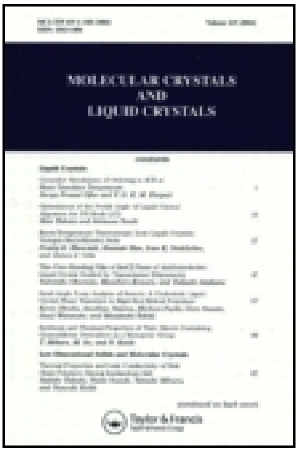

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Study on the Director Configuration and Display Properties of Amorphous Nematic Liquid Crystal Displays with Different Values of d/p

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Study on the Director Configuration and Display Properties of Amorphous Nematic Liquid Crystal Displays with Different Values of d/p

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Abstract

In this paper, based on experimental results , a model of the director configuration of amorphous nematic liquid crystal displays(a-n-LCDs) was related. From our study we find that the a-n-LCDs are characterized with disordered surface alignment. Based on the modeling, a detailed analysis of the influence of parameters on display properties is given out, and the discussion shows that d/p=1/4 is not a strict condition for display use of a-n-LCDs, even though d/p > 1/2, good E-O property for display use can also be obtained. The a-n-LCDs supply a way to avoid the rubbing treatment and exhbit display properties of good color reproduction and wide viewing angle. When the value of d/p is increased, the threshold E-O curves become steep, and this supplies the novel n-LCDs with a high-multiplexing capacity.

1. Introduction

Liquid crystal displays(LCD) have been developed according to the state of the art of electronic technology[1]. Nematic LCDs (n-LCDs), including twisted nematic(TN) LCDs and super-twisted nematic (STN) LCDs[2] , are commercially available for several years. However, both TN LCDs and STN LCDs are suffering from narrow viewing angle, and the rubbing process for the surface alignment of n-LCDs will greatly reduce the product yield, especially for axtive-matrix-adressed(AM) LCDs. These are two disadvantages which limit the application of n-LCDs.

Rubbing process reduces the yield of n-LCDs mainly in two ways: One is to cause the electra-static discharge, this will increase response time, reduce contrast ratio(CR), and be especially serious for AMLCDs: the transistors on the glass substrates may be damaged; the another is to bring dust particle in,the dust particle will make the cell ununiform and short-curcuit the electrodes on two surfaces.

The rapid reduction in CR and the inversion of Grey levels as viewing angle is increased are two major disadvantages of conventional n-LCDs, especially TN-LCDs. For single viewers using small screens this is not a major problem. However, as screen size increases, the effect becomes more evident. Many ways to improve the viewing angle property of LCDs have been proposed, such as using retardation film and using compensation LC layer. Although the viewing angle property is improved a little or more by these ways, the cost is increased considerably and there are a lot of problems in technology.

Recently a new twisted nematic liquid crystal named as amorphous(a-) TN-LCD is reported[3], which are prepared by filling chiral-molecule-doped NLCs in the isotropic phase into the no-rubbing-treated cells and cooling them to room temperature. When the ratio of cell gap d and NLC's pitch p is close to 1/4 and the angle of two polarizers is 90°, a wide viewing angle, good grey scale and high voltage holding ratio display property is obtained. In this paper, from our study we find that the amorphous NLC medium is characterized with the disordered surface alignment, an analysis of the influence of parameters on display properties is given out, which shows that when the value of d/p greater than 1/4, we still can obtain good E-O characteristics for display use if we properly choose the parameters. such as the retardation value Δnd, the ratio of d/p and the angle Φp of two polarizers. In a short way, we called this novel nematic LCDs with d/p>1/4 as amorphous STN LCDs, in contrast with conventional STN LCDs.

2. Method

On the surface without aligning treatment, we can get a disordered surface alignment(DSA). Fig.1 is the micrograph of the a-n-LCD cell under the polarized microscope. In the photo, it is shown that the a-n-LCDs are characterized by the short range orientation order of the long axes of the LC molecules, there exist many micro domains in a-n-LCD cell, in each domain the surface LC directors are homogeneous, but on a whole view the surface alignment of NLC is disordered.

