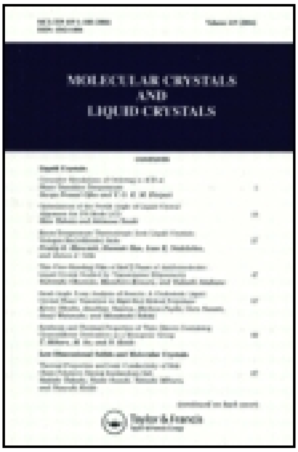

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V. M. Sorokin [a], N. G. Kuzmin [a], P. F. Oleksenko [a], Y. V. Kolomzarov [a], R. Y. Zelinski [a] & V. N. Semenist [a]

[a] Institute of Semiconductors of the Academy of Science of the Ukraine, 252650, Kiev 28 prosp. Nauki 45, Ukraine

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INVESTIGATION OF METHODS FOR MOLECULAR ALIGNMENT IN NEMATIC AND SMECTIC LIQUID CRYSTAL DISPLAYS

V.M.SOROKIN, N.G.KUZMIN, P.F.OLEKSENKO, Y.V.KOLOMZAROV, R.Y.ZELINSKI, V.N.SEMENIST
Institute of Semiconductors of the Academy of Science of the Ukraine
252650 Kiev 28, prosp. Nauki 45, Ukraine

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Abstract Comparison of electrooptic characteristics of LCD's with orienting structures made by vacuum and non-vacuum methods is demonstrated

Keywords: LCD, contrast, orientation, multiplex, glow-discharge plasma, supertwist

INTRODUCTION

One of the most important technological problems in the production of liquid crystal displays (LCD) is the problem of making high-quality oriented LC-structures.

It is preferable to explore different variants of making orienting micro reliefs for LCD by analysing the performance of vacuum and non-vacuum methods of formation of orienting surfaces.

All known non-vacuum methods of making orienting micro reliefs are based on mechanical methods of treatment of polymer films surfaces, preferably by rubbing these surfaces with napless material. This method is simple and suitable for production of TN LC-displays with limited information content. This is explained by the fact that basically rubbing of organic films yields stable orientation parameters (anchoring energy, tilt angles etc.), but with limited possibilities of changing their values appreciably.

The use of electrooptic effects in supertwisted structures or effects of bistability in SmC^* makes high demands on orienting surfaces: high tilt angles of LC molecules relatively to orienting surface (up to 25°...28°), asymmetry of orientational parameters on opposite plates of LCD, necessity of ensuring free ohmic contact between conducting ITO-film and liquid crystal, etc.

An alternative to thermal methods of producing orienting structures is vacuum treatment of the substrate in glow-discharge plasma (glow-discharge sputtering). Simultaneous sputtering of orienting material and ion bombardment of the substrate promote the formation of orienting micro relief. Modification of the orienting material and conditions of sputtering (angles of ion bombardment, ion's energy, discharge current density) allows to create structures with controlled orienting parameters. Moreover, this method ensures the possibility of forming orienting micro relief on large areas.

In this work we have investigated, and given comparative analysis of, electrooptical characteristics of LCD's with orienting structures, obtained by the vacuum method.

EXPERIMENTAL METHODS

The objects of comparison were voltage-contrast, multiplex and dynamic parameters of LCD's. Investigations were carried out on elaborated automated system of diagnostics of LCD-parameters. Experimental determinations were:

1. Dependence of light intensity passed through pixel on applied voltage.

2. On basis of the obtained dependence, static voltage contrast characteristic (VCC) of LCD C=f(U) was made, where C-contrast, $C=(F_i-F_o)/F_i$, F_o is the minimum value of light intensity passed through the cell, F_i is the value of light intensity at given U_i.

3. For given value of contrast C, threshold (Uthr) and saturation (Usat) voltage, real parameters of electric control signals were determined, imitating selected or half-selected state of pixel.

