A Novel Liquid Crystal Display Device for Memory Mode and Dynamic Mode

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Abstract
Most researches on monostable LCD and bistable LCD have separately been carried out. We introduce a novel liquid crystal display mode which can be operated as both memory mode and dynamic mode. The novel LCD mode has not only a long term memory time of memory mode but also a fast response time of dynamic mode. We describe switching characteristics of dual mode. Electro-optical characteristics of memory mode and dynamic mode are unique and show the possibility of device application.

1. Introduction

Liquid crystal display(LCD) mode can be classified into two groups. One is monostable LCD modes for mobile display, monitor, and TV applications such as VA mode [1], IPS mode [2], pi-cell [3], and OCB mode [4] which have wide viewing angle and fast response time enough to display motion picture. The other is bistable LCD mode such as BTN LCD [5], cholesteric LCD [6], zenithal bistable display [7], BiNem [8], and BCSN LC device [9-13] which have intrinsic memory characteristics suitable for electronic book and electronic paper. Most researches on monostable LCD and bistable LCD have been carried out separately.

In this paper, we introduce a novel liquid crystal display mode which can be operated as both memory mode and dynamic mode. The novel LCD mode has not only a long term memory time of memory mode but also a fast response time of dynamic mode. We describe switching characteristics of dual mode. Electro-optical characteristics of memory mode and dynamic mode are unique and show possibility of device application.

2. Operational principle of dual mode

A three-terminal electrode structure consisting of top electrode and bottom one with additional grid electrodes is used to drive each pixel of our proposed dual mode as shown in Fig. 1 [9-13]. Bottom electrode acts as the ground plane. SiO_2 layer was coated on the ground electrode for insulation. Both the width and gap of grid electrodes are 4 μm. Bottom and top substrates are coated with polyimide alignment layers. The rubbing direction of bottom substrate is perpendicular to the grid electrode direction. In order to make splay state of pixels, the rubbing direction of the top substrate is parallel with bottom rubbing direction.

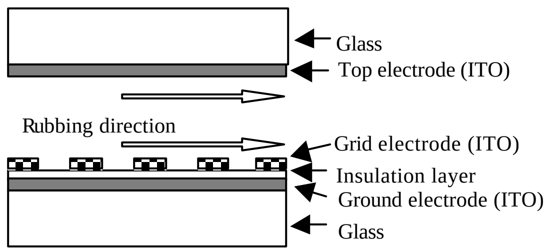


Fig. 1. Pixel structure of the proposed dual mode.

Figure 2 illustrates the operational principle of the proposed dual mode. Splay and twist states are used for the memory mode. Transition process of memory mode with respect to an applied voltage is following. By applying a voltage, V_v between the top electrode and ground one (vertical switching), the splay state is changed into high bend state via low bend state. After a bend state is formed, the bend state is transformed into the 180° twist state by removing the applied voltage of V_v. This twist state is one metastable state of the memory mode. The other stable state of the twist state can be changed into the splay state by applying a voltage, V_h between grid electrodes and ground plane (horizontal switching).

There is an interesting behavior when a vertical electric field was applied to the twist state of the dual mode. The transition texture from the twist state always relaxed into the twist state after removing the applied vertical field. This behavior can be applied to a monostable device. Moreover, with appropriate bias voltage, this dual mode can be operated between low bend and high bend states as shown in Fig. 2.

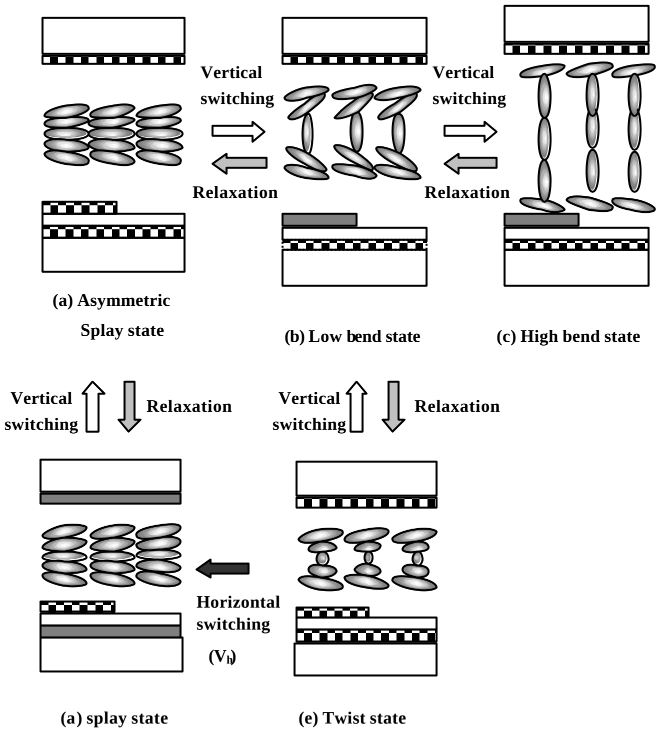


Fig. 2. Transition process of dual mode with respect to a vertical voltage and a horizontal voltage.

