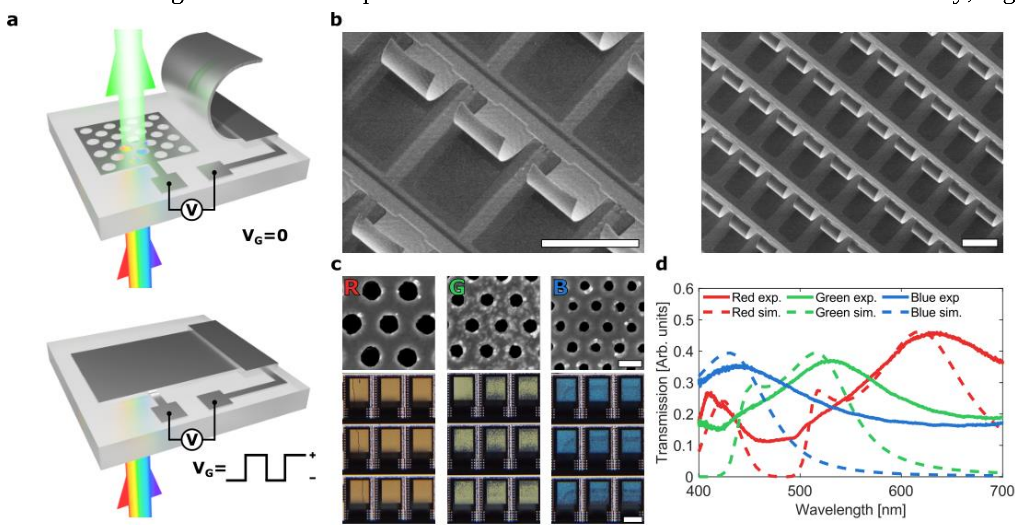

Fig. 1 **a)** Schematic of the device. A plasmonic nanohole array filters white continuum light into one color upon transmission. The array's transmission can then be modulated via a mechanical cantilever which blocks off the array when a voltage is applied between the cantilever and the nanohole array. **b)** SEM image of the fabricated cantilevers and the nanohole array. Scale bar is 50 µm. **c)** Top: SEM images of the generated nanohole arrays for the red (R), green (G), and blue (B) color pixel elements. Bottom: White light transmission microscope images for each of the color pixel elements. Scale bars for SEM images are 250 nm, and for microscope images 30 µm. **d)** Experimental (solid lines)- and FDTD simulated (dashed lines) transmission spectra of the nanohole arrays.

Our method allows for fast pixel switching speeds in the excess of 800 Hz, and by using the metasurfaces themselves as the actuation electrodes, it is possible to individually address and modulate specific color subpixels - an essential feature for making a plasmonic RGB display [3] and eliminates the need for transparent electrodes made of ITO – a material facing serious sustainability challenges in the immediate future. Furthermore, as the entire process is based on lithography and the materials used are cost-effective and CMOS compatible, it is also expected that our approach could enable significant fabrication cost reductions for mass manufacturing of optical displays.

References

[1] V. Bhakar, A. Agur, A.K. Digalwar, and Kuldip Singh Sangwan, "*Life cycle assessment of CRT, LCD and LED monitors*" Procedia CIRP, **29**:432–437, 2015

[2] Z. Han, C. Frydendahl, N. Mazurski, and U. Levy, "*MEMS cantilever-controlled plasmonic colors for sustainable optical displays*," Science Advances 8(16),eabn0889, 2022.

[3] S. D. Rezaei, et al., "*Nanophotonic structural colors*" ACS Photonics, **8**.1–18-33, 2020.