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MODELING OF ELECTRIC FIELD DISTRIBUTION IN THE REFLECTIVE CHOLESTERIC LIQUID CRYSTAL DISPLAY

key words: liquid crystals, electric field distribution, finger electrode structure.

Modeling the electrode structure of display devices is considered in present paper. The modeling of electric field distribution that applied in a different electrode structure in an anisotropy medium was done.Carried out modeling of electric field distribution in the proposed liquid crystal cell construction of the LC display suggested us to use such electrode structure in the reflective LC display on the base of cholesteric liquid crystals

1. INTRODUCTION

There is observed some progress in designing optical information processing devices developed on the base of liquid crystals (LC). Such progress is achieved not only with synthesis of new type liquid crystals but also with investigation of new constructive decisions.

The main parameter leading to wide using of LC is optical anisotropy and the main factor of influence on changing the optical anisotropy is the applied electric field.

Calculation of the electric field distribution in an anisotropy medium is important task for development of the LC device construction because the most of LC devices is controlled by using electric field [1-4].

The optimization of form and geometrical sizes of the electrode structure for assurance of the necessary electric field distribution in the devices based on liquid crystals was made.

2. ELECTRIC FIELD DISTRIBUTION IN THE FINGER FIELD SWITCHING SYSTEM, AND REALIZATION OF A FIELD CONTROL LIQUID CRYSTAL ORIENTATION

The main feature of field control orientation is realization of horizontal and vertical electric field distribution in LC – cell.

It is necessary to use three electrodes for realization of such distribution. This pixel structure is not technologically complicated. Each pixel structure consists of two finger electrodes on one substrate and one transparent ITO electrode on another glass plate. The ITO electrode is common for all pixels of display. The finger electrodes were used for switching in plane (“In Plane Switching”, “Finger Field Switching”) to obtain the horizontal and vertical electric field distribution. In the comparison with IPS and FFS technologies we used the transparent ITO common electrode here. Such electrode was used for obtaining the vertical electric field distribution [5-8].

The horizontal field distribution is generated when the finger electrodes have apolar symmetrical electric potential to potential of ITO electrode. The vertical electric field distribution appeares when electrodes A and B have the same potential (Fig. 2.)

The disadvantage of such structure is irregularity of field distribution. The modeling shows that horizontal electric field is just between the finger electrodes. The vertical electric field distribution is more uniform, since over the finger electrodes the electric field is always vertical.

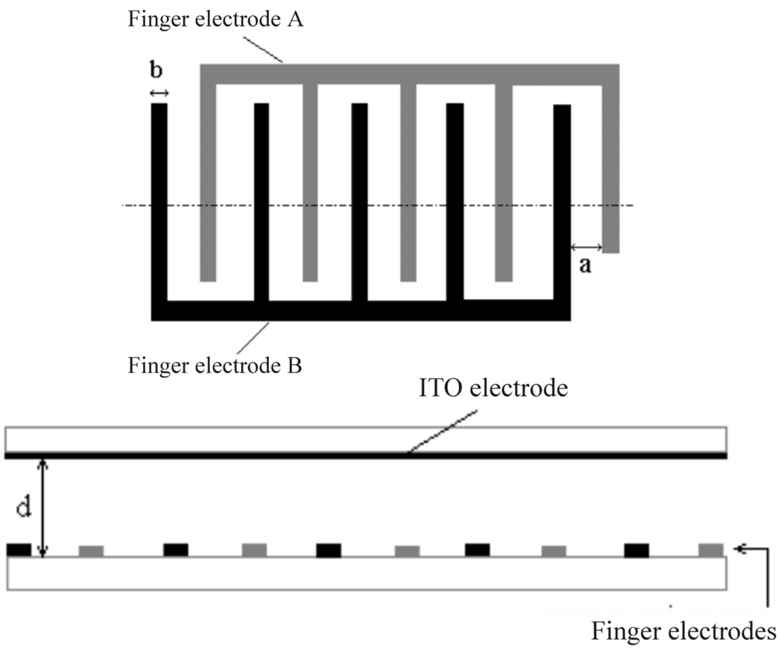


Fig. 1. Electrodes system configuration

The optical response depends of the a/d value (Fig.2.). In the case when a=d the horizontal field is more uniform than in the case when a=2d. It means that the orientation energy difference is greater in the case when a=d.

When the electric field is switched from vertical to horizontal then the orientation of liquid crystal molecules changes correspondingly if the difference of horizontal and vertical field distribution is enough to liquid crystal molecules reorientation due to free energy of system ensuring.

3. REALIZATION OF CHOLESTERIC REFLECTIVE DISPLAY

Carried out modeling of electric field distribution in the proposed liquid crystal cell construction of the LC display suggested us to use such electrode structure in the reflective LC display on the base of cholesteric liquid crystals.

In the case of using the cholesteric liquid crystal materials with the helical pitch in the visible light spectrum there is the possibility to realize the display module with color depth gradation.

Let’s consider what happen in this cell.

