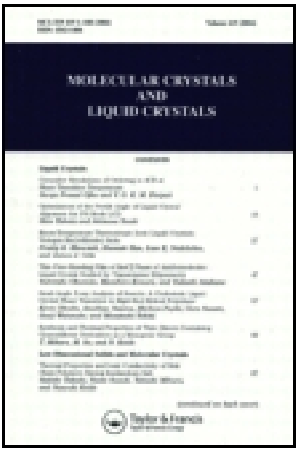

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Amorphous Highly Twisted Nematic Liquid Crystal Displays with Wide and Uniform Viewing Angle Characteristics

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Amorphous Highly Twisted Nematic Liquid Crystal Displays with Wide and Uniform Viewing Angle Characteristics

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Amorphous highly twisted nematic liquid crystal display devices have been prepared by a nonrubbing technique. The liquid crystals are injected into the cells in the isotropic phase and then cooled down to the nematic phase. Micro-domains of highly twisted nematic liquid crystals are formed during the cooling process. The twist angles of the micro-domains are controlled by the concentration of the chrial dopants. The transmission spectrum and the electro-optical characteristics of the devices have been measured. The experimental results show that the devices possess wide and uniform viewing angle characteristics (− 51 to + 52/− 49 to + 48 degrees). The 4 × 4 optical matrix method has been applied to a model of randomly distributed multi-domains of highly twisted nematic liquid crystals. The theoretical results are in good agreement with the experiment.

Keywords: Liquid crystal display, amorphous highly twisted nematic, amorphous twisted nematic, background color, chrial dopant, viewing angle.

INTRODUCTION

The twisted nematic (TN) liquid crystal displays (LCD) have been widely used and massively produced. Active matrix (AM) driven LCDs are showing their optimistic future in flat panel displays. However, TN cells used in AM-LCD show narrow and oblique viewing angle (VA) characteristics. With the development of large-screen, high-capacity, full-color AM-LCD, it is now more and more attractive to achieve wide and neutral viewing angle characteristics. Various methods have been introduced for the improvement of the VA characteristics for TN-LCDs. K. R. Sarma *et al.*, proposed a new driving method by splitting a pixel into two subpixels.[1] K. Takatori *et al.*, improved the VA characteristics by aligning the liquid crystal molecules in different pretilt and aligning directions, *i.e.*, the complementary-TN-multi-domain method.[2]

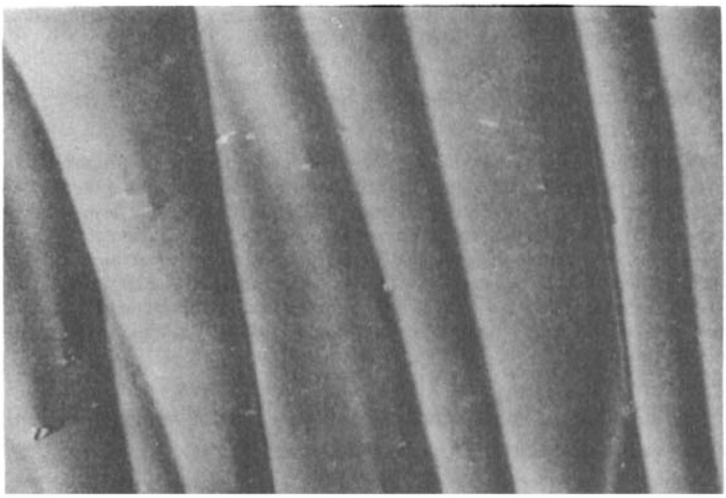
Recently, S. Kobayashi and his co-workers proposed a nonrubbing method to align the liquid crystal molecules in randomly distributed multi-TN-domains. Such a device is called the amorphous twisted nematic (a-TN) liquid crystal display.[3] Wide and uniform viewing angles can be realized in an a-TN cell. The analytical simulations of this type of device are also carried out.[4] In a previous paper,[5] we reported some of our experimental results of this type of LCD.

In this paper, we shall report a new kind of amorphous liquid crystal display device: the amorphous highly twisted nematic (a-HTN) liquid crystal display. The transmission spectrum, the electro-optical (E-O) performance and the VA characteristics are measured. The calculated spectrum with the 4×4 matrix method[6] is also presented.

