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HTML ABSTRACT + LINKS

Direction-tunable cholesteric phase gratings

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In suitable conditions, the homeotropic aligned cholesteric liquid crystal (ChLC) cell can be in fingerprint texture when abruptly switching off the applied electric field. The stripe orientation depends not only on the thickness-to-pitch (d/P_0) ratio, but also on the applied driving voltage. In this paper, the ChLC phase grating with the field-controllable grating orientation is realized and the operational mechanism of this device is presented. © *2004 American Institute of Physics*.
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In cholesteric liquid crystals (ChLCs), the liquid crystal molecules rotate in space about their helical axis. This periodic helical structure leads to very specific optical properties which are determined by the pitch and the arrangement of the helical axis of ChLCs. When the helical axis is perpendicular to the glass surfaces, the Bragg reflecting planar (P) texture is obtained. When, on the other hand, the helical axis is parallel to the glass surfaces, the diffractive fingerprint (F) texture is obtained.

Under the application of an electric field, if the field is higher than a critical value and the material has a positive dielectric anisotropy, the helical structure is unwound to a homeotropic (H) texture. The threshold voltage is denoted as V_{fh}. If the applied voltage is decreased below another threshold voltage V_{hf}, the ChLCs relax to the F texture. $V_{fh}>V_{hf}$ and their difference is called hysteresis.[1]

In recent years, the planar aligned F-type ChLC phase gratings confined between two parallel substrates have been extensively studied, both theoretically and experimentally.[2–9] The F texture can be obtained by applying an electric field parallel to the helical axis of a planar aligned ChLC cell. As the F texture is formed, the period is tuned by changing the applied electric field.[3] However, the F texture is not stable when the applied electric field is removed.[5] On the other hand, our previous experimental evidence has shown that the planar aligned ChLC cell has no more than two possible directions of stripes in the F texture.[9,10] The direction of stripes is determined by the rubbing direction and (d/P_0) ratio. In this study, the direction-switchable ChLC phase grating is realized by applying a suitable driving wave form to the homeotropic aligned ChLC cell with patterned electrode configurations.

Cell preparation and pattern formation. The cholesteric material is obtained by doping the nemetic E7 with the chiral agent S811 (both purchased from Merck Co.). The chiral mixture is sandwiched between two glass with patterned $1\ \mathrm{cm}\times 1\ \mathrm{cm}$ square indium tin oxide (ITO) electrodes, as shown in Fig. 4(a). The glass with patterned ITO electrodes is coated with the polyimide (JALS-2021) for the homeotropic alignment layer and is rubbed unidirectionally to provide an inplane "easy axis" of molecular orientation. The spacers are spread to maintain the cell gap which is measured to be $d=6\pm 0.1\ \mu\mathrm{m}$ by an interferometer. The cell is assembled such that the rubbing directions are antiparallel. In this work, we fabricated the two typical homeotropic aligned ChLC films with the same cell gap but different weight concentration of the chiral additive. The d/P_0 ratios are 2.05 and 1.83 for cell 1 and cell 2, respectively.

The pattern formation of a ChLC cell was observed under the polarized microscope. The H texture can be obtained by applying an ac voltage (1 KHz) to the cell. The unwinding voltage for cell 1 and cell 2 are 3.42 V_{rms} and 2.2 V_{rms}, respectively. This consists with that the threshold voltage V_{fh} increases with the d/P_0 value.[9] In this situation, the ChLC molecules inside the square electrodes are in a H texture, while the ChLC molecules in the fringe region (outside the square electrodes) are not fully unwound because of the weak fringe field. Hence, the F texture with the stretched pitch is formed in the fringe region. When the fringe field is further increased, the ChLC molecules in the fringe region will be further unwound and the dark region observed under the cross polarized microscope expands. Once the voltage is switched off abruptly, the ChLC molecules inside the electrodes temporarily remain in the H texture due to the hysteresis of ChLCs. However, the partially unwound ChLC molecules in the fringe region first relax to the F texture and then induce the fast stripe formation form the edges to the center of electrodes.

We classify the stripe textures into two types, according to the stripe arrangement. One is the radiant type stripe (RTS) in which the stripe orientation radiates from the texture center, as shown in Figs. 1(a) and 4(a). The other is the concentric type stripe (CTS) in which the stripe orientation circles the texture center, as shown in Figs. 1(b) and 4(c). In this experiment, RTS and CTS are obtained for cell 1 and cell 2, respectively.

