Surface Aligned by LED Light for High Yield Liquid Crystal Display Production

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ABSTRACT

Photoalignment is evaluated by the proven market for patterned alignment display. The performance of photoalignment is demonstrated to be equivalent to rubbed alignment. It allows nearly free pattern to the liquid crystal alignment direction compared to the conventional rubbed polyimide. Most of the available photoalignment materials require polarized deep UV irradiation with a finite dosage. With the consideration of the current limitation with such a small working window, a vertical photoalignment surface by non-polarized blue LED light irradiation is proposed and demonstrated. The alignment direction of proposed surface is generated by the inclined non-polarized light. The measurement results show the alignment properties of this proposed alignment surface are comparable to conventional polyimide. It has good stability and performance in terms of uniform pretilt angle, high polar anchoring energy and fast response time.

1 INTRODUCTION

Conventional technology for realization of vertical alignment relies on rubbing of vertical PI. However, the rubbing process will bring contamination on the alignment layer to affect the quality of the products. The non-contact property of photoalignment surface for liquid crystal (LC) alignment is the key advantage of increasing yield rate. It can also generate multi alignment direction by utilizing patterned masks within one pixel. Photoalignment have shown promising alignment properties as traditional rubbed polyimides (PI) [1-4]. Hence, photoalignment have been being attractive to the researchers and manufacturers in recent years. Many applications have been made available by advanced photoalignment materials including conventional LCD display, micro-display, optical devices and etc.

Photoalignment technology of liquid crystals can be generally divided into four main types, including photo-isomerization [5], photo-crosslinking [6], photo-degradation [7] and photo-induced molecular rotation [8]. Poor long-term stability makes photo-isomerisation photoalignment less popular since its molecular constituents of the alignment layer is a reversible mechanism. Photo-crosslinking materials consist of uncommon used materials as a liquid crystal layer. Both photo-crosslinking and photo-degradation materials involved permanent change to the structure of the alignment layer and this narrows the working window since both of them need finite light exposure dosage. For the Photo-induced molecular rotation materials, it also has the stability problem unless for some specific application [9,10]. For convention display usage, it needs stabilization.

In this work, we demonstrate a robust photo-induced molecular rotation alignment surface for vertically aligned liquid crystal devices. It has all the advantages of photoaligning process, including high yield and multi-domain patterning. More importantly, the proposed vertical alignment material has a wide working window for the light dosage. This can further increase the yield. It has been confirmed that in addition to the stable orientation direction, the electrical characteristics of the alignment layer are good. For example, the relevant parameters, VHR, RDC, anchor energy and image residual parameters, have met in accordance with industry standards. In addition, the proposed photoalignment material is not only sensitive to the ultraviolet (UV) light, compared to the existing materials in the market, but also can be aligned by the larger wavelength such as blue light. A simple LED light array exposure system can be the light source.

2 TILTED ALIGNMENT GENERATION

The pretilt direction of photoalignment technique is normally generated by an anisotropy UV light in the layer which induces a particular alignment direction to the liquid crystal. The UV intensity was measured at 365nm and the value is 19 mW/cm2. The total exposure energy was controlled by varying the exposure time.

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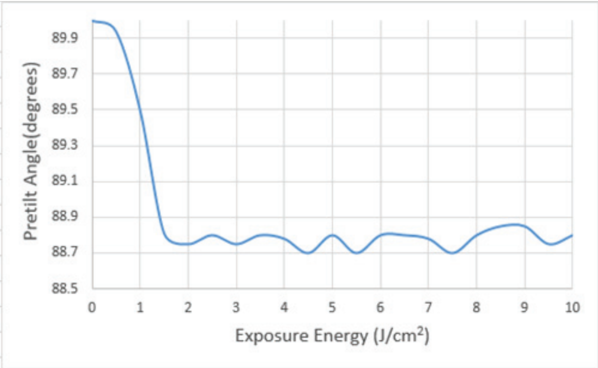

Fig. 1 Pretilt as a function of exposure energy at 365nm UV light for proposed vertical photoaligned material

Different exposure energy test cells were prepared by the proposed photoalignment material. The test cells were 8μm and assembled in an antiparallel alignment direction. They were filled with a negative dielectric anisotropy liquid crystal material with delta n equals to 0.11. According to the results shown in Figure 1, in order to achieve a pretilt angle approximately 880 to 890, 1.5Jcm-2 or higher UV exposure is required for both alignment layers. The key advantage for this material is that it maintains stable pretilt angles when the amount of light dosage reaches a certain value.

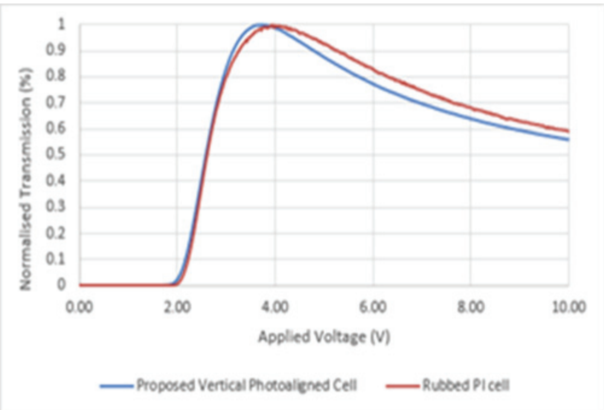

Fig. 2 TVC curves for proposed vertical photoaligned and rubbed VAN cells.

A reference cell was also prepared by the conventional rubbed vertical PI (Nissan, SE4811) for comparison. Figure 2 demonstrates similar transmission/voltage curves for the proposed vertical photoalignment cell and the rubbed reference VAN cell.

