Flexible Photoaligned Permanent Bistable TN-LCD

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ABSTRACT

Flexible Bistable Nematic Liquid Crystal Display (π-BTN) based on photo-alignment technology is developed on two 200μm plastic substrate. This display can be switched between φ and π + φ twisted states by means of breaking anchoring condition on one of the plastic substrates. Low baking temperature of 100^0C is needed to avoid high temperature distorting the substrates. The advantages of both photoalignment and π-BTN technologies, such as no contamination of electrical charges and impurties, high contrast and bistability are shown.

INTRODUCTION

Today, there is an increasing demand for flexible liquid crystal display (LCD) in many applications such as mobile phones, smart cards, electronic newspaper and Integrated display[1]. Compared to traditional glass LCD's, flexible displays have many advantages like being thin, lightweight and more mechanically robust. They also offer a clear advantage in design, since it allows integration into devices of non-rectangular and curved nature. For many aimed application, it's also desirable if the device is bistable since it will result in low power consumption. Several bistable technology fabricated with plastic substrates have been demonstrated. Jesper etc.[2] demonstrated bistable flexible display using photoalignment ferroelectric liquid crystal (FLC) technology. But the FLC material is very sensitive to mechanical bump and temperature influence. Huang et.al[3] reported flexible bistable display based on cholesteric liquid crystals technology. But flexible cholesteric displays will not reach the marketplace until the materials are better adapted to coating and printing processes suitable for manufacturing.

On the other hand, photoalignment technology can avoid many drawbacks of traditional rubbing technique for LC alignment, such as sample contamination, static charge generation and mechanical damage[10]. The technique is attractive as a promising alternative to the rubbing process for the next generation of displays, especially for multidomain, vertically aligned, and/or in plane switching mode displays.

In these few years, people have put great efforts in making the truly bistable TN display. Dozov et al[4,5,6] demonstrated BTN using thin LC cell which is less than 2um and a combination of strong and weak surface anchoring, together with large pretilt angles. For the comb-on-plane (COP) case, Guo et al[7] reported a 3-terminal BTN LCD. however, such electrodes are difficult for fabrication. Recently, Fion et al[8,9] made the π-BTN using the usual rubbed polyimide (PI) layer and photoaligning azo-dye (SDA-1) layer successfully. However the temperature of PI baking is about 230^0C, which makes flexible substrates distorted. So it is difficult to fabricate flexible BTN using traditional rubbing technology.

Our main idea for the bistable flexible π-BTN is based on the combination of two different concentrations of the same photoaligning material as alignment layer. One side of the cell has to be strongly polar anchored by using a higher concentration of photoaligning materials with longer exposed time while the other has to be very weak employing a smaller concentration of photoaligning materials exposed for a relatively short time. The weak anchoring layer helps breaking surface anchoring in order to realize the (φ, π + φ) switching. However, such kind of photoalignment layer is difficult to obtain.

In this paper, we would like to report a flexible π-BTN with 1.8μm cell gap using a novel photo-alignable polymer SD1[11] as shown in Fig. 1. The anchoring energy of SD1 can be adjusted from a high value of 1.8×10^{-3}J/m^2 to smaller value 6.5×10^{-4}J/m^2 by changing the UV exposure time. Jesper et al.[12] has investigated the alignment properties of the azo dye SD-1/SDA-2 mixture on both plastic PES and conventional glass substrates. The results on plastic substrates are in agreement of those achieved with glass substrates.

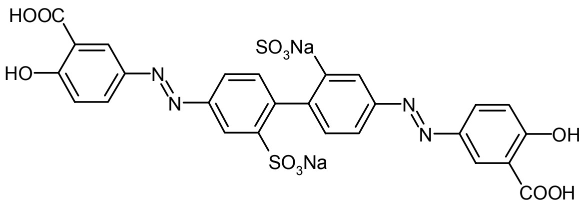


Fig. 1 Structure of azo-dye SD1

This is the first time to use one same photoaligning material to make π-BTN successfully on plastic substrates. The lifetimes of the two bistable twisted states are unlimited. Normal STN driver can accomplish the switching of the flexible π-BTN.

