Photopatterning of Molecular Orientations for Fabrication of Liquid Crystal Flat Optical Devices

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Recently we developed a technique to photo-pattern molecular orientations in a fashion similar to photolithography, by using engineered plasmonic metasurfaces, denoted as plasmonic metamasks (PMMs)[1, 2]. This technique makes it straightforward to pattern arbitrary designer molecular orientations with high spatial resolution in single exposure, and has enabled a number of new applications, including flat optical devices[3], commanding active matter[4] and programmable stimuli-responsive surface morphing[5]. One critical issue of the prior PMM design is that its optical efficiency is quite low in the UV (<10%) and near UV regions (<50%).

Here we present a new design of PMMs that yield very high and broad-band transmission in the UV-visible wavelength range, (>85% at i-line and 95% in the visible). The new PMMs are made of rectangular parallelepipeds posited in a triangular lattice with spatially variant orientations. Experimental and numerical studies are performed to elucidate the physical mechanisms behind the high optical transmissions and the capability to yield designer polarization patterns. Dose test experiments show that such PMMs can significantly reduce the exposure time for the photopatterning. As an example, we will present the application of this photopatterning technique in fabricating liquid crystal optical devices with engineered Pancharatnam-Berry phase profiles that can shape Gaussian laser beams into flattop beams with diffraction-limited performances. These flat liquid crystal optical devices exhibit ~100% efficiency and non-zero order leakage, an outstanding feature critical for practical applications.

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[2] Guo Y, Jiang M, Peng C, Sun K, Yaroshchuk O, Lavrentovich OD, and Wei QH. Designs of Plasmonic Metamasks for Photopatterning Molecular Orientations in Liquid Crystals. *Crystals* 7: 8, 2017.
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[4] Peng C, Turiv T, Guo Y, Wei, QH and Lavrentovich OD. Command of active matter by topological defects and patterns. *Science* 354: 882-885, 2016.
[5] Babakhanova G, Turiv T, Guo Y, Hendrikx M, Wei QH, Schenning APHJ, Broer DJ, and Lavrentovich OD. Liquid crystal elastomer coatings with programmed response of surface profile. *Nat Commun* 9: 456, 2018.

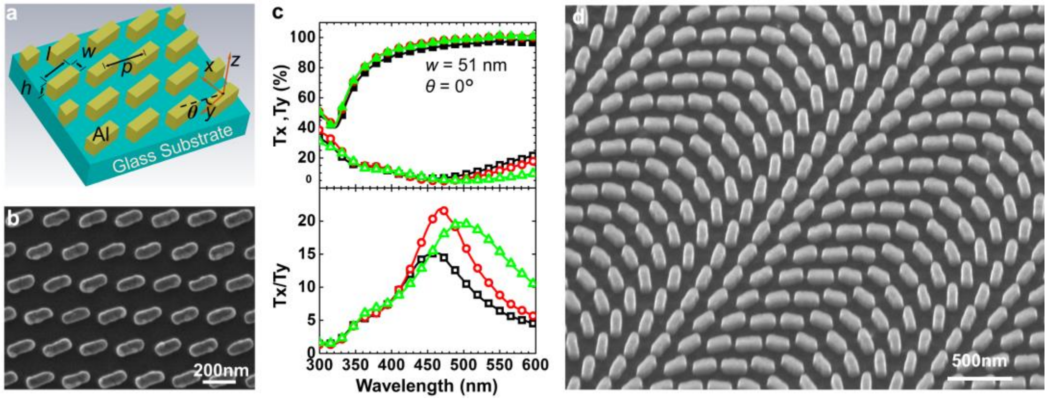

Figure 1 (a), (b) Schematic and representative SEM image of the new PMM made of rectangular parallelepipeds. (c) Representative measured optical transmittance (top) and polarization contrast (bottom) for l = 156 nm (black square), 166 nm (red circle), 175 nm (green triangle), w = 51 nm, and θ = 0. (d) Representative SEM image of a PMM with spatially variant orientations (i.e. polarization directions).

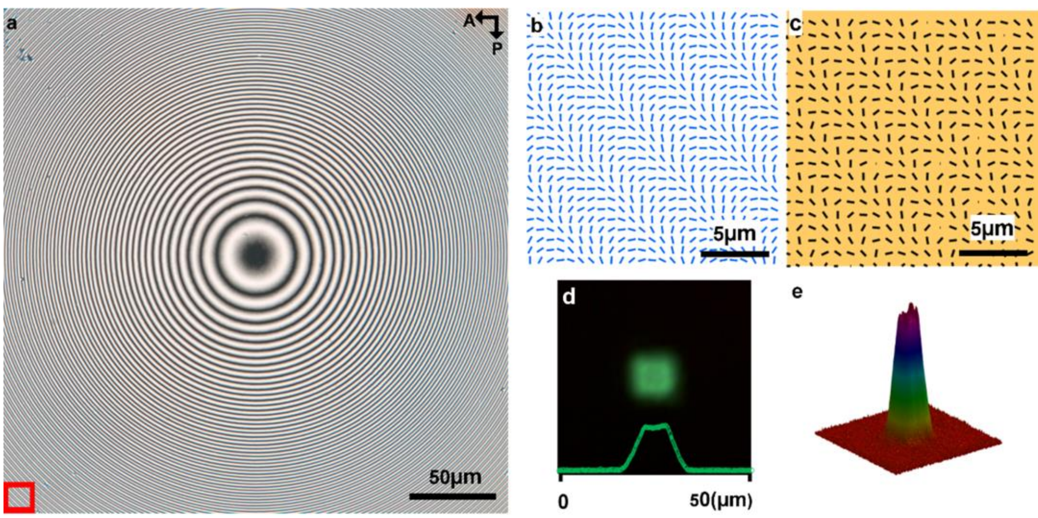

Figure 2 Fabrication of a liquid crystal flat optical device for shaping a Gaussian laser beam into square flattop beam with 10μm size. a) Polarizing optical microscopic image of the fabricated liquid crystal device. b, c) Designed b) and measured c) molecular orientations of the red area in a). d) Microscopic image of the laser beam at the device focal plane. e) 3D view of the laser intensity profile in d). The labels A and P in (a) indicate the directions of the polarizer and analyzer in the optical microscope.