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Fast Switching Liquid Crystal Display by Carbon Nanotube-Dispersed Alignment Layer

Chuhyun Cho[1], You-Jin Lee[1,2], Chang-Jae Yu[1,2] and Jae-Hoon Kim[1,2*]

[1]*Department of Electronic Engineering, Hanyang University, Seoul 133-791, Korea,*
[2]*Department of Information Display Engineering, Hanyang University, Seoul 133-791, Korea,*
e-mail: jhoon@hanyang.ac.kr

We proposed a method to improve the response time of the liquid crystal display (LCD) using carbon nanotubes (CNTs)-dispersed alignment layer. The dispersed CNTs enhanced the response time due to their conducting property and steric force between the LC molecules and them. As a result, we obtained the fast response time characteristics over whole gray levels

1. Introduction

The liquid crystal displays (LCDs) have been extensively studied and used for a wide range of display applications because of their several advantages such as low power consumption, high resolution and light weight and so on. However, response time of the LC molecule is not fast enough to obtain the fast moving picture and three-dimensional displays. Therefore, in order to improve the response time, the blink backlight driving method[1] or the overdriving technologies such as dynamic capacitance compensation[2] were proposed. However, in these cases the complicated driving schemes and additional processes were inevitably involved.

Recently, the CNT-dispersed LCs were introduced to enhance the response time characteristics of the LCDs.[3-5] Here, the CNTs were dispersed in bulk region and arranged parallel to the LC molecules. The CNTs reduced the rotational viscosity[6] of the LC mixture which is proportional to the response time and thus the fast response time was obtained. In the CNT-dispersed LC mixture system, however, threshold voltage was increased by the ion/electron trap on alignment layer and the thick cell gap was required to prevent the electrically short effect between CNTs and electrode which gave rise to a slow decay time. In addition, the CNTs dispersed in the LC were vibrated with critical electric field due to the dielectric torque.[3]

In this paper, we proposed a method to improve the LC response time through the surface modification using the CNTs without any complicated driving method and the changing of LC cell parameters. We mixed the CNTs with vertical alignment (VA) and planar alignment (PA) materials. The CNTs dispersed in the alignment layer enhanced the internal electric field inside the LC layers (rising process) and the elastic forces between the CNTs and the LCs on the substrates (falling process). As a result, we can obtain the fast response time characteristics by the CNTs in alignment layer without changing the LC cell parameters and driving scheme in both rising and falling dynamics of the LC cell.[7]

2. Experimental details

Arc-discharge single-walled CNTs(SWCNTs) (ASP-100F, Hanwha Nanotech) were used in this work. The CNTs with about 90% purity typically contain bundles of the SWNTs with 5~10μm in length and 20~30nm in diameter. First, to prepare the polyimide (PI)/CNT nano-composites, the CNTs mixed with N-methylpyrrolidone(NMP) using ultrasonic treatment for 48h without surfactant. The weight ratio of NMP to CNTs was about 5000:1. The NMP solution was added to PI materials of AL60702(JSR) for VA and AL22620(JSR) for PA. The PI/CNT solution was immediately stirred with magnetic bar (1000rpm) at 40 °C. The weight ratio of NMP solution to PI was 1:1, which the concentration of the CNTs is 0.01wt%. After stirring the mixtures for 72h, the CNTs were separated by gravity for further 72h to obtain the uniform SWCNTs 1~2μm long determined by an atomic force microscopy (XE-100, Park System).

The PI/CNT nanocomposites were spin-coated on to the indium-tin-oxide(ITO) substrate and baked at 180 °C for the PA/CNT mixture or 210 °C for VA/CNT one for 1 h for complete imidization. Both substrates were rubbed in anti-parallel direction and the cell gap was maintained using glass spacers of 2.5 μm. The LC (ZKC5085-XX, $\Delta\varepsilon$ = 3.8, Δn = 0.151, Chisso) for the PA cell and the LC (MLC-6608, $\Delta\varepsilon$ = –3.2, Δn = 0.083, Merck) for the VA cell were injected by capillary action at isotropic temperature.

3. Results

We investigated the surface morphologies of the CNTs mixed PI layers. As shown in Figs. 1 (a) and (b), we observed the CNT bundle containing PI layers. The CNTs were dispersed on the PI surface in both cases. Therefore, we expect that those kinds of the CNTs at the surface can increase the internal electric field and we can obtain the fast response time by those increased electric field due to the conducting characteristics of the CNTs.

To indicate the electro-optic characteristics of fabricated sample, we measure voltage-transmittance and response time curve using a square wave voltage of 1 kHz with an increasing step of 0.1 V. Both of them show slightly decreases the threshold voltage in the CNT-added samples. The dispersed CNTs on the surface of the alignment layer enhance the internal electric field inside the LC layers. Due to the delocalized electrons and the huge area of interaction with surrounding materials, the CNTs efficiently trap the ions/charges. However, the CNTs directly contact with the ITO and thus they produce the local strong electric field.

Fig. 2 shows response time characteristics of the PI and PI/CNT-coated cells. In case of the CNTs mixed cells, the response time improved compare to that of conventional cells, which comes from the enhanced surface anchoring energy due to elastic force on the surface between the CNTs and LCs. This elastic force between the LC and CNTs on the substrate plays an important role in improving the relaxation process.

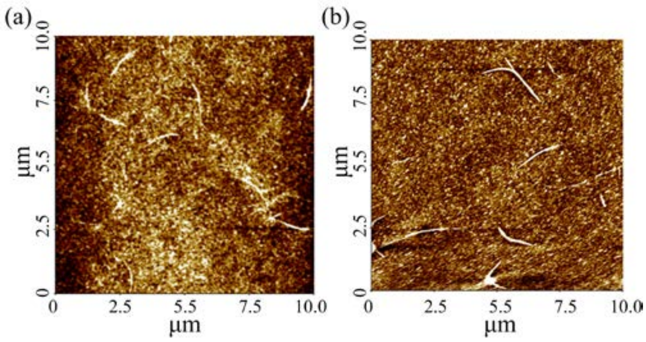

Figure 1. AFM image of CNTs mixed alignment layer of PI (a) AL60702 and (b) AL22620.

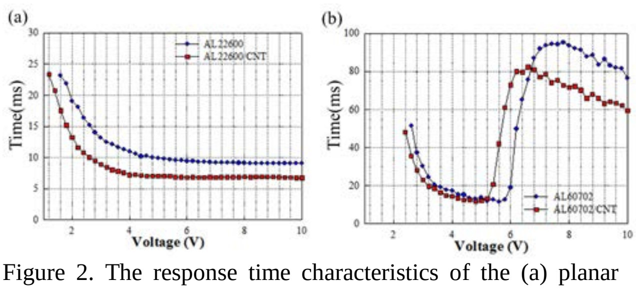

Figure 2. The response time characteristics of the (a) planar alignment and (b) vertical alignment cell. Each graph has the following conditions : PI, PI/CNT composite.

4. Summary

We proposed the method to improve the response time of the LC cell through the surface modification using the CNT dispersion in alignment materials. The dispersed CNTs enhanced the internal electric field inside the LC layers and the elastic force between LCs and CNTs on surface, which gave rise to the fast response time in both rising and falling processes over whole grey levels. We expect this method is useful to other modes using TN mode, IPS mode[8] or FFS[9] mode, and so on.

5. Acknowledgment

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