Between two surfaces the configuration of LC director still keeps in helic structure. For there is no surface torsional anchoring, the twist angle of LC director from one boundary to another is only decided by the cell gap and the pitch of LC, expressed as:

$$\Phi t = 2\pi d/p$$

Here, Φt is the twist angle, d is the cell gap, p is NLC's pitch. When d/p=1/4, we can got a twist angle of 90°. We measured the twist angle in those domains of amorphous NLC medium under a polarized microscope, the method of measurment is related in ref. 4 and 5, and found that the values of twist angle in domains of a-n-LCDs is very close to the value of $2\pi d/p$.

So we can give out a model for the director configuration in a-NLC medium:

1) The NLC medium consists of many micro domains, in each domain the surface NLC director is aligned homogeneously, the number of domains with one oblique surface aligning direction is the same as that with another

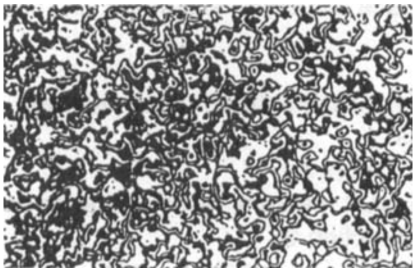

Fig.1 The micrograph of the DSA cell under the polarized microscope

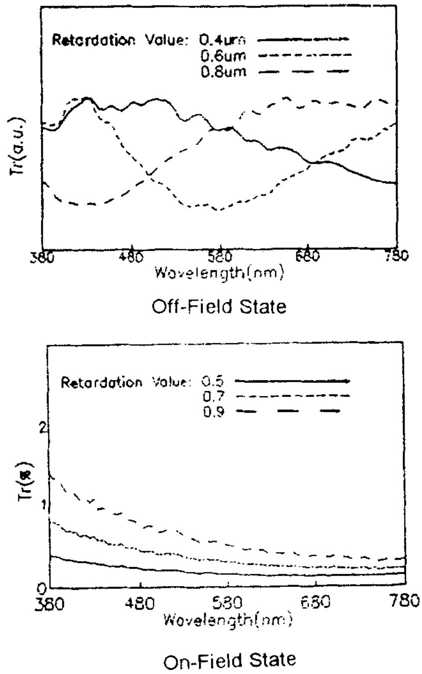

Fig.2 The calculated spectral transmission of a-TNLCDs with different retardation value Δnd at off-field stat and on-field state

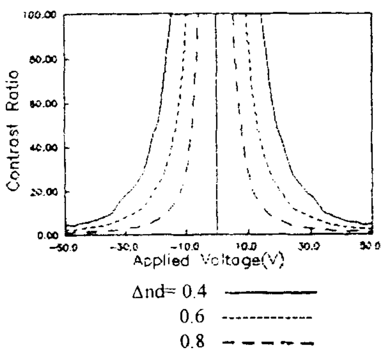

Fig.3 The simulated CR versus the zenithal viewing angle of a-TNLCDs with different value of Δnd

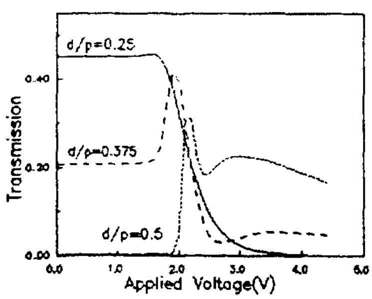

Fig.4 The E-O property of a-n-LCDs with the value of d/p from 0.25 to 0.5

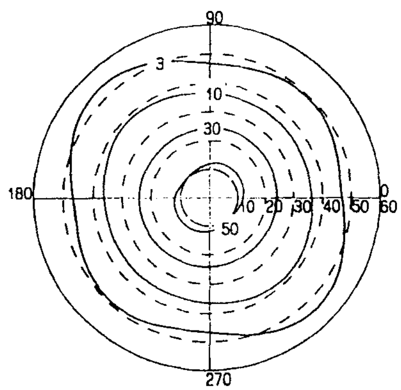

Fig.5 The iso-CR curves of one a-STN-LCD cell with d/p=0.5

oblique direction, the probability of surface director alignment in each direction can be expressed as:

$$P = 1/2\pi$$

The optical properties of a-NLC medium can be considered as an average of these micro domains, which is expressed as:

$$OPa = 1/2\pi \int Op(\Theta)d\Theta$$

Here, OPa means the optical property of a-NLC medium, op(Θ) is the optical property of a domain with surface aligning direction Θ.