EXPERIMENTAL

The a-HTN cells are prepared with two polyimide (PI) coated indium-tin-oxide (ITO) glass substrates, which are unrubbed. The Δ n. d of the liquid crystal is chosen to be

(a)



(b)

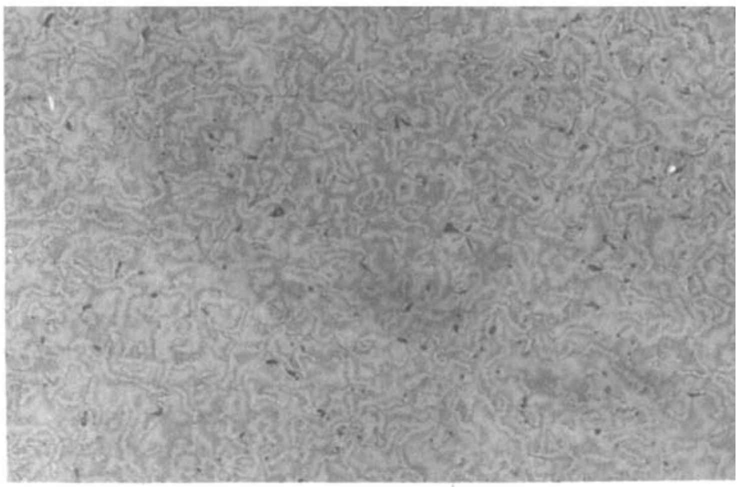


FIGURE 1 Microscopic photograph of (a) the flowing pattern; (b) the randomly distributed micro-HTN domains. See Color Plate I.

0.48, which is close to the first minimum of the Gooch-Tarry condition[7] for the 550 nm light wave. The d/p value of the liquid crystal is adjusted to be 1/3, which ensures a twisting angle of about 120 degrees. The liquid crystal is injected into the cell in the isotropic phase and then cooled down to the nematic phase. If the liquid crystal is injected in the nematic phase, a flowing pattern will form and it cannot be removed by the heat-and-cool method (Fig. 1a). Randomly distributed multi-domains can be found in the a-HTN cell under a polarizing microscope (Fig. 1b). Disclination lines can be found in the domain boundaries under a polarizing microscope, especially in ON state. The samples used in the measurements are prepared at a cooling rate of about 100 °C per minute. In a cell prepared at a low cooling rate (for instance, 1 °C per minute), we found that the disclination lines are less dense, the domains grow bigger and the viewing angles become narrow. As long as the random multi-domains form, they are stable at room temperature. This is caused by the memorizing effect of adsorbed liquid crystal molecules on the PI surfaces.[8]

An a-HTN liquid crystal cell is placed between two crossed polarizers. The measurement of the E-O performance is carried out on an Otsuka MCPD-1000 system. The electrical signal is supplied by a PM5191 generator. The luminance contrast ratio contour of the cell is obtained by a Melchers Display Measuring System.

RESULTS AND DISCUSSIONS

The luminance contrast ratio contour of the a-HTN cell is given in Figure 2. From this figure, we can find that the a-HTN has uniform and wide VA characteristics. For the contrast ratio larger than 3.0, the viewing angle in the up-down and left-right direction is -51 to $+52$ and -49 to $+48$ degrees, respectively.

The measured transmission spectrum of the a-HTN sample is given in Figure 3 in dotted line. It can be found that the sample shows a quite white background color. The CIE 1931 colorimetry coordinates of x, y are 0.3130 and 0.3439, respectively. The

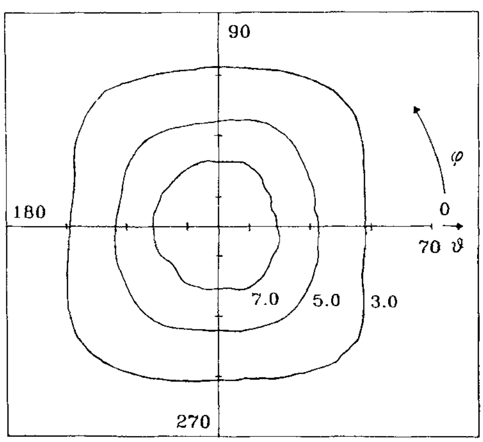


FIGURE 2 The luminance contrast ratio contour of the a-HTN sample.

