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The stabilization technique for the enhanced retention time of memory state based on the PILC structure

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Recent fundamental research of bistable liquid crystal (LC) mode is focused on the enhanced retention time of memory state and the application based on flexible substrate. We have solved the limited time of memory state based on the pixel-isolated LC (PILC) structure. The polymer wall of the PILC structure provides the reliable operation of the device against the external shocks and deformations. The retention time of memory state was extended over 24 hours by creating $\pi/2$-twisted LC domain in the sub-pixels through the multi-rubbing method. This fabrication technique of stabilized bistable LC mode is highly applicable to the future portable roll-up display.

1. Introduction

For the requirement of the high quality on information-oriented society, the portable application of display is certainly required to the communication of a variety of information without relating to time and place. The flexible display has secured their excellent portability like light weight. Also, it can be easily transformed and rolled up to reduce its volume. For the enhanced flexible display, various researches are developed so far [1-8]. Especially, LC display has merits the attractive techniques such as well-established process and good electro-optical properties in a field of FPD [9]. For the realization of flexible LC display, the stabilized technologies are needed to control the hydrodynamic property of liquid crystal like PILC structure. Previously, the PILC technique has secured the good device performances and high mechanical reliability with the micro-structure for the flexible display [4, 5]. The wall-supporting structure of PILC technique maintains cell-gap and provides the reliable operation of the device against the external deformations. Also, in the portability of display device, the low power consumption for various mobile conditions is highly important. The present technique of display has limited that a user must possess the dynamic and memory mode according to need and its investment is overlapped from technical development and production.

For the demanded flexible technique, we demonstrated the stabilized bistable LC mode based on PILC structure by enhancing retention time of memory state. The dynamic and memory modes were simultaneously achieved in the each sub-pixel using the bistable chiral splay nematic (BCSN) mode [10]. We can use the dynamic mode for displaying the motion images and the memory mode for the application such as E-paper with low power consumption. The basic operational principle of proposed technique is the same as that of the conventional BCSN mode. Specially, we created the $\pi/2$-twist domain area which can be stable the π-twist state by multi-rubbing method in the sub-pixels, respectively.

2. Device Configuration

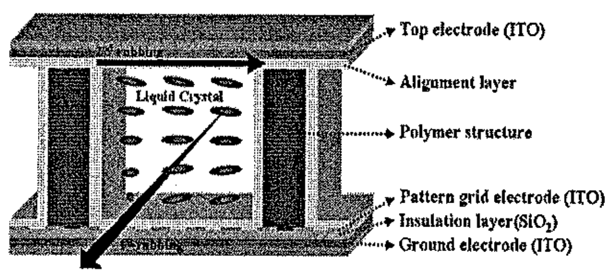

Figure 1. The schematic image of the proposed stabilized bistable LC mode based on the PILC structure.

Figure 1 shows the cross-sectional view of our stabilized bistable LC mode based on PILC structure. The polymer wall maintains a stable and a uniform cell gap of device against various external deformations. LCs are isolated in each sub-pixel and their alignment get influenced the surface anchoring energy by the multi-rubbing method. The initial LC director is created $\pi/2$-twisted domain around near side of the wall according to the shadow effect of polymer wall.

The driving of LCs is nearly similar to the conventional OCB (Optically Compensated Bend) mode [11]. We can obtain the three states such as the splay, the bend and π-twist state according to the total free energy of LCs, it is related on the surface anchoring energy, the parameter of LCs, the applied voltage and the concentration of chiral dopant. For using of the dynamic mode, we distinguished low bend and high bend. These two states are obtained by controlling the amount of applied vertical field. According to the basic driving principle of conventional BCSN mode, we used the three terminal electrodes for operating the vertical and horizontal field simultaneously in a single cell. The initial splay state is transferred to the high bend state by the vertical field. When the applied field is removed, the high bend state is transferred to the π-twist state by the total free energy. And then, the π-twist state is transferred the initial splay state by the horizontal field.

We observed that the retention time of π-twist state is very short in the PILC structure unless the proposed stabilized technique. The π-twist state is easily transferred to the splay state spontaneously from the rubbing direction. It is appeared because of the shadow effect by polymer wall in the rubbing process. So, we proposed the stabilized BCSN mode by means of multi-rubbing process to form the multi-domain. We can form the initial splay area and the $\pi/2$-twist state by the seed area for the stabilization of memory mode simultaneously in the each sub-pixel.

3. Experimental

To stabilize the dynamic and memory state based on PILC structure, we optimized the various factors such as the height of polymer wall, the concentration of chiral dopant and the boundary conditions of each pixel.

