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Multi-stable patterned devices enabled by soft-matter liquid crystal photonic structures

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Abstract

Patterned photonic crystals that exhibit structural colours attract considerable attention owing to their exceptional color saturation and variability. A unique paintable helical photonic architecture featuring both multi-stability and dynamic light-actuation is proposed. The method shows great potential for applications in anti-counterfeiting, information encryption, and smart windows.

Keywords: Photonic crystals, Light-actuated paintable, Multi-stable

Photonic crystals, characterised by their unique periodic micro- or nano-architectures, can interact with light to form photonic bandgaps, which prohibit the transmission of light in specific wavelength ranges[1]. When the photonic bandgap falls within the visible spectrum, photonic crystals display iridescent structural colours that are environmentally friendly[2]. For patterning applications using photonic crystals, the saturation and variability of colours are crucial metrics to evaluate the performance of photonic crystal materials[3]. In recent studies, the dynamic changes in the structural colours of photonic crystals have attracted considerable attention, with the research focus on the stability and durability of the architectures[4].

Among the photonic crystal materials proposed to achieve colour changes, liquid crystals (LCs), a class of soft-matter photonic materials, offer distinct advantages[5]. Cholesteric liquid crystals (CLCs), which rely on the helical arrangement of LC molecules, enable wavelength-selective Bragg reflection and, exhibit vivid reflective colours and favourable polarisation-selective properties[6,7]. Current research efforts to achieve colour changes in LCs have extensively explored the modulation of cholesteric pitch through various external stimuli, including applied electric fields[8,9], temperature[10,11], light irradiation[12,13], and mechanical deformation[14–16].

In previous studies, the spatial patterning of polymer-stabilised LCs (PSLCs) was facilitated by inkjet printing and photo polymerisation. This approach significantly enhances the design flexibility of liquid crystal optical devices, thereby facilitating the on-demand fabrication of LC patterns with diverse colours, shapes, and functionalities[17–19]. Consequently, it achieves high-resolution-customisable optical effects and offers a novel fabrication strategy for high-performance liquid crystal optical devices. However, the existing functional optical devices based on CLCs require rigid glass encapsulation to maintain surface anchoring and prevent distortions caused by material fluidity, which fundamentally limits their potential for flexible photonic applications. In a recently published paper, Hu proposed a paintable soft photonic architecture using a coating techniquethat enables the fabrication of programmable patterns on various substrates[20]. The fundamental principles are illustrated in Fig. 1. A photonic architecture with a photo-programmable multi-stable status was constructed by painting it on a flexible substrate. The intrinsic chiral photo-switch induces a broad range of structural colour variations due to helical

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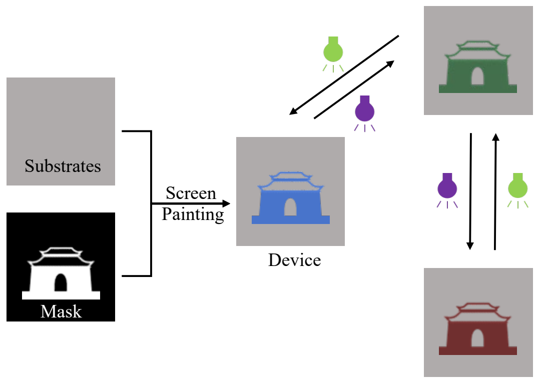

Fig. 1 Schematics of the proposed paintable soft photonic architecture. Photonic architecture with photo programmable multi-stable status constructed by painting on flexible substrate. Here, the intrinsic chiral photo-switch induces a broad range of structural colour variations due to helical pitch expansion. Measured images reproduced from Ref. 20.

pitch expansion. A unique intrinsic chiral photo-switch with excellent thermo-stability was introduced into the LC to enable remarkable manipulation of the helical pitch, thereby allowing precise multi-stable modulation across a wide spectral bandwidth spanning the entire visible to near-infrared regions upon light stimulation.

Using this method, several studies on material applications such as anti-counterfeiting, information encryption, and smart windows have been conducted. This method demonstrates excellent performance in achieving precise paintability with the advantages of avoiding multicenter chirality, significant helical pitch modulation, and robust thermal stability[21]. With long-term switching cycles, light-actuated paintable LC photonic devices enable controlling viscosity and resolution, sustaining well-ordered photonic structures, and achieving a robust multi-stable photo-response.

Future research on soft matter photonic crystals may further focus on enhancing the stability, colour richness, and response sensitivity. These novel materials, characterised by their non-toxicity, compact size, and flexible structures, demonstrate significant application potential in areas such as flexible textiles and wearable displays[22,23].

Data availability

All data are available from the corresponding authors upon reasonable request.

Conflict of interest

The authors declare no competing interests.

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