3. Experiments

In order to investigate the dynamic behavior, we fabricated several dual cells. Electrode structure is the same as explained in Fig. 1. The substrates were coated with an alignment material SE-3140 (Nissan Chemicals Co.) which produced a pretilt angle of 5 ° after the parallel rubbing process. The cell gap was 4.2 ㎛. The chiral additive S-811 was doped in the liquid crystal ZLI-2293 (Merck Co.) to make a d/p ratio of 0.2. Though the higher d/p ratio above 0.25 makes the 180° twist state more stable, in our BCSN LC device the splay state should be more stable than the twist state for horizontal switching. In order to measure the electro-optic response characteristics, the test cell was located between two crossed polarizers in which the angle between the rubbing direction and the transmissive axis of the input polarizer was 45 ° as shown in Fig. 3. A He-Ne laser with wavelength 543.5 ㎚ was used as the light source. The transmitted light was measured by a PIN photodiode. The voltage waveforms applied to the test cell were generated by an arbitrary function generator. Both the applied voltage waveform and the output of the photodetector were simultaneously monitored on a digital storage oscilloscope.

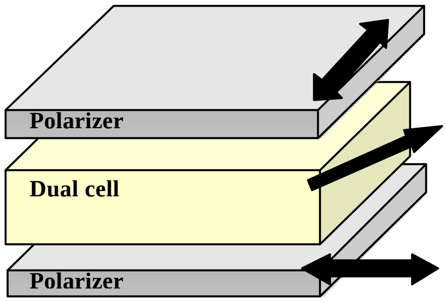


Fig. 3. Basic structure of dual mode.

3-1. Electro-optical characteristics of memeory mode

Figure 4 shows one example of memory switching in the dual mode between splay and twist states with the

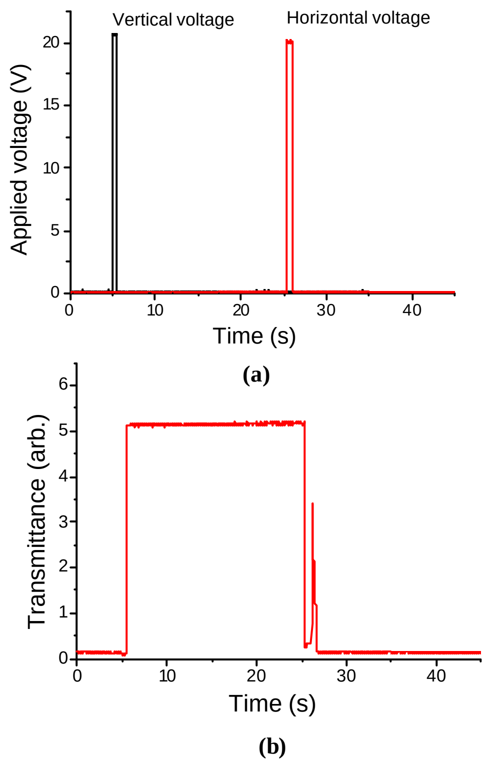


Fig. 4. (a) Applied vertical and horizontal voltages, and (b) memory switching between splay and twist states.

vertical and horizontal voltages of 20 V. The width of vertical voltage is 500 μs and that of horizontal voltage is 700 μs. The low and high transmittances represent those of the splay and twist states, respectively. We observed memory characteristics of the fabricated multidimensional dual cell under crossed polarizers as shown in Fig 5. Rubbing direction of splay state is coincident with transmissive axis of the one of crossed polarizers. Memory time can be extended by multidimensional alignment technique, because 90 ° twist domain of pixel boundary can prevent nucleation of defects and the subsequent motion of disclination lines. Memory time is verified to be permanent experimentally and the pictures below were taken up to 80 hours.

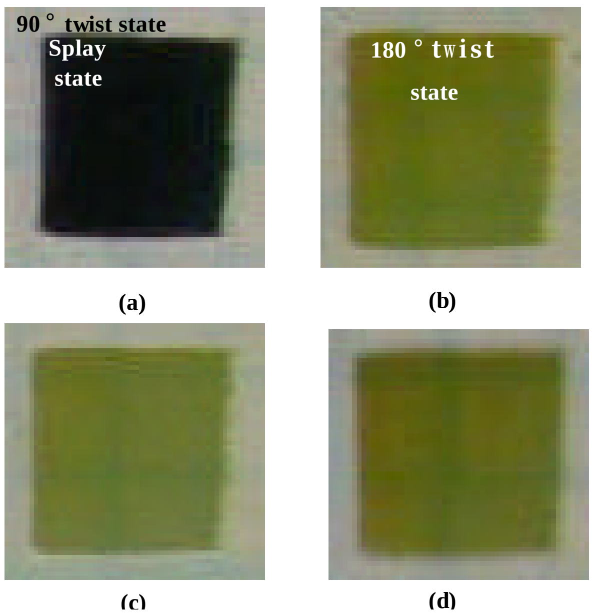
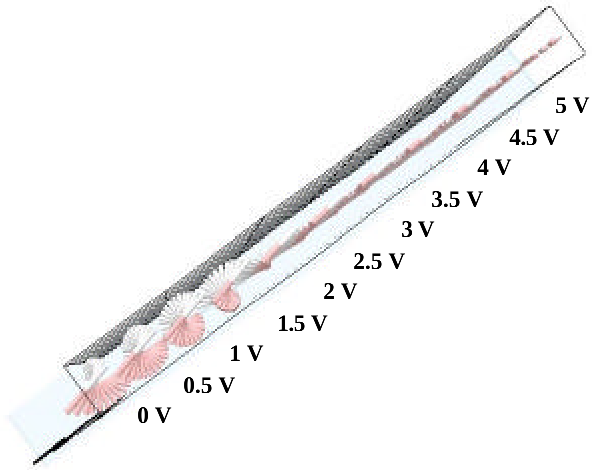