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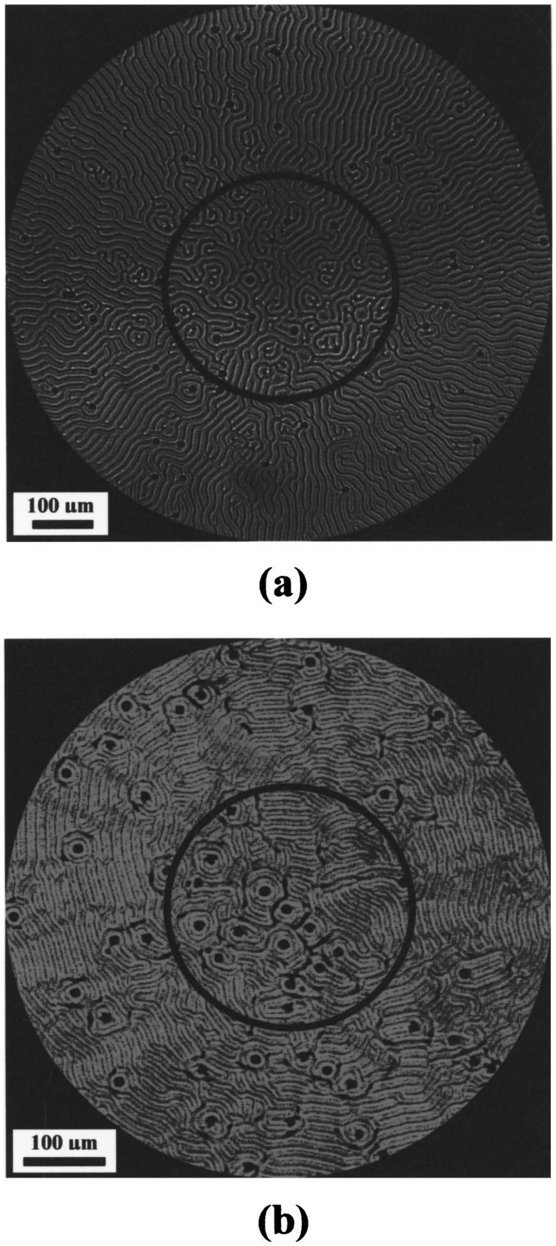

FIG. 1. Polarized microscope textures of stripes. (a) Radiant type stripe texture (d/P_0=2.05); (b) concentric type stripe texture (d/P_0=1.83). The circles in both figures indicate the texture centers.

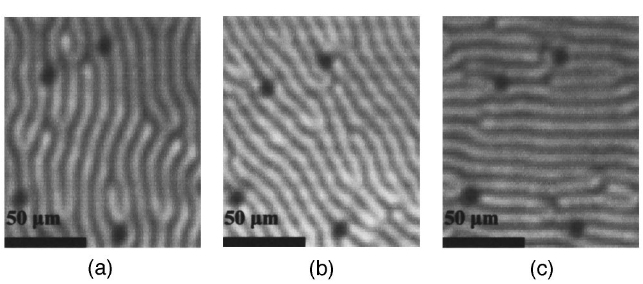

FIG. 2. Observed stripe directions at different applied voltage for cell 1. (a) 30 V_{rms}; (b) 13 V_{rms}; (c) 2.5 V_{rms}.

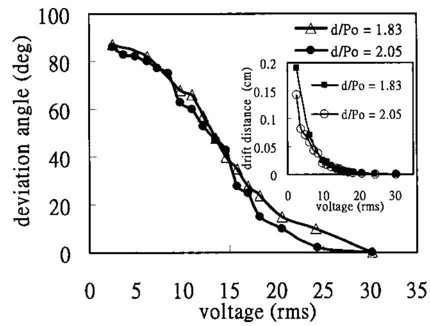

FIG. 3. The deviation angle vs applied voltage for cell 1 (d/P_0=2.05) and cell 2 (d/P_0=1.83). The insert shows the drift distance of the texture center as a function of the applied voltage.

Controllable stripe orientation. In this experiment, the stripe formation is observed by applying a voltage (which is larger than V_{fh}) for 10 s and then switching off. Here and below, we observe the stripe formation under the above conditions but only change the applied voltage. Figures 2(a)–2(c) illustrate how the applied voltage changes the stripe orientation for cell 1. The applied voltage are 30 V_{rms}, 13 V_{rms}, and 2.5 V_{rms}, respectively, and the angles between the rubbing direction and stripe direction are about 90°, 45°, and 0°, respectively. These stripes are stable for several months. The same results are obtained for cell 2. For convenience, we define the angle between the stripe orientation at one applied voltage and that at 30 V_{rms} as the deviation angle. Figure 3 shows the measured deviation angle as a function of the applied voltage. It is obvious that the deviation angle decreases with the applied voltage and is independent of the types of stripes (CTS or RTS).

