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Opinion

Liquid Crystals for On-Chip Optoelectronics: An Opportunity

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Opinion

Optoelectronic technology is one of the most important scientific and technological pillars in the development of modern society. Thus, it is crucial to devote efforts to revolutionizing related technologies and developing high-performance optoelectronic elements, especially on-chip functional devices. In today's double-carbon strategy, we should take the chance to chart the course from the source, i.e., to develop green, intelligent, and high-efficiency optoelectronic materials that lie in the heart of optoelectronics. Liquid Crystals (LCs) [1], as a kind of magic optoelectronic material, have remained an unfailing paradigm for display industries, with the annual value of production reaching hundreds of billions of dollars. Whether LCs can provide unique opportunities for high-performance on-chip devices is a question but seems to have had an answer. It is also significantly important for the further development of LCs beyond displays. LC is a kind of mysterious "fourth state" of matter following solid, liquid, and gas. It exhibits abundant interesting phases and widely exists in living organisms and synthetic composites. Usually, LCs are composed of a series of rod-like molecules with rigid groups and flexible chains. These molecules can self-assemble into specific arrangements under certain anchoring conditions with distinct orientational orders. The shape anisotropy of LC molecules combined with the orientational order imparts the anisotropic feature to several physical properties, including elastic, viscous, dielectric and optical anisotropies. The other fascinating feature is that LCs can respond to various external stimuli to adapt to the environment, which makes them very promising for intelligent on-chip applications.

Recently, noncontact photoalignment techniques have been newly developed as an encouraging method in high-quality LC alignments. Usually, photoalignment relies on photo responsive agents that can respond to polarized light by reorienting their axes perpendicular to the polarization. It exhibits clear superiority to fabricate complex multidomain alignment patterns for LCs and eliminates dust contamination, mechanical damage, and electrostatic charge. Thus, it has attracted extensive attention from researchers worldwide [2-4]. By combining a digital micromirror device-based photopatterning system, we can easily manipulate the in-plane director field of nematic LCs for structured light generation [5-7] and create specifically photopatterned helical superstructures for high-quality diffraction elements [8-11], programmable self-propelling actuators [12], particle manipulators [13] and planar optical elements [14,15]. In addition, three-dimensional smectic layer origami has been achieved through preprogramming the underlying two-dimensional alignment [16,17], which demonstrates complete control of topological defects in smectic LCs, including the size, shape and orientation of focal conic domains, as well as lattice symmetry [16]. Thus, self-assembled asymmetric micro lenses have been proposed for four-dimensional visual imaging [18]. The "top-down" photopatterning process combined with the "bottom-up" self-assembly ability pushes the hierarchical architecture control of LCs to an unprecedented level. Furthermore, laser direct writing, 3D printing, soft lithography, and geometric confinement continuously spring up, speeding the advancement of LC applications beyond displays. With the rise of these new technologies, LCs are encouraging for applications in next-generation on-chip optoelectronics.

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