Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Experimental Research on Amorphous Twisted Nematic Liquid Crystal Displays

Shide Cheng [a] & Zhengmin Sun [a]
[a] Liquid Crystal R & D Center, Tianma Microelectronics Co. Ltd., 3/F., 1A, Jinlong Industrial Building, Majialong, Nanshan District, Shenzhen, 518052, P.R. China
Version of record first published: 04 Oct 2006.

To cite this article: Shide Cheng & Zhengmin Sun (1995): Experimental Research on Amorphous Twisted Nematic Liquid Crystal Displays, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 265:1, 623-630

To link to this article: http://dx.doi.org/10.1080/10587259508041728

Mol. Cryst. Liq. Cryst. 1995, Vol. 265, pp. 623–630
Reprints available directly from the publisher
Photocopying permitted by license only

EXPERIMENTAL RESEARCH ON AMORPHOUS TWISTED NEMATIC LIQUID CRYSTAL DISPLAYS

SHIDE CHENG and ZHENGMIN SUN
Liquid Crystal R & D Center,Tianma Microelectronics Co. Ltd.,
3/F., 1A, Jinlong Industrial Building, Majialong, Nanshan District,
Shenzhen, 518052, P.R.China

Abstract Amorphous twisted nematic liquid crystal display(a-TN) cells have been prepared without rubbing. The liquid crystal is injected into the cell in the isotropic phase and then cooled down to the nematic phase. The cooling rate and the uniformity are critical for the preparation of the a-TNs. Nematic liquid crystals, both with and without chiral dopant, have been used for the a-TNs. The electro-optical characteristics of the a-TN have been measured. Theoretical calculations have been carried out by 4 X 4 matrix method. A rising time of 700 μ s and a decreasing time of 48ms have been detected. It is shown that the a-TN devices exhibit wide and uniform viewing angle characteristics. A viewing angle of $\pm$ 30 degrees has been achieved.

INTRODUCTION

The first liquid crystal display (LCD) device was in dynamic scattering mode[1] and the substrate surfaces were unrubbed. However, since the twisted nematic (TN) LCD was invented by Schadt and Helfrich[2], the rubbing technique has been widely used for the alignment of liquid crystal molecules in LCD manufacturing process, including TN-LCD, STN-LCD, and ferroelectric liquid crystal display devices(FLCD). Recently, Y.Toko and his co-workers [3] proposed a new method in preparing TN-LCDs: the nonrubbing technique. The cells were made without rubbing, The liquid crystals were injected in the isotropic phase and then cooled down to the nematic phase. Randomly distributed micro-TN domains were formed during the cooling process. Such mode is called

amorphous twisted nematic (a-TN) liquid crystal display. This technique can eliminate defects caused by the electrostatic charge . Unlike traditional TN-LCD, an a-TN LCD can provide neutral and wide viewing angles. Therefore the a-TN is very optimistic for large size active matrix driven LCDs. In this paper, the characters of the a-TNs are further investigated, both experimental results and theoretical calculations are presented.

EXPERIMENT

We prepare the a-TN cell with indium-tin-oxide(ITO) glass plates coated polyimide (PI) films which were unrubbed. The cell spacing is 7 μ m. It is