Operational mechanism. The mechanism of the rotation of stripes results from the drift of the texture center. The insert of Fig. 3 shows the relationship between the drift distance of the texture center and the applied voltage. The drift distance is measured with respect to the location of the texture center at 30 V_{rms} and decreases with the applied voltage. Figures 4(a)–4(d) show the schematic diagrams of the rotation of stripes for cell 1 and cell 2, respectively, as the texture centers drift with the applied voltage. The reason for the drift of the texture center is caused by the surface rubbing direction. To confirm the above interpretation, we fabricated a cell

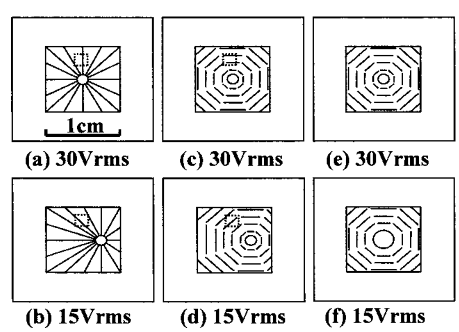

FIG. 4. Schematic diagrams of the rotation of stripes as the texture centers drift with applied voltage: (a) and (c) show the schematic diagrams of RTS and CTS, respectively; (b) and (d) show the drift of texture center for RTS and CTS, respectively; (e) and (f) show that the texture center of unrubbed cell is fixed with the applied voltage. The stripe direction observed in the dashed square rotates with the applied voltage.

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using the same conditions with cell 2 except that the alignment layer is unrubbed.

In an unrubbed cell, the mediating velocity of the fringe field induced *H-F* texture transition is the same for each side of square electrode. Therefore, the location of the texture center does not drift in the unrubbed cell while the size of the texture center decreases with the applied voltage, as shown in Figs. 4(e) and 4(f). When the cell is rubbed, the effect of the lateral field of the fringe field parallel to the rubbing direction on the mediating velocity of the *H-F* texture transition is different to that perpendicular to the rubbing direction. In other words, this rubbing direction destroys the symmetric mediating velocity of the *H-F* texture transition and results in the movement of the texture center. Because the mediating velocity of the *H-F* texture transition increases with the fringe field, we can make use of that to control the drift velocity of texture center along one direction which is caused by the rubbing direction.

In summary, we found two types of stripes in homeotropic aligned ChLC films with patterned electrode configurations. The stripe direction for each type of stripes can be electrically tuned. Moreover, the stripes in each direction are stable. This device provides a potential application in the electro-optical switching of the grating and the optical information processing.

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[1] Y.-M. Zhu, and D.-K. Yang, Phys. Rev. Lett. **82**, 4855 (1999).
[2] D. Subacius, P. J. Bos, and O. D. Lavrentovich, Appl. Phys. Lett. **71**, 1350 (1997).
[3] D. Subacius, S. V. Shiyanovskii, P. J. Bos, and O. D. Lavrentovich, Appl. Phys. Lett. **71**, 3323 (1997).
[4] C. M. Titus and P. J. Bos, Appl. Phys. Lett. **71**, 2239 (1997).
[5] S. N. Lee, L. C. Chien, and S. Sprunt, Appl. Phys. Lett. **72**, 885 (1998).
[6] C. V. Brown, E. E. Kriezis, and S. J. Elston, J. Appl. Phys. **91**, 3495 (2002).
[7] C.-H. Lin, Y.-G. Fuh, T.-S. Mo, and C.-Y. Huang, Jpn. J. Appl. Phys., Part 1 **41**, 7441 (2002).
[8] Y.-G. Fuh, C.-H. Lin, and C.-Y. Huang, Jpn. J. Appl. Phys., Part 1 **41**, 211 (2002).
[9] J.-J Wu, Y.-S. Wu, F.-C. Chen, and S.-H. Chen, Jpn. J. Appl. Phys., Part 1 **41**, L1318 (2002).
[10] J.-J Wu, F.-C. Chen, Y.-S. Wu, and S.-H. Chen, Jpn. J. Appl. Phys., Part 1 **41**, 6108 (2002).

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