Plastic Bistable Nano-Ferroelectric Suspension LCD

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Abstract

We developed a plastic bistable LCD based on the suspension of sub-micron ferroelectric particles in a cholesteric liquid crystal. 2.5 inch 160x160 pixel display with enhanced contrast and improved electro-optical characteristics was achieved. The display is extremely light and possesses good flexibility, demonstrating multifold bending in a radius about 1.5 cm.

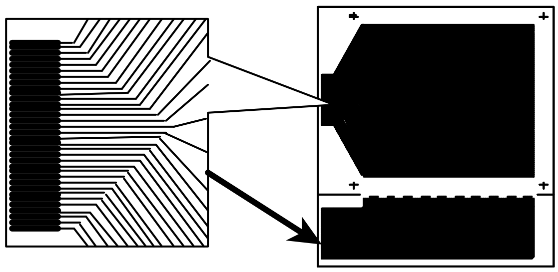
1. Introduction

Light weight and inexpensive plastic displays are very promising for the application to smart cards, mobile phones and pocket computers. Since physical and chemical properties of plastic substrates greatly differ from the properties of traditional glass substrates, the production of plastic LCD's require the development of novel technology and materials. The plastic LCD fabrication process includes low temperature deposition of ITO, micro-structured substrates, barrier polymers layers, etc. [1]. Extremely complicated mechanical stresses exerted on the display when bending make the design of flexible plastic LCD a very complicated task. Besides, the contrast of the developed plastic LCDs does not satisfy customs' requirements.

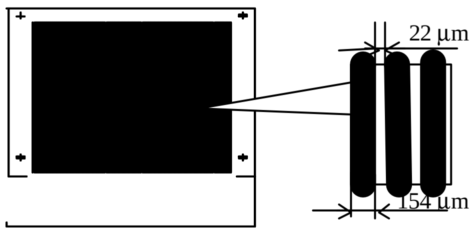
Recently we reported on the development of 16 x16 bistable cholesteric LCD, which high flexibility was provided by relatively free sliding of one substrates over the other during the bending of the LCD [2]. We also reported on the development of a new material for bistable LCDs, which consisted of dispersion of sub-micron ferroelectric particles in cholesteric host [3]. It was found that the doping of a ferroelectric particles into cholesteric LCs resulted in an increase of the contrast between focal-conic and planar textures and in a decrease of the driving voltage of cholesteric LC. The objective of the present studies was to combine the technology of sliding LCD and advantages of the ferroelectric nano-particle suspension to develop flexible and light 160x160 pixels bistable cholesteric display.

2. Results

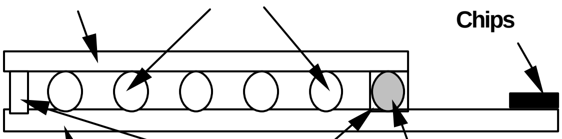
The specific feature of the design of the flexible 160x160 bistable LCD was a particular layout of the plastic substrates which allowed effective bending of the panel; both driving chips are disposed on the one of the substrate (bottom substrate) and the connection between the electrodes from the top substrate and the chip on the bottom substrate was provided by calibrated conductive balls (See Fig.1).



a) bottom substrate



b) top substrate



c) Cross-section of LCD panel

Figure 1. Schematic structure of the 160x160 pixels plastic cholesteric LCD

The substrates were made from 75μm-thick films of PET (DuPont Teijin Films) and prepared by ion cleaning in argon-oxygen plasma. The electrode stripe pattern on the inner surface of the top substrate was formed by standard photolithography process.

The obtained films had the resistance R = 20 Ohm/? and the transparency T_0 = 92 % (λ = 550 nm). The electrode stripe pattern on the inner surface of the bottom substrate was made in black and had the same resistance as the top substrate. The gap 4.5μm in the cell was kept by ball spacers stuck to the bottom substrate. The sample was sealed with polyurethane based glue DP610 (3M) by screen-printing technique.

We have investigated the suspensions of ferroelectric particles thiohypodiphosphate ($Sn_2P_2S_6$) in a cholesteric hosts BL-118 and MDA -00-1824 (Merck). Initial ferroelectric microcrystals (≤1 μm size) were mixed with a solution of oleic acid (surfactant) in heptane in a weight ratio of 1:2:10 respectively. The mixture was ultrasonically dispersed and ground in a vibration mill for 135h. The resulting ferroelectric particle solution was mixed with the cholesteric matrix. After that heptane was evaporated and the mixture was ultrasonically dispersed during 5 min. The resulting mixture contained ferroparticles (concentration (0.5-1)% by weight, < 0.2 μm size) in cholesteric matrix.