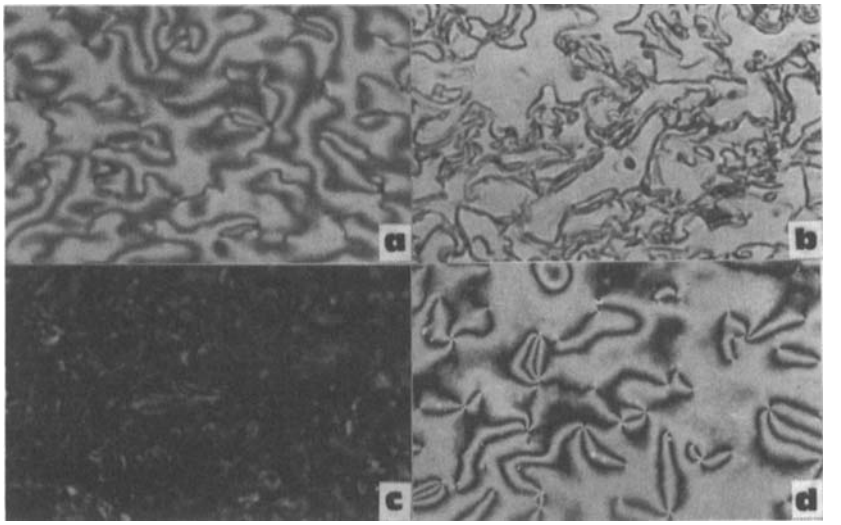


FIGURE 1 The microscopic photographs(X 95) of the micro-domains in a-TN cells (a) molecular textures of OFF state in sample 1; (b) the WHITE state of sample 1 by applying 2.4 Vpp 20Hz square wave; (c) the ON state of sample 1 by applying 5 Vpp 20Hz square wave; and (d) the molecular textures of OFF state in sample 6. See Color Plate XXIII.

found that unlike glass plates coated PI, bare ITO glass plates can align the liquid crystal molecules homeotropically. This demonstrates that the PI films are necessary for nematic liquid crystal molecules aligning parallel to the surfaces of the substrates.

The nematic liquid crystal is injected into the cells in the isotropic phase between 120-140°C. The cooling process is critical because the cooling rate strongly affects the final formed amorphous textures, the sizes of the domains and the electro-optical (E-O) characteristics. The typical cooling rate is about 100°C per minute. If the liquid crystal is injected in the nematic phase, a flow-pattern will appear, just as that described by Mr. Toko et al [3]. The texture for the a-TN cell is identical to the Schiliren texture. Figure 1 shows the textures of the micro-domains (magnified by 95 times), (a) texture of sample 1 in regions without ITO pattern; (b) the white state of sample 1 by applying 2.4 Vpp volts of square wave; (c) the select state of sample 1 by applying 5 Vpp volts of square wave; and (d) the texture of sample 6.

Once the a-TN texture is formed, it always keeps this pattern .Such phenomenon may be caused by the memory effects of the surface molecular anchoring [4].

The macroscopic characteristics of the a-TN cell do not change when turning the cell between the crossed polarizers, this suggests that the micro-domains are distributed randomly. Samples are prepared with different liquid crystals and the specifications[5] are listed in table.I.

RESULTS AND DISCUSSIONS

The measurement of electro-optical characteristics of the a-TN is performed on an Otruka Electronics MCPD-1000 system. The light source is calibrated to be E-source. The electric signal is supplied by a Philips PM5191 function generator.

Background colour

The samples show different background colors. We assume that the sample 1 and sample 2 consist of micro domains with TN structure. These micro-TN domains distributed randomly in relative to the crossed back and front polarizers (figure 2). By applying 4 X 4 matrix method[6], we carry out calculations for

different aligning angles. The aligning angle is defined an angle between the director of the surface molecules in a micro-domain relative to the

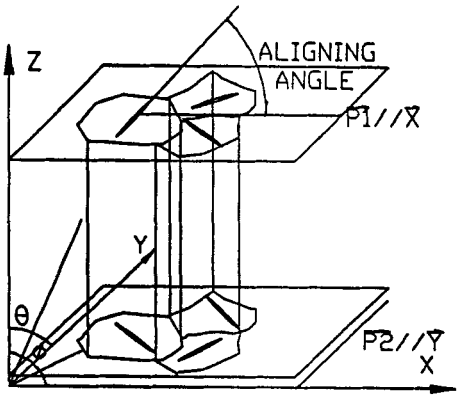


FIGURE 2 Schematic of the a-TN sample geometry showing the micro-domains

polarization direction of the top polarizer. The colors of the micro-domains are different for different aligning angles, but the peaks of spectrum are the same. The calculated spectrum for different aligning angles of sample 2 is shown in figure 3(a), and the measured curve in figure 3(b). The measured positions for the peak and the valley are in consistent with those calculated. Similar calculations are also carried out for cells filled with the non-dopped liquid crystal. The calculated and measured peaks are shown in table I.

