Crystallography of liquid crystalline cholesteric blue phases for electro-optic applications

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Abstract

Nematic liquid crystals that change their refractive index in response to electric fields are commercialized in displays, but research is ongoing for better materials to improve their relatively slow response of several milliseconds. Cholesteric blue phases in which rod-like molecules self-organize into three-dimensional periodic structures show a fast electro-optic response in the sub-millisecond range, and are viewed as next-generation materials. However, there are challenges for their commercialization such as high driving voltage, hysteresis, and anisotropy in the electro-optic effect due to their crystalline structure. To better understand and control blue phases, we characterized of the structure and stability of crystal twins in blue phase devices. We also proposed a field-assisted method of achieving monodomain alignment over large areas.

Background & Results

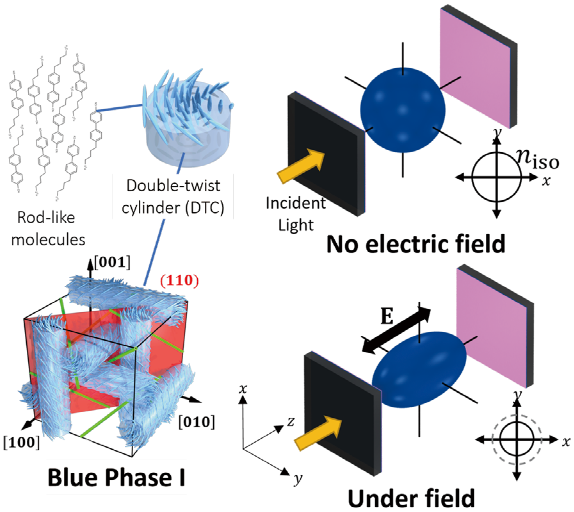
In nematic liquid crystals used in displays, the rod-like molecules are aligned uniaxially over large areas, and the refractive index is switched by an electric filed to tune the light intensity. In blue phases, the molecules form a three-dimensional periodic structure on the order of few 100 nanometers, leading to the molecules being switched inside tiny volumes, thereby responding quickly. However, blue phases face challenges for commercialization, such as high driving voltage, hysteresis and alignment control. The fact that they show crystal structure makes the electro-optic response anisotropic, complicating their electro-optic behavior.

Our group has focused on crystallographic methods to understand and control blue phases. In recent work, we analyzed the crystal twin that forms when the blue phase electro-optic cell is fabricated. We found that the twin plane is the (112) plane of blue phase I subphase, and that twinning can occur both in the lateral and perpendicular directions of a thin, slab-type device, with lifetimes of more than several days. Because the directions of the optic axes differ in the twinned crystals, we concluded that it should become important to prevent the occurrence of twins for high-performance devices.

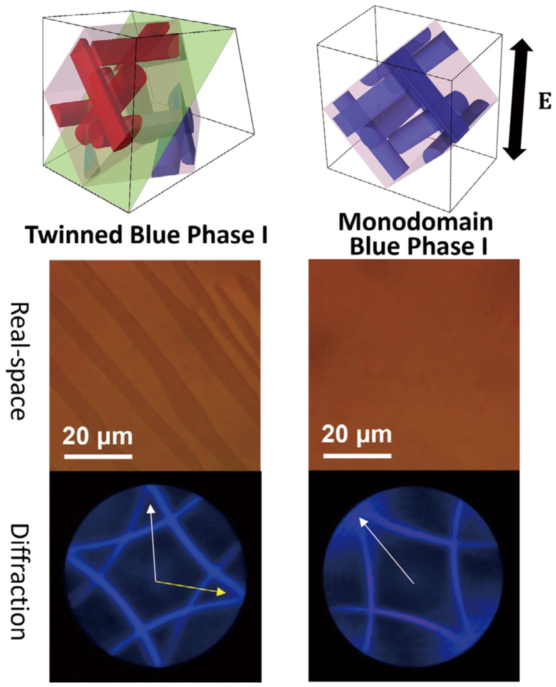
To achieve high-quality alignment of blue phases in devices, we proposed a field-assisted method of alignment control. By exploiting the field-induced phase transition of blue phases, we found it is possible to achieve monodomain alignment over large areas.

Significance of the research and Future perspective

Our findings on twinned blue phases will provide a physical basis on which to understand the performance of blue phase-based electro-optic devices. The field-assisted alignment control technology is easy to implement and will be useful in fabricating high-quality blue phase devices. Application of liquid crystals range from displays and spatial light modulators in telecommunications and laser processing, to next-generation devices such as LIDARs and tunable lenses; the commercialization of blue phases will thus lead to better devices used in various scenes of everyday life.



Electro-optic effect of Blue Phase



Patent

Treatise

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URL

Keyword liquid crystals, cholesteric blue phase, crystallography, electro-optic materials