There are two possible ways of liquid crystal behavior:

1. If there is no field applied to the liquid crystal cell the planar reflected texture with the certain spiral pitch appears.

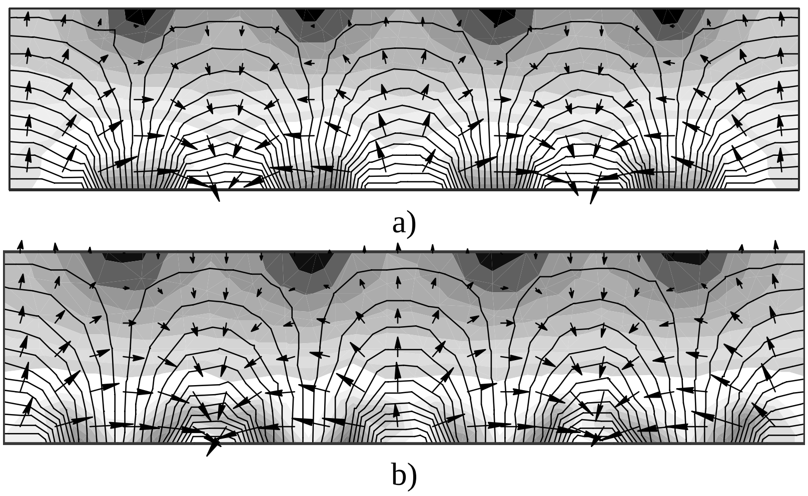
In the case when the vertical electric field is less than the cholesteric-nematic transition critical value, and horizontal field value is enough for cholesteric spiral unwinding, appears interesting situation.

Such field distribution is real, that can be seen from the modeling results (Fig.1,2), the vertical field value is twice less than the horizontal field value. In this case spiral unwinding takes place in the horizontal field region and in the vertical field regions the strong certain color does not change.

When the electric field value increases then the cholesteric-nematic transition takes place in the vertical electric field regions.

When to change the polarity of finger electrodes to the same polarity then the cholesteric-nematic transition takes place in all LC cell.

As result we obtain the color depth gradation in such LC-cell electrode configuration.



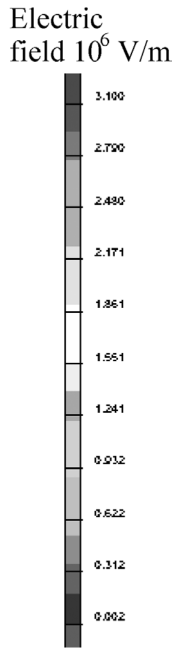


Fig. 2. The modeling of electric field distribution in LC cell with finger electrode structure:
a) a=3μм, b=2μм б) a=4μм, b=1μм

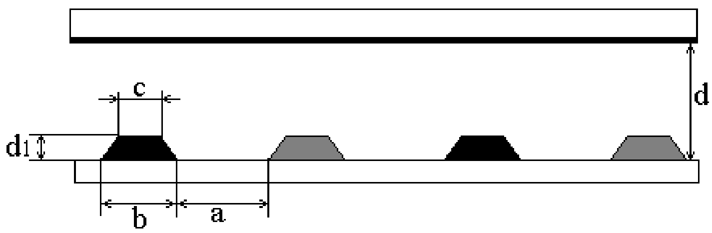


Fig. 3. Electrodes system sizes with trapezium electrodes form

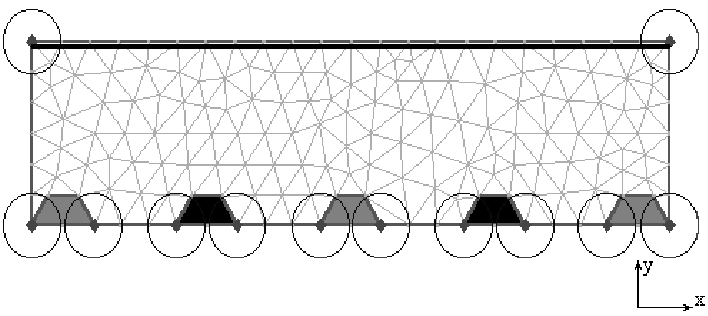


Fig. 4. The modeling process of electric field distribution

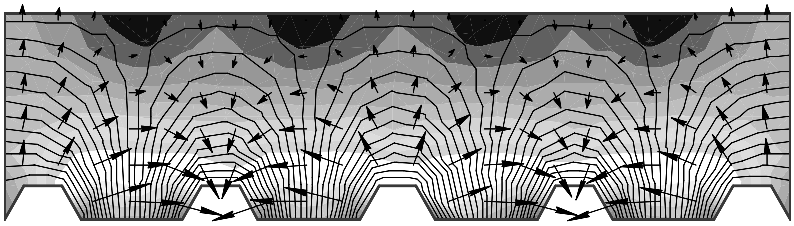


Fig. 5. Electric field distribution in LC cell:
a=70μм, b=40μм, c=20μм, d=100μм, d_1=20μм, $\varepsilon_{\parallel}$=10, $\varepsilon_{\perp}$=5

2. When the field distribution has a form as shown in the Fig.2. the strong planar reflected texture take place just in the horizontal field region, if the field value is not enough for spiral pitch unwinding, but in the region of vertical electrical field distribution the field value is enough for cholesteric-nematic transition appearance. We obtain the black color in the vertical electric field distribution regions and certain color in the regions of horizontal field.

