Scientists demonstrate electrically tunable microlens array using simple PSCOF approach

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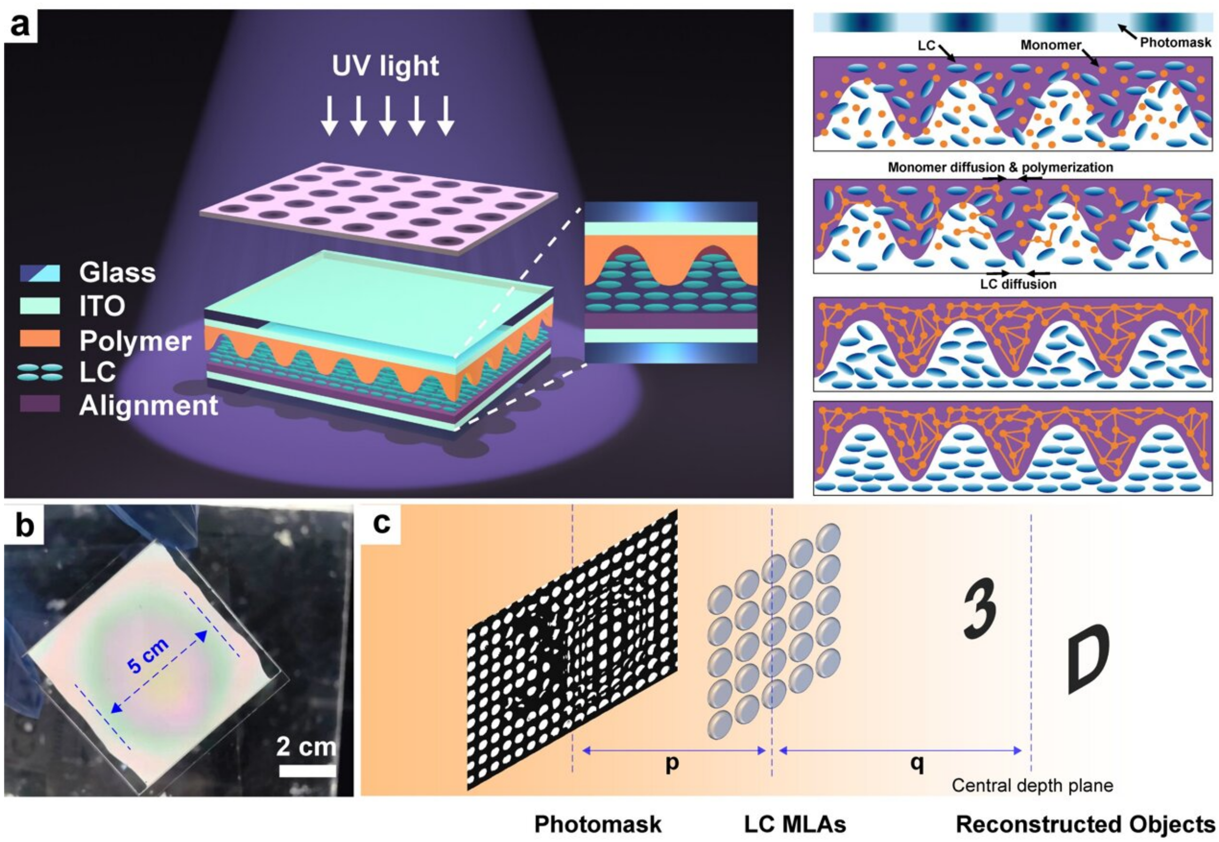

a) Schematic of the UV exposure and phase separation processes. Above is a grayscale mask with a microlens array pattern. The bottom is a liquid crystal cell with a composite structure of a polymer layer and a liquid crystal layer with microlens array morphology. When a cell filled with the mixture of LC and prepolymer is exposed to a normally incident, collimated UV laser beam, an intensity gradient of the UV beam will be created inside the cell due to the strong absorption of UV light. By adding a designed photomask, an additional intensity gradient in the *x*-*y* plane of the cell will be then created as well. The monomers in the high-intensity regions will first undergo polymerization. The monomers and the LCs in the low-intensity regions will diffuse toward the high-intensity regions to maintain their relative concentration. With deliberate exposure conditions, long enough UV exposure eventually consumes all the monomers and causes LCs to move out of the polymerized volume. Meanwhile, the LC molecules will be also orientated by the alignment layer. As a result, the phase separation is anisotropic in three-dimensional space inside the cell. b) The photograph of a typical sample with an area of 5 cm ´ 5 cm under crossed polarizers. c) Schematic diagram of 3D image reproduction. A white light source illuminating the photomask serves as the display panel. The LC-MLAs were placed in front of the photomask. The objects "3" and "D" are reconstructed near the central depth plane. The central depth plane can be tuned by the LC-MLAs. Credit: Wenfeng Cai, Delai Kong, Zongjun Ma, Mengjia Cen, Jiawei Wang, Dandan Yuan, Ke Li, Ming Cheng, Shaolin Xu, Dan Luo, Yan-Qing Lu, and Yan Jun Liu

Microlens arrays are one of the key elements that are promising in autostereoscopic display, optical communication, wavefront sensing, integral imaging, etc. For example, microlens arrays are the critical components in integral imaging, which are used to collect and display images. In most cases, the image depth in integral imaging is limited due to the fixed focal length of the used microlens arrays.

Liquid crystal (LC) with electrically, optically, or acoustically tunable refraction has been exploited extensively for tunable microlens arrays. Thanks to the tunability of the microlens arrays, the image depth can be explored. However, the design and preparation of the liquid crystal microlens arrays (LC-MLAs) usually involve multiple fabrication processes, increasing fabrication complexity and cost.

In a new paper published in *Light: Advanced Manufacturing*, a team of scientists, led by Professor Yan Jun Liu from the Department of Electrical and Electronic Engineering, Southern University of Science and Technology, Shenzhen, China cooperates with Professor Yan-Qing Lu from the College of Engineering and Applied Sciences, Nanjing University, Nanjing, China, and co-workers have proposed a simple method to prepare large-area LC-MLAs with only a single-step exposure.

The LC-MLAs are formed via photopolymerization-induced phase separation (PIPS) inside a polymer/LC composite, which yields adjacent layers of LC and polymer known as phase-separated composite films (PSCOFs). The morphology of the composite film can be controlled by a grayscale photomask.

The LC-MLAs demonstrate a high focusing and imaging quality with polarization-dependent, electrically tunable focusing properties. Without applied voltage, the microlens has a natural focal length of 8 mm as a result of its inherent gradient index profile. As the applied voltage exceeds a threshold, the LC reorientation occurs and the focal length of the microlens gradually increases. The researchers demonstrate the realization of image acquisition and electrically tunable central depth plane in 3D displays with the prepared microlens array.

Such a fabricating technology is fundamentally different from the reported ones, such as inkjet printing, compression molding, thermal reflow of photoresist, and three-dimensional printing, which features a facile, single-step, low-cost, and high-throughput production.

In addition, with a purposely designed photomask, the technique can be used as a general platform to fabricate liquid crystal micro-optical devices with other functions, such as liquid crystal lenticular microlens arrays, liquid crystal blazed gratings, etc.

More information: Wenfeng Cai et al, Optically anisotropic, electrically tunable microlens arrays formed via single-step photopolymerization-induced phase separation in polymer/liquid-crystal composite materials, *Light: Advanced Manufacturing* (2023). DOI: 10.37188/lam.2023.028

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