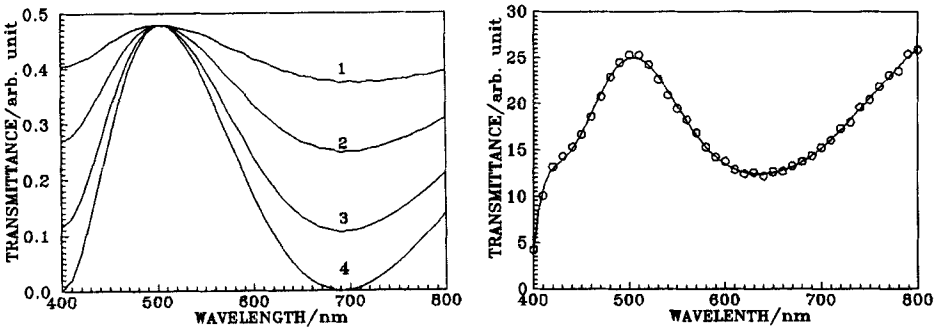
The discrepancies are probably caused by the following reasons: (a) the molecule domain configurations are more complicated than those depicted in figure 2.; (b) the polarizers in the experiment are not ideal. The polarization efficiencies of the polarizers do not keep same, especially for the range of long wavelength: the polarization efficiency of the polarizers decease rapidly as the wavelength increase in the region of 650nm-800nm.

Samples 1 and 2, samples 3 and 5, samples 4 and 6 show very similar colours, respectively. From table I, we can find that the background colour

TABLE I Optical and E-O characters of a-TN samples

Sample No.	Δ n(589nm)	Peak/valley wavelengths(nm)		CIE1931 x/y	Vw(V)
		Meas.	Cal.		
1	0.1395	530/730	500/690	0.308/0.369	1.2
2	0.1400	500/730	500/690	0.289/0.352	1.4
3	0.1227	580/720	570/---	0.367/0.404	1.9
4	0.1581	470/560	440/550	0.321/0.240	2.1
5	0.1206	550/720	560/---	0.358/0.429	2.3
6	0.1587	490/580	440/550	0.292/0.246	2.7

strongly depend on Δ n of the liquid crystals. This may be explained by statistical average of the spectra calculated for different aligning angles



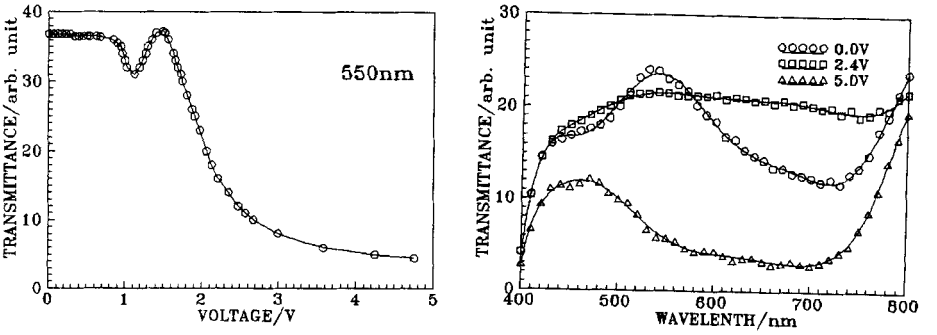
(a) (b)

FIGURE 3 The comparison of the calculated spectra of sample 2 with those measured. (a) calculated spectrum for different aligning angles: lines 1,2,3, and 4 are for 10, 20, 30 and 45 degrees, respectively; (b) the measured spectrum.

and twist angles which we will report elsewhere.