We used the conventional photo-lithography method using the negative photoresist named SU-8 (Micro-Chem) as polymeric material. The interval of polymer wall is 300μm x 100μm. The width of wall is 30μm and the height is 6.5μm. SU-8 is highly applicable for the rigid polymer wall because it shows the excellent physical and chemical stabilities after the heat treatment and it doesn't react with LCs.

To optimize the bistability of our mode, we used MLC 6204 (Δn: 0.1481, $\Delta\varepsilon$: 35.2) from E. Merck and a commercial polyimide AL3046 from JSR (pre-tilt angle: 4~5°). And the chiral dopant (S-811) was used to match the pitch of LC as 32.5μm which was adjusted to the ratio of cell thickness (d) and pitch (p) as 0.2 (d/p) for realizing the condition of bistability [12]. Also, for the stabilized π-twist state, we have rubbed twice perpendicularly. But the initial alignment of LCs is accompanied with the disclination by the perpendicular rubbing direction. For fabrication the high quality device, we controlled the strength of the first and second rubbing.

4. Results

Figure 2 shows the applied BCSN mode on the PILC structure. The π-twist state is easily transferred to the splay state spontaneously after the short retention time. The phase transition of the π-twist state to splay state is appeared a same direction from the rubbing and all of the sub-pixels has occurred simultaneously. When we changed the rubbing direction, the result was identical.

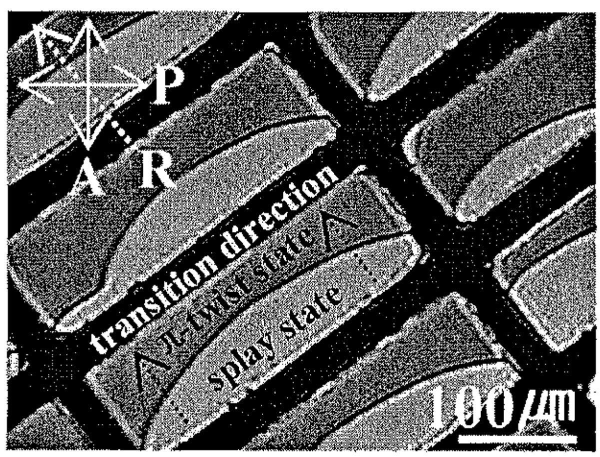

Figure 2. The short retention time of memory state (the spontaneous transition of π-twist to splay).

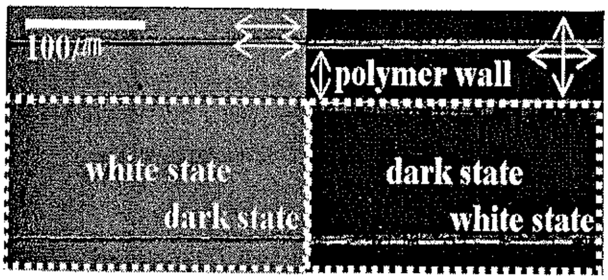

Figure 3. The observation of the formed $\pi/2$-twist domain into the sub-pixel.

The results show the problem of the rubbing process on the PILC structure. This structure has the some area that is no rubbed area by the shadow effect of polymer wall. And these transition phenomena occurred randomly with the different speed at the whole area.

To create the seed of stabilization at the π-twist state, we formed the $\pi/2$-twist domain by the multi-rubbing process in the whole sub-pixels. Figure 3 shows the microscopic textures of the formed $\pi/2$-twist domain into the sub-pixel under the paralleled and crossed polarizers. In case of paralleled polarizers, the dark state of the pixel was observed near the polymer wall while the white state was monitored at the other side. The $\pi/2$-twisted LC structure exhibits the dark state and the splay state shows the white state under these optical settings. It shows that the $\pi/2$-twist domain is successfully achieved uniformly inside of each sub-pixel by using our multi-rubbing method.

We checked the relation of rubbing strength between first and second to find the optimized rubbing condition. We fixed first rubbing condition and then second condition gradually increased.

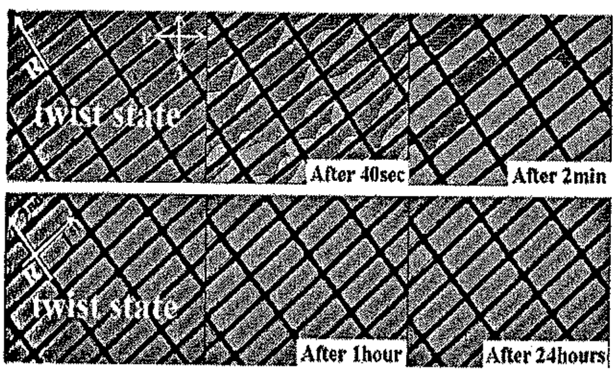

Figure 4. The observation of the formed $\pi/2$-twist domain into the sub-pixel.