The reflection spectra from the planar textures and focal-conic structures of the suspensions and pure cholesteric are shown in Figure 2.

The reflection due to the light scattered from the focal conic domains is much less for the suspension then for the pure cholesteric. In addition, the planar state of the suspension reflects more light. As the result, the contrast of the ferroelectric suspension is much better than of the pure cholesteric LCs.

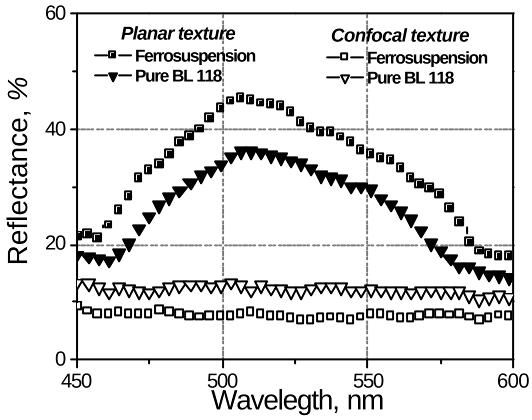


Figure 2. The reflection spectra of the BL-118 and the suspensions.

The reflectance dependences of the cells on the addressing pulse voltage for pure cholesteric LCs and ferrosuspensions are shown in Figure 3.

One can see that ferroelectric particles resulted not only in increase of the reflectivity in a planar state but in increase of the steepness of the planar-focal conic and the reverse transitions. Moreover, adding of the ferroelectric particles leads to the decrease of the voltage of these transitions. The ferroelectric particles that posses a giant dielectric constant and huge permanent dipole moment, change the balance between textures essentially. The data depicted in Figures 2,3 shows that the ferroelectric particles encourage the formation pure textures – either planar or focal-conic ones. These result in the increase of the reflectivity of the samples in the reflective planar states, decrease of the reflectivity/scattering of the focal conic state, and in the sharpness of the texture transitions. The decrease of the transitions voltage is caused by the enhanced effective dielectric anisotropy of the ferroelectric suspension [4].

The LCD cell was filled with suspension based on BL118 cholesteric LC, that posses a better properties in compare with MDA-00-1824, by a syringe at elevated temperature T > T_c and cooled down to a room temperature.

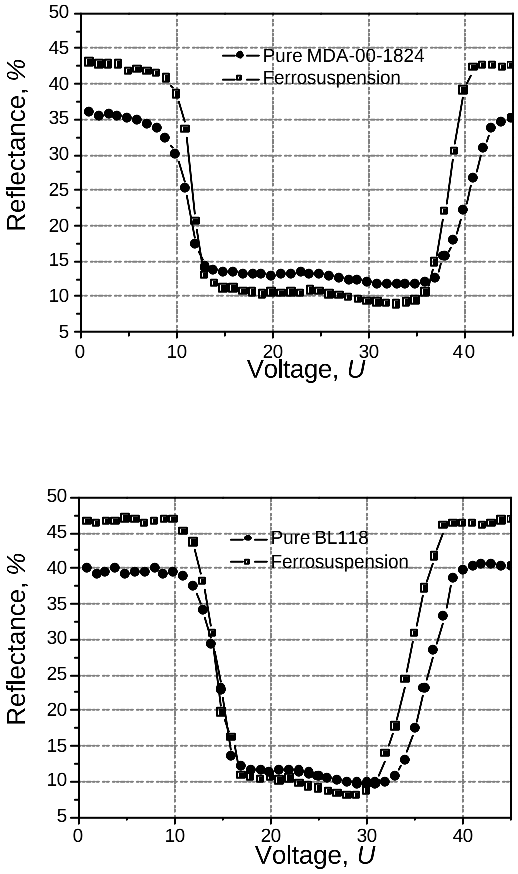


Figure 3. Dependence of reflection of the suspensions and pure cholesteric on voltage.

The LCD was driven by a microcontroller ATMega128 (Atmel Corp.) with integrated DC-DC (3/42 volts) converter (See Fig. 4). Controller was programmed and commanded from computer via COM ports. Two ZIF sockets on the controller board were used for connecting two driver chips (row and column) attached to LCD.

The PCB provided output of binary images on a bistable passive LCD panel. Controller receives graphic information from a computer via COM port to save it in internal ROM and then output it onto the panel through two chips. Controller was programmed via COM port and generated all power supplies from a single external source 3~6 Volts.

