Nanoparticles-induced Alignment in Liquid Crystal Cells

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Keywords :nanoparticles, vertical alignment.

Abstract

Nanoparticles-induced vertical alignment (NIVA) in the liquid crystal (LC) devices was observed and has been applied successfully on fabricating the hybrid-aligned nematic LC cells and guest-host LC cells. In this talk, we will discuss the characteristics of the electric and optical properties of NIVA-LC cells with different dopant concentrations and demonstrate that nanoparticles can be spin-coated on the substrate at a low temperature.

1. Introduction

Nanoparticles-doped liquid crystal (LC) has been widely investigated recently. This nonsynthetic method to modify LC by adding nanoparticles in the LC is much easier than the conventional chemical synthetic methods, and it has produced many new electro-optical properties. In our previous research, the spontaneous vertical alignment of LC induced by adding nanoparticles of polyhedral oligomeric silsesquioxanes (POSS) in the LC layer (NIVA) was observed[1]. NIVA can produce vertical alignment in LC cell without using conventional vertical alignment layers. The LC device without using alignment layers is especially suitable for producing flexible plastic LC displays requiring a low temperature process. The NIVA has been applied successfully on fabricating the hybrid-aligned nematic LC cells and the guest-host LC cells[2,3].

To accurately design and fabricate the NIVA LC devices, the influence of the POSS concentration on the electric and optical properties of the LC device was examined in this work. It is suspected that the phenomenon of NIVA is due to the adsorption of the nanoparticles on the inner surfaces of the ITO glass substrates. The adsorption of the nanoparticles on the substrates will mediate and lower the surface tension of the substrates and the homeotropic alignment is induced according to the empirical Friedel-Creagh-Kmetz (FCK) rule[4]. In this work, nanoparticles of polyhedral oligomeric silsesquioxanes (POSS) were spin-coated on the substrates to serve as the alignment layers of the LC devices. The contact angle was measured to verify the FCK rule and the anchoring energy of POSS alignment layers was determined by measuring the decay time. A flexible GH-LCD by using NIVA was also demonstrated.

2. Experimental and results

The LC cell was fabricated using two ITO-glass substrates with a gap of 7.5 μm. The phenethyl substituted POSS (AminoethylaminopropylIsobutyl-POSS, Aldrich) was used as the nanoparticles. The mixed solutions of the POSS and LC ($\Delta\varepsilon = -3.1$, $\varepsilon_{//} = 3.6$) was prepared in different weight ratios (0.1%, 0.2%, 0.5%, 1%, 2.5%, 5%, 7.5%, and 10%). The dependence of POSS concentration on the electric and optic properties of homeotropic LC cells was evaluated by the Capacitance-Voltage (C-V) measurement with a precision LCR meter and transmission-voltage measurement, respectively. NIVA in LC cell with different concentrations observed under crossed POM was shown in Fig. 1. The LC molecules in a pure LC cell without alignment layer cannot align in a certain direction, so that a bright picture caused by the random orientation of LC molecules was observed as shown in Fig.1 (a). However, as POSS material was doped in the LC cell, the vertical alignment was induced and the induced alignment ability increased with the POSS concentration. The experimental results of the voltage-dependent dielectric constant ε_{cell} of the LC cell were obtained by the CV measurement as shown in Fig.2. As the applied voltage is below the threshold value, voltage-dependent dielectric constant ε_{cell} of the LC cell decreased with increasing POSS concentration and gradually approached to the value ($\varepsilon_{//}$) of the pure LC. The electro-optic properties of the LC cell with different dopant concentrations were measured as shown in Fig.3. In this study, the ~ 1 wt% POSS dopant is enough to provide a uniform coverage on the substrates and produce a pretilt angle of ~89^{o}. When the POSS concentration is less than 1 wt%, the substrates are not fully covered with the POSS and the effective pretilt angle will be changed with the concentration of POSS and become the combination of the vertical alignment (with POSS) and parallel alignment (without POSS).

For spin-coating the POSS on the substrates, the nanoparticles were dissolved in the butanol solvent by an ultrasonic mixer for few minutes. Thereafter, the solution was spin-coated on the ITO glass substrates, and a uniform POSS film of ~ 30 nm in thickness was formed after evaporating the solvent. The contact angles of LC drop on the ITO glass with and without POSS coating were 43^{o} and 22^{o} respectively. The LC cell was manufactured by using two POSS-coated ITO glass substrates and the cell gap was maintained by photo spacers at 5.4 um. The switching properties of the LC cell from 0V to 4.2V is shown in Fig. 4, where the applied voltage is turned on and off at T=0.1 sec and T= 1.6 sec, respectively. Recently, Nie *et al.*[5] proposed two approaches to estimate the anchoring energy of a LC cell when the anchoring energy is finite[5]. According to their methods, our preliminary results showed that the anchoring energy was ~1 x 10^{-5} J/m^2.