3 STABLE AND UNIFORM TILTED ANGLE

The proposed photoaligned VA material does not strictly required collimated light exposure system. A blue LED array with a divergence of 100 could be used for exposure. Another important characteristic of the proposed vertical photoalignment material is sensitivity to a wide range of wavelengths (280nm – 460nm). Figure 3 shows the intensity uniformity of a high power LED array. The exposed area is 10cm x 10cm and the wavelength is 450nm. The power is about 90mW/cm2 at a height of 10cm from the light source.

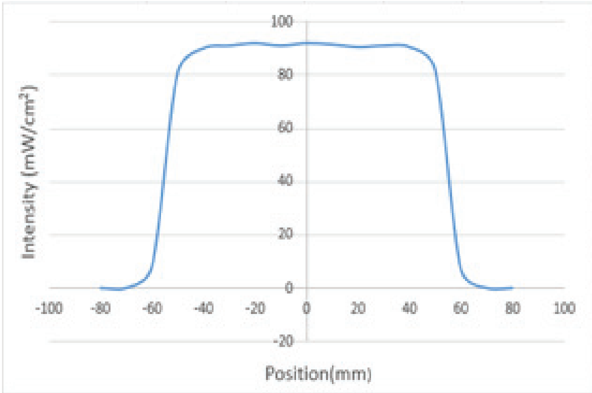

Fig. 3 Light intensity profile against positions

In order to check uniformity of the pretilt angles, two 10x10cm substrates were coated with the proposed vertical photoalignment material, and the experimental results is shown in Figure 4. The pretilt angle profile shows a great uniformity, ranging from 88.7^0 to 88.9^0.

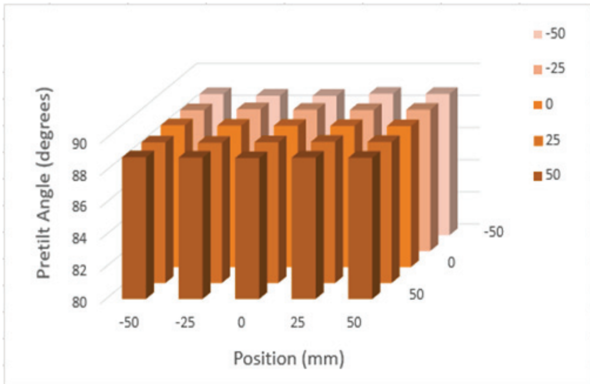

Fig. 4 Pretilt angle profile in 10cm x 10cm LCD with proposed VA photoalignment using blue LED array exposure

4 RESULT AND DISCUSSION

Table 1 Anchoring energy and response time for both proposed VA photoalignment and rubbed PI VAN LCDs

	Proposed Vertical Photoalignment	Rubbed VA PI (SE-4811)
Polar anchoring (J/m^2)	$2.08x10^{-4}$	$2.35x10^{-4}$
Response Time (ms)	27	29

To compare alignment quality with rubbed PI, the anchoring energy and response time of both proposed vertical photoalignment material and the rubbed VAN LCDs were measured. Table 1 shows the comparison results, which demonstrates that the LCD cells fabricated by proposed vertical photoalignment have the same performance as the cells fabricated by conventional rubbed PI. Some demo cells were prepared by proposed vertical photoaligned material were shown in Figure 4. The contrast ratios are higher than 1500.

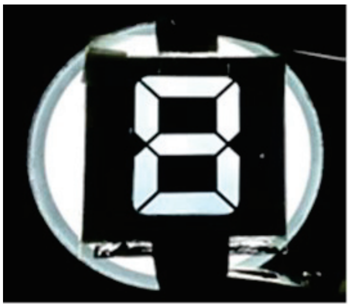

Fig. 5 A small cell prepared by proposed vertical photoaligned material

Fig. 6 A prototype prepared by proposed vertical photoaligned material

5 CONCLUSIONS

A robust and easily aligned photoalignment material with a generated uniform pretilt angle for vertical LCDs is presented and demonstrated. The working window is large compared to existing materials on the market. The proposed vertical photoalignment material could be aligned by a wide range of wavelength (280nm-450nm), fearless of overexposure, and has a large acceptance ability regarding to the incident angle of the light source. This is the best candidate for implementing multi-domain and high performance LCDs.

REFERENCES

[1] V. G. Chigrinov, V. M. Kozenkov and H. S. Kwok, Photoalignment of Liquid Crystalline Materials, Wiley, 2008

[2] H. G. Galabova, D. W. Allender and J. Chen, Phys. Rev. E, Vol. 55, p.1627, 1997

[3] I. H. Bechtold, M. P. De Santo, J. J. Bonvent, E. A. Oliveira, R. Barberi and Th. Rasing, Liq. Cryst., 30, p.591, 2003

[4] C. Ruslim and K. Ichimura, Adv. Mater., 13, p.641, 2001

[5] W. M. Gibbons, P. J. Shannon et al., Nature, vol.351, p.49, 1991

[6] M. Schadt, K. Schmitt et al., Japanese Journal of Applied Physics Part 1, vol.31, p.2155, 1992

[7] M. Hasegawa and Y. Taira, International Display Research Conference 94, p.213, 1994

[8] V. Chigrinov, A. Muravski, H. S. Kwok, H. Takada, H. Akiyama and H. Takatsu, Phys. Rev. E, Vol. 68, 061702, 2003

[9] A. Muravsky, A. Murauski, V. Chigrinov and H. S. Kwok, SID Sym. Dig. Of Tech, 39, 915, 2008

[10] Wanlong Zhang, Man Chun Tseng,ChungYung Lee, Jiatong Sun, Shu Tuen Tang, Yuk Lung Cheung, Abhishek Srivastava, Vladimir Chigrinov, Hoi Sing Kwok, SID Sym. Dig. Of Tech, 47, p.1421, 2016