White states

For every cell we prepare, we find that under certain voltages, it always exhibits a white state which gives a flat spectrum in the range of 500nm-780nm. As mentioned above, the photography of the white state of sample 1 is given in figure 1(b), while its spectrum, in figure 4(b).



(a) (b)

FIGURE 4 The E-O characteristics of sample 1. (a) The transmittance of 550nm light wave v.s. the applied voltage. (b) The spectra under different voltages.

E-O performance

The electro-optical characteristics of sample 1 are given in figure 4. Figure 4(a) gives the transmittance of 550nm light v.s. voltage. The V_{on} and V_{off} are 1.68V and 3.85V, while its TN counterpart are 1.28V and 1.79V, respectively. Figure.4(b) gives the spectrum under several voltages. By applying 2.4 Vpp, the cell appears white, its coordinates in CIE 1931 colorimetry system is 0.356 and 0.370 for x and y, respectively. However, the white state appears a little yellow. The selected state of the sample is very similar to that of a TN cell.

The response times, Tr and Td of, sample 1 are measured to be 48ms and 700ns, respectively.

Viewing angles

The a-TN cells exhibit perfect viewing angle characteristics, as shown in figure 5. There is little difference between θ and ϕ (as denoted in figure 2). The neutral and uniform viewing angle are preferred than tilted ones,

especially in large area AM-LCDs.

For the contrast ratio larger than 2.0, a viewing angle of ± 30 degrees of θ and ϕcan be realized in sample 1 (operating in transmission mode). The

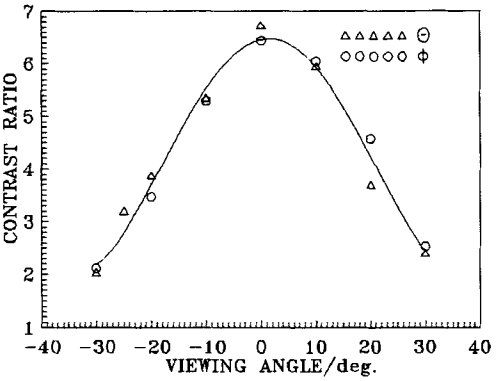


FIGURE 5 The viewing angle characteristics of sample 1.

maxium contrast ratio of the sample is 6.8. Moreover, when operated in refractive mode, the contrast ratio of the device can be improved.

CONCLUSION

We have prepared a-TN cells with uniform micro domains and wonderful viewing angle characteristics. The background colour of the cells are found to be dependent on the optical anisotropy of the liquid crystal, then that normally white a-TN devices can be achieved by adjusting the Δ n of the LC material. The a-TN may be utilized in static driven LCDs and active matrix driven LCDs. Further study for a-TN, including the optical retardation selection, theoretical calculation, practical application are underway.

ACKNOLEGEMENT

Thanks are giving to Mr.Bin WANG for his continuous support for the research, Mr. Shuxing LI for his helpful discussions and Ms. Yonghong ZHU for her kindly help in the experiment.

REFERENCES

1. G.H.Heilmeier and L.A.Zanoni, Appl. Phys. Lett., 13, 91 (1968).
2. M. Schadt and W. Helfrich, Appl. Phys. Lett., 18, 127 (1971).
3. Yasuo Toko, Takashi Sugiyama, and Kazuhisa Katoh, J. Appl. Phys. 74, 2071, (1993).
4. S. Sato and M. Wada, Jpn. J. Appl. Phys., 11, 1566 (1972).
5. Catalog of E. Merck Liquid Crystals, Unpublished (1992).
6. D.W.Berrenan and T.J. Scheffer, Phys. Rev. Lett. 25, 577 (1970) ; D.W.Berrenan, Phil. Trans. R. Soc., A309 127 (1983).