Compared with traditional alignment layers, such as polyimide, the low temperature process of using POSS alignment layers is a potential method for the applications of flexible displays. Hence, we applied POSS alignment layers by spin-coating within the flexible LC cells. Fig. 5 shows the measured voltage-dependent transmission curves of flexible LC cells with POSS alignment layers under different bending curvatures. It reveals that the bending stress can't affect LC orientation which is aligned by POSS alignment layers. Finally, we successfully applied NIVA in fabricating a GH-LCD with normally-white characteristics and a plastic GH-LC price tag is demonstrated as shown in Fig. 6.

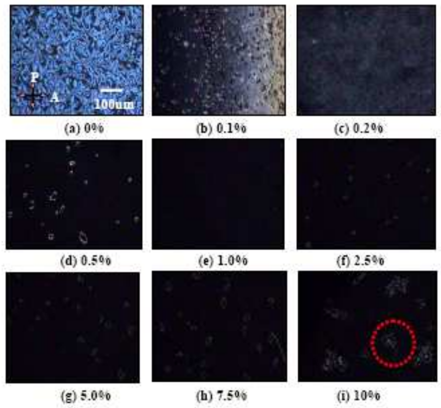

Figure 1 POM photos of a LC cell doped with different POSS concentration.

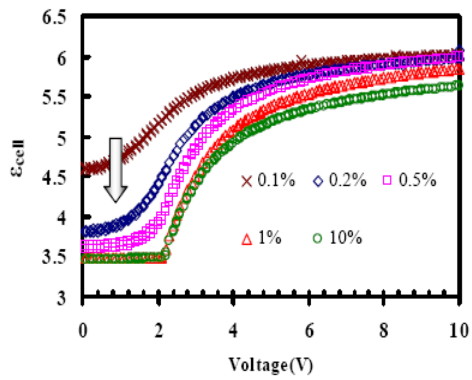

Figure 2 Measured voltage-dependent capacitance curves with different wt% POSS.

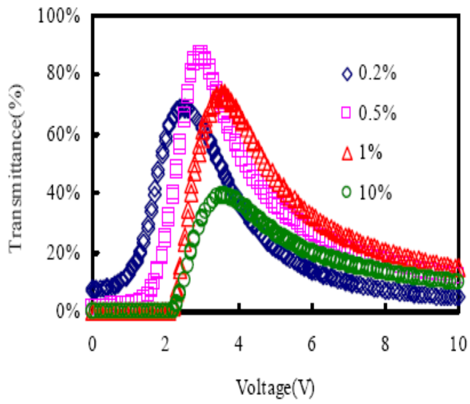

Figure 3 Measured voltage-dependent transmission curves with various POSS wt%.

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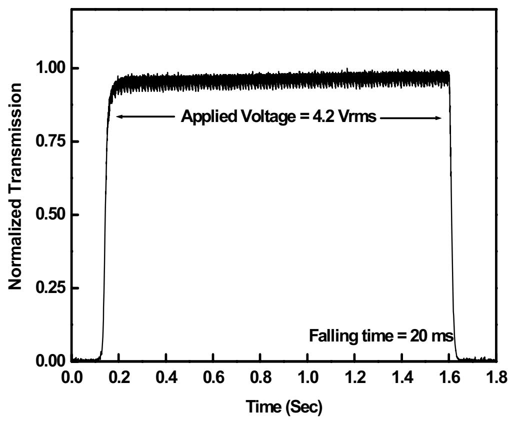

Figure 4 Optical transmission upon electrical switching.

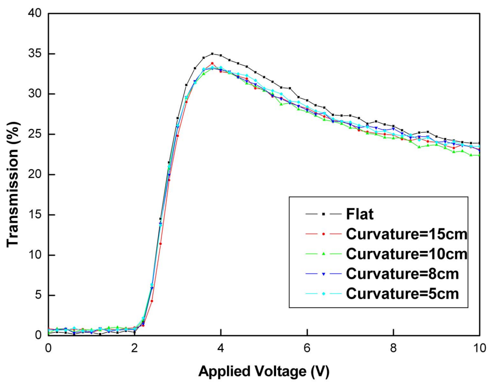

Figure 5 Electro-optical properties of bended NIVA LC cells

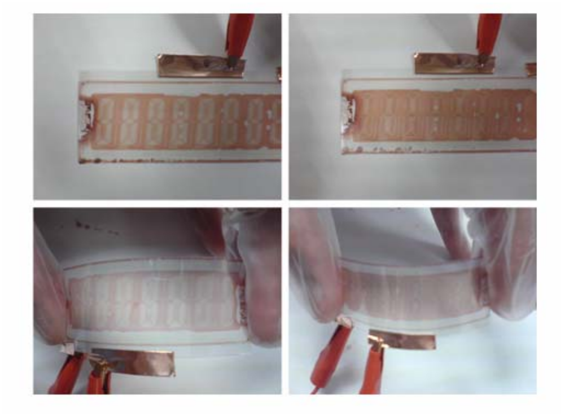

Figure 6 A flexible GH-LCD by using NIVA.

3. Conclusions

We have applied the NIVA on fabricating hybrid aligned nematic LCDs, GH LCDs and flexible homeotropic LCDs. POSS nanoparticles can induce vertical alignment due to nanoparticles absorbed on the ITO substrates and lower the surface energy. NIVA shows its potential for light-weight and low-cost flexible electronic applications.

4. References

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