Novel Plasmonic Metamasks for Photopatterning Molecular Orientations in Liquid Crystals

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Emerging applications of liquid crystal (LC) materials such as Pancharatnam lens, programmable origami and directed colloidal assembly rely on well designed and spatially non-uniform molecular orientations. To align LC molecules in these desired complex orientation patterns, a few techniques have recently been developed, including rubbing polymer films using AFM tips[1] and pixel-by-pixel direct writing[2]. These techniques are based on serial patterning processes and thus are suitable for fast device prototyping, but face limitations in scaling up manufacturing.

Here, we present a new photopatterning technique for aligning LC molecules in arbitrarily complex orientation patterns by using carefully engineered plasmonic metamasks (PMMs). The PMMs are made of two dimensional rectangular nano-holes in thin Aluminum films, and when illuminated by non-polarized white light, generate spatially non-uniform polarization patterns. By projecting these polarization patterns onto the photoalignment materials coated inside LC cells, the orientation patterns encoded in the nanohole orientation are transferred into the photoalignment layer and then imposed in the bulk liquid crystals. Fig. 1 presents a representative PMM for arrays of +1/-1 topological defects, and its measured polarization directions, and optical microscopic images of the patterned liquid crystals and the measured molecular director field. We demonstrate that arbitrarily LC molecular orientations such as combinations of topological defects (Figure 2) can be patterned with high resolution and high throughput.[3] This technique makes the patterning of LC molecular orientations a repeatable and scalable process for large scale manufacturing.

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[1] B. S. Murray, R. A. Pelcovits, C. Rosenblatt, Phys. Rev. E 90, 52501 (2014)
[2] M. E. McConney, A. Martinez, V. P. Tondiglia, K. M. Lee, D. Langley, I. I. Smalyukh, T. J. White, Adv Mater. 25, 5880 (2013); and C. Culbreath, N. Glazar, H. Yokoyama, Rev. Sci. Instr. 82, 126107 (2011).
[3] Y. Guo., M. Jiang, C. Peng, K. Sun, O. Yaroshchuk, O. Lavrentovich, and Q.-H. Wei, Adv. Mater. (2016) doi:10.1002/adma.201506002

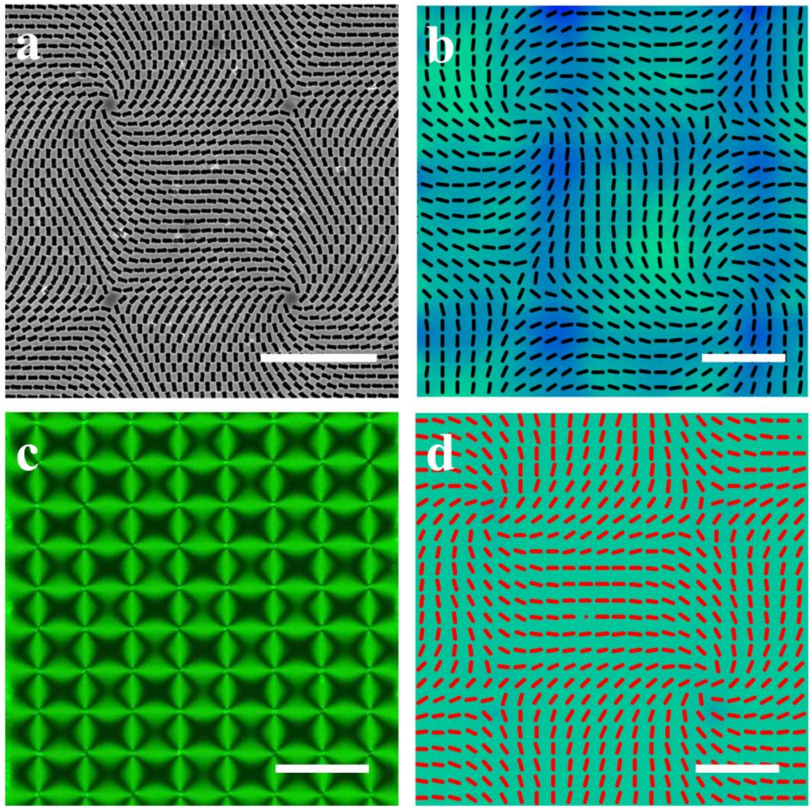

Figure 1 Plasmonic photopatterning of +1/-1 defect arrays. a) SEM image of the PMM. b) Measured polarization pattern of the PMM. c) Cross-polarized microscope image of a LC cell patterned with the PMM. d) Measured molecular orientation. The scale bars in a-d are 3µm, 2µm, 25µm, and 10µm, respectively.

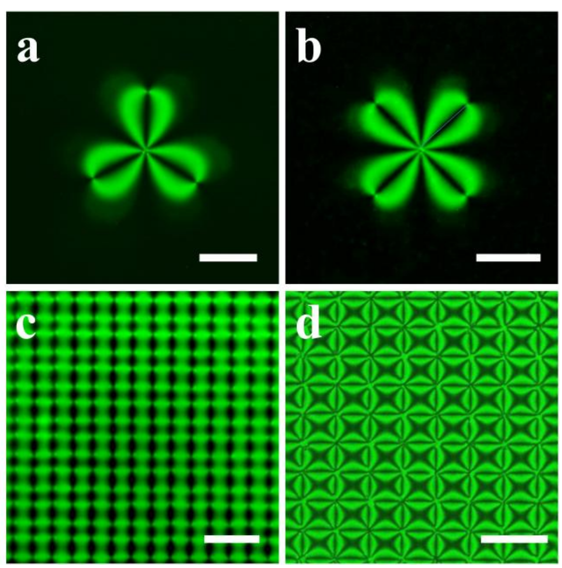

Figure 2 Examples of patterned combinations of topological defects. Cross-polarized optical microscopic images of a) cluster of 4 defects, b) cluster of 5 defects, c) 2D arrays of +0.5/-0.5 defects, d) 2D arrays of +2/-2 defects. The scale bars in a-d are 50µm, 50µm, 15µm, and 50µm, respectively.