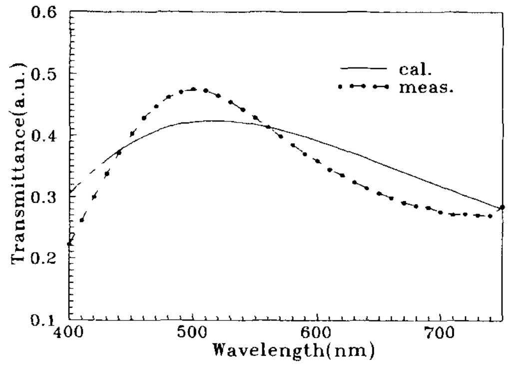


FIGURE 3 The transmittance of the a-HTN sample. The measured result is in doted line, the calculated in solid line.

calculated spectrum by the 4 × 4 matrix method for the sample is also given in the figure in solid line. In the calculation, we adopt the cell model where the multi-domains distribute randomly in different aligning angles. The aligning angle of a domain is defined between the director of the liquid crystal molecules anchored on the upper substrate and the transmission axis of the upper polarizer—see Reference 5.

Comparing with the experiment, one can find that the theoretical calculations are in good agreement with the experimental results. The discrepancies are thought to be caused by the following reasons: (a) the transmittance and the polarization efficiency of the polarizers in the calculation are assumed to be 49% and 99.0% in the range of 400–750 nm, while in the experiment there exist dispersions. (b) the dispersion of the liquid crystal is not taken into account. (c) the alignment of the liquid crystal molecules in the domain boundaries is very complex and it is not taken into account in the calculations.

The E-O performance of the a-HTN sample for different incident angles is given in Figure 4. From the curve for the 0 degree incident angle, it can be found that the steepness is about 1.9. The a-HTN cell possesses a wonderful gray scale capability.

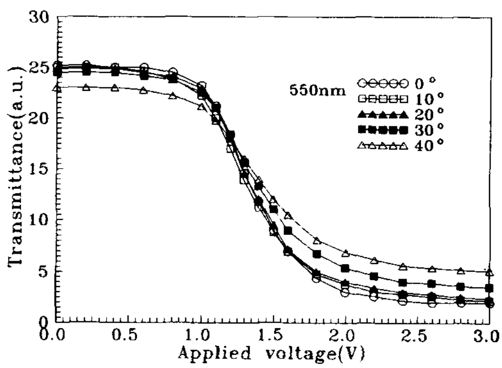


FIGURE 4 The electro-optical performance of the a-HTN for different incident angles.

The response time of the a-HTN cell is similar to that of the TN cell. The rising time and the decreasing time, T_{on} and T_{off}, of the a-HTN sample are measured to be 31.5 ms and 58.5 ms, respectively.

The E-O performance and the VA characteristics of the a-HTN cell are similar to those of the a-TN cell.[3-5]

The introduction of high twisting angle can provide a normally white a-TN cell with liquid crystals over a wider range of Δ n. d. One can also prepare an a-TN cell with 90 degrees twist when the value of the Δ n. d of the liquid crystal is chosen to be 0.48, the same as that for the a-HTN cell, and the d/p value 1/4. However, the background color of the cell appears slightly yellow, which is unfavourable to the full-color displays.

CONCLUSION

We have prepared a-HTN cells with uniform micro-domains and perfect viewing angle characteristics. The background color of the cell depends on the optical anisotropy of the liquid crystal cell and the twisting angle. Normally white a-HTN cells can be achieved by choosing appropriate Δ n. d and the twisting angle. Theoretical considerations based on the 4×4 optical matrix for a model with randomly distributed a-HTN domains are given and they are in good agreement with the experimental results.

Similar to the a-TN devices, the a-HTN devices can be utilized in the large-screen active-matrix-driven LCDs.

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