Four-stage dynamic driving sequence was applied to refresh an image at the panel [1]; preparation, hold, selection and evolve stages. During the preparation stage the sample set to the homeotropic state. Within holding stage the sample was kept in homeotropic state. Timing chart for cholesteric LC Panel updating is shown in figure 5. During the selection stage the sample passed either to confocal state or to homeotropic state depending on the voltage applied the column. During the evolve stage the selected states are kept unchanged till the finish of the frame recording.

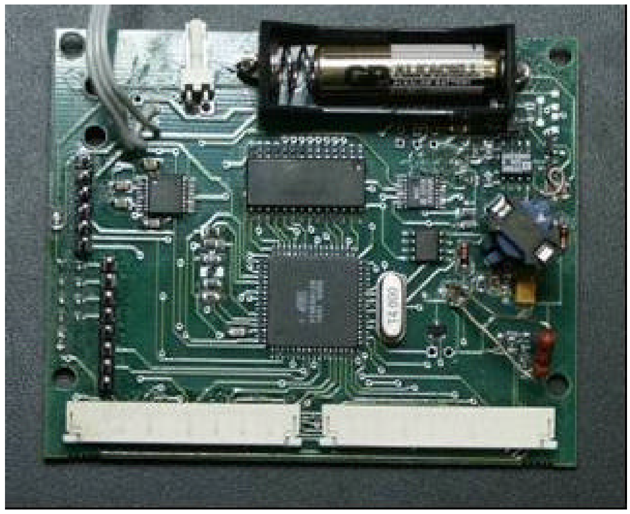


Figure 4. Picture of the PCB.

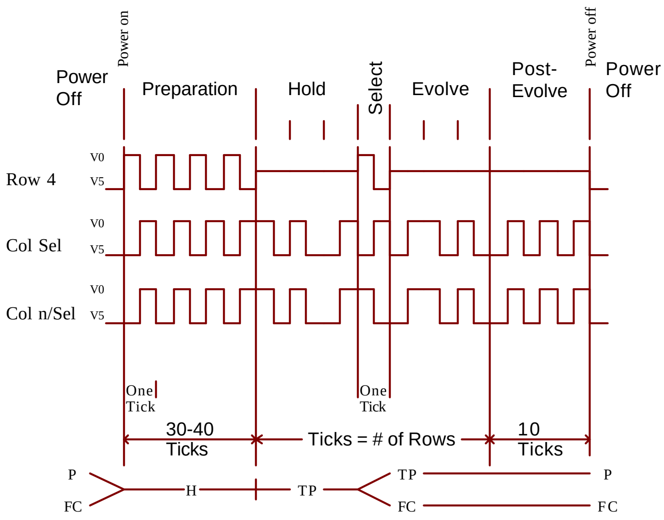


Figure 5. Timing chart for ChLCP updating (Voltages applied to Rows and Columns).

The first operating sample of plastic bistable nano-ferroelectric suspension LCD is presented in Figure 5. The sample allowed manifold bending in a radius about 1.5 cm and weighted about 5 grams. The panel is characterized by advanced contrast and electro-optical characteristics in compare with the LCD filled with cholesteric BL-118.

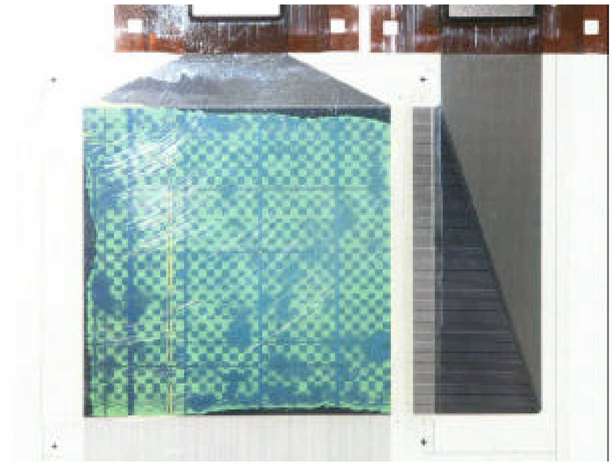


Figure 6. picture of the first sample of the plastic bistable nano-ferroelectric suspension LCD. The color inhomogeneity is caused by non-uniformity of the cell thickness.

3. Conclusion

The results obtained showed that novel LC materials based on suspension of ferroelectric nanoparticles in LC host can be successfully applied to develop hight-contrast, light flexible LCDs. We believe that ferroelectric LC nanosuspensions can be applied not only to cholesteric LCD but also to various advanced smectic and nematic LCDs. The ferroelectric nanoparticle suspension LCDs should show better properties than convertional LCDs; enhanced contrast, fast response and low driving voltage.

4. Acknowledgements

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