4. During half period T pulse voltage (Vs + Vd) with duration T/N (N-multiplexity) was formed for selected pixel state and (Vs-Vd) for half-selected state, where $Vd = (Uthr^2+Usat^2)^{1/2}/2$, Vs=N-Vd. For the remaining time during half-period voltage Vd was applied to pixel. During second

half-period similar signals were given to the pixel, inverted in phase. This classic circuit of representation element control allows to determine display contrast in real terms of dynamic control.[1]

5. For given values N and contrast level VCC (from 0.1 up to 0.9) signals were formed, imitating selected and half-selected image elements, and real display contrast was determined. Analysis of this result allows to determine maximum multiplex abilities of the display at given contrast level and simultaneously define with high accuracy requirements of parameters of electric signal for matrix display control.

6. For investigation of temporal parameters of the display, signals of special form were made and relaxational characteristics were recorded on printer.

EXPERIMENTAL RESULTS

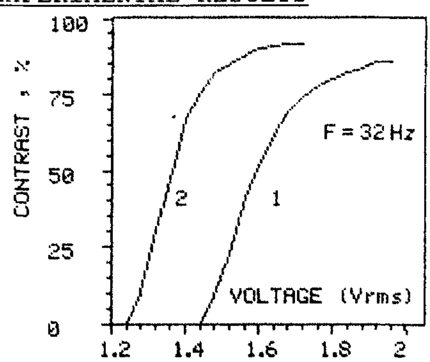


FIGURE 1 Contrast vs Voltage for TN LCD with orienting structures made by rubbing (1) and treatment in the glow discharge plasma (2).

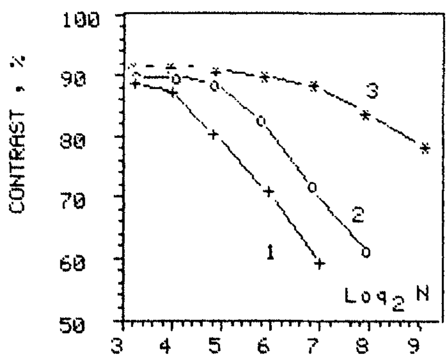


FIGURE 2 Dependence of the contrast on the multiplex ratio for TN LCD with orienting structures made by rubbing (1), TN LCD (2) and SBE LCD (3) with orienting structures made by treatment in a glow discharge plasma.

On fig.1 are given volt-contrast characteristics of TN-displays with orienting structures, obtained by mechanic rubbing of polymid, and SiOx structures created by glow-discharge sputtering. Both displays had a gap d=9 μm and were filled with the same eutectic mixture of cyanobiphenil.

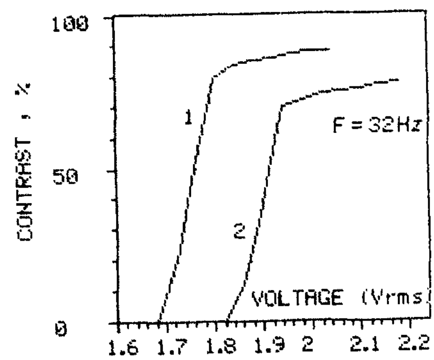
Practically all displays with SiOx-orienting structures have smaller voltage Uthr and Usat (from 0.2 to 0.4 V). Such high level contrast of static VCC shows that displays of this type can function in multiplex control mode with voltages which are some volts smaller than displays with rubbed orienting structures.

On fig.2 dependence of contrast of displays of the 1 and 2 types on the value of multiplexity N is shown. Obviously, that for level $N=2^6-2^7$ high contrast (real) of displays with SiOx - orienting structures (C > 70%) permits to use them effectively in high information content LCDs. One more important feature of these displays is high thermal stability (up to 450°C) of non-organic orienting structures, which permits to realize high-reliability hermetic sealing by glass-frit compositions.

A special interest is shown in obtaining electrooptic parameters of LCD from SBE - effect.[2-4] The greatest slope of VCC (having even hysteresis) is realized at twist angle 270°. The main requirements for realization of this effect are: tilt angle about 30° and optimal relationship $\Delta n/d$. We have made samples of LCD's satisfying these requirements. Their VCC were measured at the wave length of 534 nm. Orienting structures on both surfaces of LCD was made by glow-discharges sputtering and have LC-molecules tilt angles relative to orienting surface ranging 28°± 1° (the measurement of the tilt angles were made by magnetic-capacitance null method). With application of driving voltage the domain structures of image elements was not observed.