If the second rubbing condition is same as first condition, there is a numerous disclination and if the second rubbing condition is too strong (>1:15), we couldn't obtain the stable retention time of π-twist state. It means that the surface anchoring energy of $\pi/2$-twist domain is remarkable low. At the case of rubbing condition ratio between 1st and 2nd is 1:10, we obtained the most good retention time.

Figure 4 shows the difference of retention time in the two cases of using the general sample and the proposed multi-rubbing method. The retention time of the π-twist state can be dramatically increased by using the proposed technique. This π-twist state was maintained over 24 hours.

5. Conclusion

We demonstrated the stabilized bistable LC mode in the PILC structure. The PILC structure provides the reliable operation of the device against the external deformations. The dynamic and memory modes were simultaneously achieved in a single cell using the BCSN mode. To obtain the stable memory state of the device, we created the partial $\pi/2$-twisted domains in each sub-pixel through the multi-rubbing process. As the result, we obtained much enhanced retention time of π-twist state over 24 hours through whole sample area. The proposed technique can be very useful for portable flexible display applications with the low power consumptions and the high quality device performance.

6. Acknowledgements

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7. References

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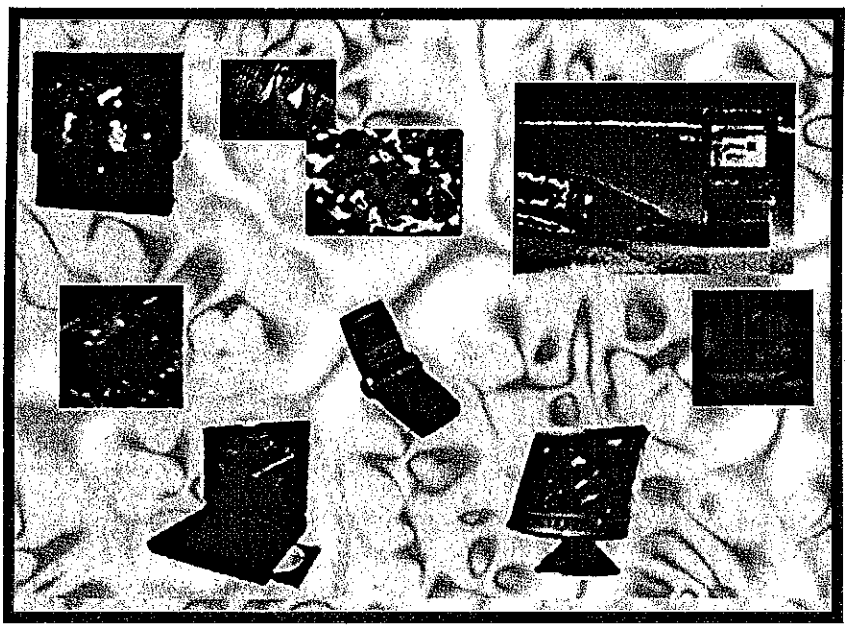

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Research Institute of Computer, Information, and Communication, PNU

제 10회 한국액정토론회

Thursday, July 12. 2007
(14:00 ~ 18:00)

14:00 Registration and Introduction
14:20 Welcome Remarks by Prof. Sin-Doo Lee

SESSION 1 (14:30~16:00)
Chair : G. D. Lee (Dong-A Univ.)

14:30 01. 화소 분리 폴리머 격벽의 앵코링 효과가 파이셀에 미치는 영향
이성룡, 이중하, 장홍직, 조진석, 윤태훈, 김재창,
Pusan National University

14:50 02. The stabilization technique for the enhanced retention time of memory state based on the PILC structure
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[1]Department of Information Display Engineering, Hanyang University,
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15:10 03. Infinite memory time of BCSN with dual cell gap structure
Sang-Hyun Park*, Yi-Jun Kim, Kwan-Sik Min, Chul Gyu Jhun and Soon-Bum Kwon,
Hoseo University

15:30 04. Vertically aligned ferroelectric liquid crystal with short pitch for optical devices
Dong-Woo Kim[1], Hak-Rin Kim[2], Ju-Hyun Lee[3], and Sin-Doo Lee[1*],
[1]Seoul National University,[2]Kyungpook National University,
[3]University of Central Florida

COFFEE BREAK (15:50 ~ 16:00)

POSTER SESSION
(Thursday, 16:00 ~ 18:00)

P1. Synthesis and Physical properties of 3-(2,3-Difluoro-4-propylbiphenyl)-6-ethoxy-pyridazine derivatives using in liquid crystals
I. H. Yang , H. I. Hwang, Y. B. Kim,
Konkuk University