2) In each domain, the surface NLC directors are aligned homogeneously, and the NLC director configuration is helic structure, the twist angle between two boundaries can be expressed as eq.(1).

Based on the above model, the simulation of properties of a-n-LCDs can be carried on: we can calculate out the NLC director configuration and transmission in domains with all values of surface aligning direction Θ, then calculate out the transmission of a-n-LCDs from eq.(3). Dr. T. Sugiyama et al [6] have done many work on the simulation of a-TNLCDs. Here we will try to demonstrate display properties of a-n-LCDs with different parameters.

3. Display Properties of a-n-LCDs

a) d/p=1/4

From eq.(1), d/p=1/4 means $\Phi t=90°$, so a-n-LCDs with d/p=1/4 is called as a-TNLCDs. Fig.2(a) and (b) are the calculated spectral transmission of a-TNLCDs with different retardation value Δnd at off-field state and on-field state. The cell gap d is 4um, the LC's pitch is 16um, and the polarizers are vertical to each other. From fig.1 we can conclude that the best value of Δnd for black/white display is 0.4~0.6um, as the value of Δnd is increased, the transmission spectrum of off-field and on field states become colorish instead of white and dark.

Fig.3 is the simulated CR versus zenithal viewing angle of a-TNLCDs with different value of Δnd. From fig.3 we can obviously find that compared to convetional TNLCDs, the viewing angle property of a-TNLCDs is extremely wide and symmetrical, and a higher CR and a wider viewing angle will be obtained at a lower retardation value.

b) d/p>1/4

From eq.(1), we know d/p>1/4 means $\Phi t>90°$. Fig.4 is the E-O property of a-n-LCDs with the value of d/p from 0.25 to 0.5. The LC's pitch is 16um, the Δn is 0.113, and the angle between two polarizers is also 90°. The wavelength of incident light is 535nm. From fig.3 we can find that as the value of d/p is increased, the contrast ratio is reduced, but the threshold E-O curves become more steep, and so the multiplexing capacity of passive matrix adressing mode is improved. When d/p=0.5, the maximum number of scanning line can be more than 100. Fig.4 is the transmission spetrum of a-n-LCD with d/p=0.5 at on-field and off-field states. We can find that off-field state is not white state and on-filed state not black state, this is very different from that of a-TNLCDs, and very similar to that of conventional STN LCDs, so we called a-n-LCDs with d/p >0.5 as a-STN LCDs. Fig.5 is the iso-CR curves of one a-STN-LCD cell with d/p=0.5. We can find that the viewing angle property is extremely well, and no inversion of CR occurs.

Compared to a-TNLCDs, a-STNLCDs have a sharp threshold E-O property, so a-STN LCDs are more proper for large area passive adressing displays. But a-STN LCDs have a drawback: neither on-state nor off-state is not black or white state. Using optical compensation layer to obtain black/white image may be a good idea, and now this work is underway.

4. Conclusions

From our study we find that the a-n-LCDs are characterized with disordered surface alignment, and this model supplies a theoretical basis for computer simulation. Computer simulation and analysis shows that the best retardation value for a-TNLCDs is 0.4~0.6um. In this paper we introduces a novel display mode, a-STN LCDs, which avoid rubbing process in manufacturing. A-STNLCDs distinguished them from a-TNLCDs by the value of d/p and the E-O property. Compared to a-TNLCDs, a-STNLCDs have a more steep threshold E-O property and multiplexing capacity of passive adressing mode, but a-STNLCD cannot display a white/black image without compensation layers. However, both a-TNLCDs and a-STNLCDs exhibit a wide viewing angle display property, and this supplies a-n-LCDs with possibility of application in large area, high definition flat displays.

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