On fig.3 the VCC of the SBE LC-sample (1) is shown. For comparison we present on the same figure (2) VCC LC-sample on STN with twist angle 210°, in which substrate orientation was obtained by rubbing of polyimid. On fig.1 curve (3) dependence of display contrast C (270° LC- sample) on multiplexing level is shown. It can be seen that in spite of the fact that SBE-effect is the most critical due to the difficulty of achieving strict control on tilt angle and thickness of LC-layer , it gives nevertheless very high contrast even at multiplexing level N > 480.

Special interest is paid to the investigation of dynamic characteristics of LCD on ferroelectric liquid crystals. From the point of practical use for producing LCD with high information content the most promising is the effect of reorientation of LC director in surface stabilized structure SmC^* (SSFLC).[5]



N	Vd	Vs	V:kV	C%
16	1.10	4.42	V: 5V	91
32	1.11	6.63	V: 7V	91
64	1.12	8.93	V: 9V	90
128	1.11	13.25	V:13V	88
256	1.11	18.69	V:18V	84
512	1.12	25.68	V:24V	78

FIGURE 3 Contrast vs Voltage for SBE LCD (1) and STN LCD with twist angle 210° (2) and the table of optimal regime of the control scheme SBE LCD.

This effect allows to utilize such important features of ferroelectric liquid crystals as small time response and optical bistability. In the SSFLC-cells the boundary leads to compensation of helicoid spiral in the whole cell volume. The necessary condition for obtaining a good bistability is the absence of defects in the molecular orientation in so called "book-shelf" geometry[6,7]. This geometry is optimal from the theoretical point of view[5], but for some reasons is hardly realized. In reality in most cases "chevron" type or tilt structures[7] are formed. Within the limits of these structures there are two main switching modes: - between homogeneous states (so called homogeneous mode), - between twist states (twist-mode).

In the present work an example of switching between homogeneous states is described. While making the display the orienting layers were created by glow-discharge sputtering and on one of the display plates we realized direct ohmic contact between SmC^* and conducting electrode. Orienting coating on second substrate ensured tilt angle of LC molecules ranging 18°...21°.

To determine bistability parameters of these displays a bipolar impulse of duration 2T was applied to the LCD. The polarity of first impulse always resulted in cell switching in dark (closed) state. On fig.4 the dependence of cell transmission on time period at different duration of driving impulses (T) is shown.

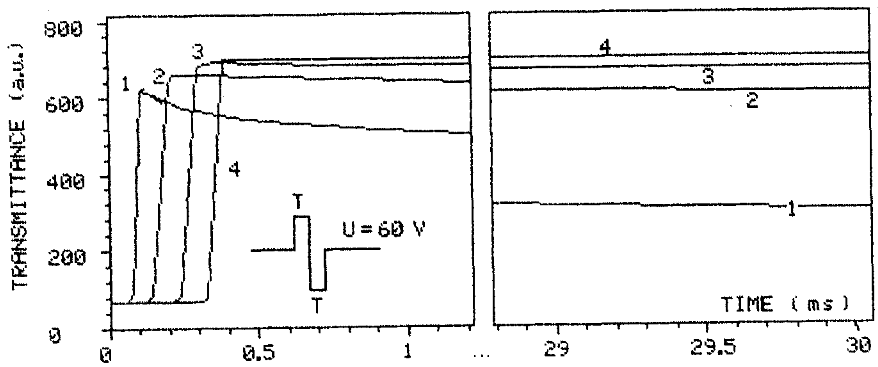


FIGURE 4 Dependence of the transmittance on the time for SSFLC cell. Period of the driving cycle 2T=100 (1), 200 (2), 400 (3), 600 (4) μS.

Obviously with a duration of write cycle 2T=100...200 μS the realization of LC - screen is possible with N=160... 320 with contrast level C>85%. Another important characteristic feature is the presence of bistability (upon removal of driving voltage) for a time period which is enough for frame writing. Moreover, we note that the information storage time may take up to several hours.

CONCLUSIONS

We have presented a comparative study of electrooptic LCD-characteristics with orienting structure obtained by glow-discharge sputtering. This technological method made possible the control of orienting parameters and the production of LCDs with high information content.

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