Fig. 5. Memory time of a multidimensional alignment dual cell: (a) Before applying voltage, (b) 1 hour, (c) 5 hours, and (d) 80 hours after transition to 180 ° twist state.

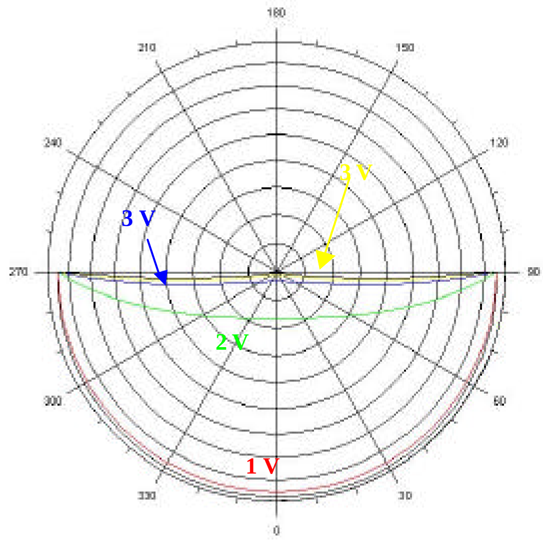
3-2. Electro-optical characteristics of dynamic mode

We found an interesting behavior in practical viewpoints when a vertical electric field was applied to the twist state of the dual mode. The transition state from the twist texture always relaxed into the twist one after removing the applied vertical field. This behavior can be applied to a monostable device.

We calculated the director profiles with respect to magnitude of vertical voltages by using the commercial software ‘DIMOS’. From the calculated director profiles, Dynamic mode of dual cell can be operated like pi cell [3] or OCB mode [4] with a bias voltage of 3.5 V.



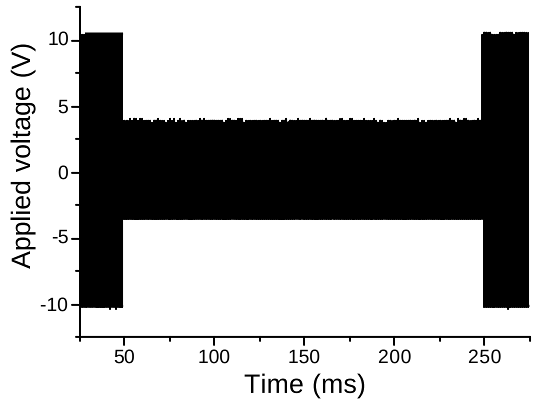
(a)

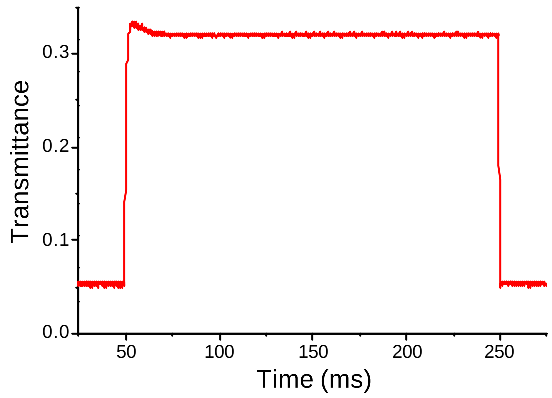


(b)

Fig. 6. (a) Director profiles, and (b) polar plot of dirctor profiles with respect to magnitude of the vertical voltage.

Figure 7 shows the response time of dynamic mode, when the applied voltage was changed between a voltage of 10 V with 1kHz and a voltage of 3.5 V. The response time is 1.7 ms.





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4. Summary

We introduce a novel liquid crystal display mode which can be operated as for both memory mode and dynamic mode. The novel LCD mode has not only a long term memory time in memory mode but also fast response time in dynamic mode. We describe switching characteristics of dual mode. Electro-optical characteristics of memory mode and dynamic mode show the possibility of practical device application.

5. Acknowledgements

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