Experimental

Fig. 2 shows the cross section of flexible π-BTN. We use the commercially available plastic substrates of 200μm thickness. These substrates are coated with a thick Indium Tin Oxide (ITO) layer (~100nm). The SD1 solution used is mixed SD1 with N,N-Dimethylformamide (DMF) in weight. First we coated the upper substrate with 1% SD1 and the lower substrate with 0.175% SD1. The speed for spin-coating is 800rpm/s for 10s and then 3000rpm/s for 40s. As a following, the substrates were baked on hot plate of 100 degree for 10 minutes to remove DMF solvent. We varied both the exposure time and the concentration of SD1 to achieve strong and weak polar anchoring energies on two different plastic substrates. For the one coated with 1% SD1, three steps are needed to generate the pretilt angle of about 3 degrees and strong anchoring energy. First, it is exposed to linear polarized UV light (500 Wt Hg lamp with interferometric filter, λ_{exp} = 365 nm, P_{exp} =3.8 mWt/cm²) for 5 minutes. The alignment of SD-1 layer is perpendicular to the linear light polarization. Then it's exposed to unpolarized UV light for another 5 minutes with an oblique angle of 45^0. Finally, it's laminated under the same polarized UV light for additional 1 minute to restore alignment with strong anchoring energy. For another substrate, which coated with 0.175% SD1, the linear polarized UV light exposed for 1 minute was used in order to obtain a weak polar anchoring energy (~6.5×10^{-4}J/m^2). After UV lamination, conventional LCD fabrication process is followed to make π-BTN.

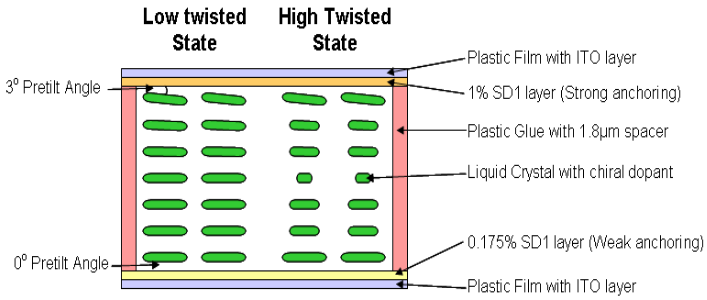
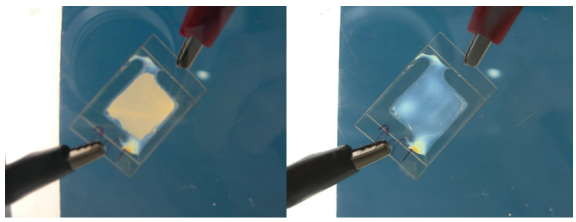


Fig. 2 Cross section of flexible π-BTN structure

Results and discussion

Fig. 3 shows the final product of π-BTN with two permanent bistable states. The pictures on the left and right are the low twisted (yellow,bright) state(a) and high twisted (blue,dark) state(b) respectively.



a) b)

Fig. 3 Photo of plastic π-BTN cell with 1.8μm cell gap

The liquid crystal we used for fabricating is BN-104 with a birefringence Δn=0.17 courtesy by Nemoptic Company. The idea d/p ratio, from a heuristic point of view, should be given by[8,9]:

$$\frac{d}{p} = \frac{90^0}{360^0} = 0.25$$

However, as the high twist state usually has a higher elastic energy, the LC has to be doped in a way that the high twist state is more favored. So, a larger d/p ratio should be used in order to balance the elastic energy of the two twist states. Therefore, the d/p ratio was adjusted to be about 0.295 in order to achieve a reliable bistability.

Fig. 4 shows the simulated and measured spectrum of 1.8μm π-BTN. The two curves are closely matched with each other except there is a little drop in the 400nm region. It may be due to the absorption of plastic film and the photoalignment layer. The maximum contrast ratio is about 150:1 (measured value) at the wavelength of 675nm.The contrast ratio can be further improved by optimizing the direction of linear polarization of two stable state switching. The details of the optimization can be referenced to another paper from Tang et al[13].

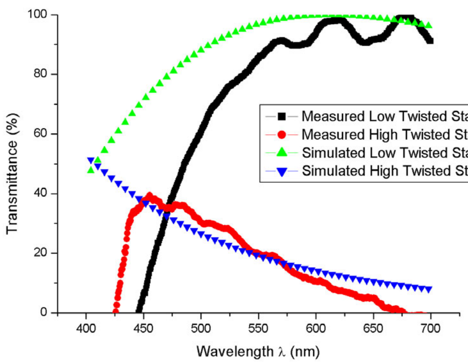


Fig. 4 Transmission spectrum of plastic 1.8μm π-BTN

Conclusion

It is the first time bistable π-BTN was successfully made on flexible plastic substrates by using photo-alignment technology. The low baking temperature of 100°C was used to cure the alignment layer, which avoids the distortion of plastic substrate under high curing temperature of polyimide.

Our proposed method solves the problem of anchoring breaking for flexible substrates and makes it as simple as normal LCD fabrication process. We believe, with our efforts, flexible BTN display can be soon appeared in some applications, especially for smart cards.

Acknowledgements

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