In the case when the polarity of the finger electrodes changs to the same polarity it is the same situation as in the first case. That leads to cholesteric-nematic transition in all the LC cells, and as result all the LC cells are transparent and have black color of plane.

As a result an observer can see the three gradation of color.

Let’s conclude that the carried out calculation is very interesting in the ergonomic display characteristics performance. At first this are the contrast and viewing angle. Now these characteristics perform by the surface stabilization. Thus it is not technologically easy way [9-10]. The fine alternative of new technological methods is using the non-linearity of electric field nearby surface region of suggested display.

The viewing angle of suggested display construction is wide enough. It is the result of field orientation of near surface molecules in the perpendicular to the direction of field lines, thus appear the possibility to realize the “Віяло” texture, that characterize the wide viewing angle [11]. Because the wavelength of maximum reflection as a function of a viewing angle is given by:

$$\lambda = \lambda_z \cos\frac{1}{2}\left[\sin^{-1}\left(\frac{n}{n'}\sin\Phi_i\right) + \sin^{-1}\left(\frac{n}{n'}\sin\Phi_s\right)\right], \qquad (1)$$

where λ - wavelength of maximum scattering, λ_0 - wavelength of maximum scattering for normal light incidence and observation, n- average index of refraction, n'- index of refraction of liquid crystal (about 1,5); Φ_i - the angle of incidence, Φ_s - the angle of scattering.

There was carried out the optimization of electrode system construction with the aim of obtaining the maximum horizontal controlled field distribution. The example of full finger structure with the conic electrodes is shown in the Figs.3-5. As it can be seen the field distribution is more horizontal, than in previous electrode construction.

4. CONCLUSION

There was carried out the modeling of electric field distribution in LC-cell with a combination of the finger electrode structure and the common ITO electrode.

The interconnection between the electric field distribution and the geometrical electrode configuration in the anisotropy medium was shown.

The investigation of induced cholesteric behaviors in non-linear electric field gives the possibility of using last in the LC-cell with the proposed electrode structure, with the aim of increasing the viewing angle.

There was shown that by using proposed electrode structure there is possibility to construct the reflective display with color gradation and high viewing angle.

REFERENCE

[1] Z. Mykytyuk, V. Ivanytskyy, V. Cherpak, B. Dalanbayar. Concept of full-color WGLCD.// Proceeding of 21th International display research conference in conjunction with the 8th International display workshops, Nagoya, Japan, 2001, 257-259.

[2] Z. Mykytyuk, B. Dalanbayar, V. Cherpak, V. Ivanytskyy. Wave guide spectral selector on base of liquid crystal.// Proceeding of 21th International display research conference in conjunction with the 8th International display workshops, Nagoya, Japan, 2001, 105-108.

[3] Z. Mykytyuk, V. Cherpak, V. Ivanytskyy, B. Dalanbayar. Light scattering on domain structure in induced cholesterics.// Abstracts of 6th European confence on liquid crystals, Halle, Germany, 2001, 2P-29.

[4] Z. Mykytyuk, V. Cherpak, J. Semenova. A new creation method of color display based on cholesteric liquid crystal.// 4th International Conference on “Electronic Processes in Organic Materials”, June 3-8, Lviv, Ukraine

[5] K Kondo, "Materials and components optimization for IPS TFT-LCDs," Proc Inti Symp Digest Tech Papers, 389 (1998).

[6] K H Kim et al, "New LCD modes for wide viewing angle applications," SID Inti Symp Digest Tech Papers, 1085-1088 (1998)

[7] S H Lee et al, "A novel wide-viewing angle technology; Ultra-trans view," SID Inti Symp Digest Tech Papers, 202-205 (1999).

[8] H S Kwok, "Parameter space representation of liquid crystal display operating modes,"// Appi Phys 80(7), 3687-3693 (October, 1996).

[9] V.Sorokin, Yu.Kolomzarov, A.Kozachenko, V.Nazarenko, J.Parka. Ronning Line Type LC-Display on Cholesteric-Nematic mixture// Proc. of the 16th Int. Display Research Conference, Eurodisplay-96, Birmingham.-1996, p.341-344.

[10] V.Sorokin, Yu.Kolomzarov, A.Kozachenko, V.Nazarenko. Influence of orientation factors on the cholesteric-nematic liquid crystal displays//Proc. of the 5th Int. Symposium on Information display, Minsk, 1996 p.124-127.

[11] Sorokin v., Kuznin N.G., Oleksenko P., Kolomzarov Y., Zelinski R., Semenist V. Investigation of methods for molecular aligment on nematic and smectic liquid crystal disply // Proc.of European Conference on Liquid Crystal, Cour-Mayeur-Valle, 10-16 March, 1991, p.37.