The Systematically Investigation on the Influence Factor on Vertical Alignment State of Polyimide-free Liquid Crystal Displays

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Abstract

In this report, we systematically investigated the influence of types of substrate, different treatment method, the concentration of additive, the routes and temperature of possess on the polyimide-free liquid crystal display. We presume two key factors, one is self-assembly capability between additive molecule and liquid crystal (LC) molecule, the other is hydrogen bond force between substrate and additive molecule.

1. Introduction

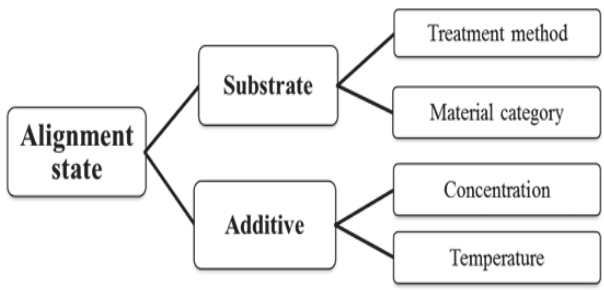
Nowadays, liquid crystal displays (LCDs) have attracted considerable attention due to their special properties, including high contrast[1], high transmittance[2], rapid response[3], etc. LCDs are widely used in information-oriented society, such as television sets , notebook computers, digital signal, etc. To date, various LC modes are used to fabricate LC device, such as twisted nematic (TN) mode[4], in-plane switching (IPS) mode[5], fringe-field switching (FFS) mode[6], polymer-stabilized vertical alignment (PSVA) mode[7]. Among these various modes, PSVA mode have a significantly high contrast ratio due to LC molecules are vertically aligned with the help from vertical alignment (VA) layers. Polyimide layers (PI) are widely used as VA layers in conventional LCD modes for LC initial alignment.. However, the preparation of VA layers usually requires large amount of chemical solvent, high temperature during post-bake, cleaning possess. Otherwise, some technology margin is limited by PI layer. Therefore, it is necessary to develop polyimide- free technology in LCD fabrication process to avoid risk, cost reduction and enhance performance.

Recently, many researches have proposed using various additive types, such as nanoparticles, polymer monomer, to replace conventional VA layers. Jeng et al. [8]reported adding silsequioxanes (POSS) nanoparticles in LC material. With help form POSS, LC maintain initial vertical alignment. Yuichi Inoue et al[9]developed a novel reactive monomer for self vertical alignment (SAVA). The different kinds of additives show different properties, adjusting additive types will improve SAVA ability. Nonetheless, alignment force is affected by many factors.

In this report, we systematically investigated the influence of types of substrate, different treatment method, the concentration of additive, the routes and temperature of possess on the polyimide-free liquid crystal display (SAVA). Various kinds of substrate was employed in this study, explored LC contact angle changed with adjusting type of substrate. Different substrate treatment methods were investigated, measuring contact angle to chosen which method is best for polyimide-free liquid crystal display. Then we explores a series of LC cells containing SAVA additive with different concentration, including mass ratio of 1 %, 2 %, 3 %. Adjusting process temperature and routes, we raised temperature at 120 ^{o}C before UV light irradiation, then compared alignment force variation at different concentration of additive. We presume the inner relationship among alignment state, additive concentration, and hydrogen groups. The self alignment force will increase with additive concentration and surface's hydrogen groups increasing .

2. Results and discussions

To evaluate the influence of the parameters to SAVA display, a series of experiments with conditions were executed, as seen as in Scheme1. As road-map shown, the main factors which influence alignment state are substrate and additive. In this study, the types of substrate and treatment method were carried out. The concentration of additive and process temperature were also investigated in this research.



Scheme 1. The road-map of influenceing factors of alignment state on SAVA.

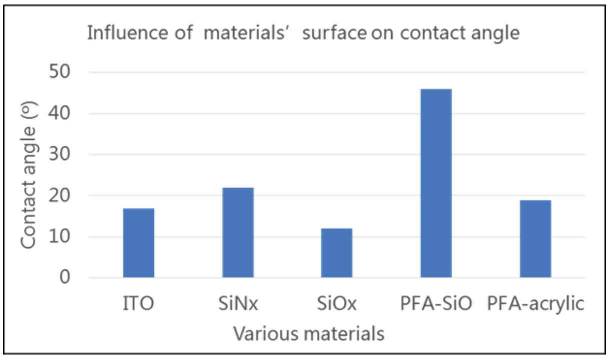


Fig. 1 Influence of various materials 'surface on the contact angle of the sample, such as ITO, SiNx, SiOx, PFA-SiO, PFA-acrylic.

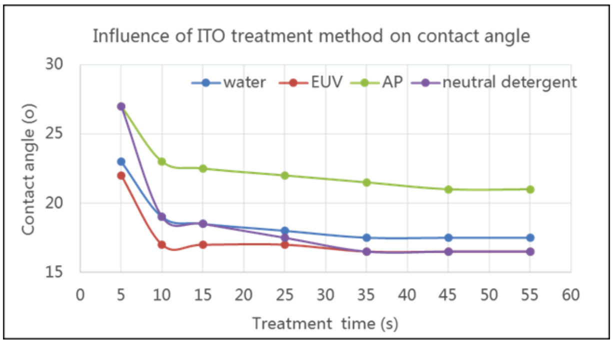
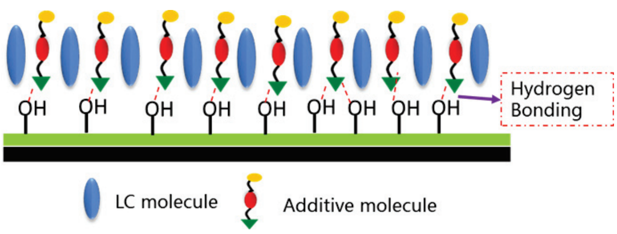


Fig. 2 Influence of various treatment method on the contact angle with ITO substrate, such as water scrubbing, EUV, AP, neutral detergent.

The properties of various types of substrates are quiet are different. As shown in **figure 1**, a serious of substrates were chosen and measured LC contact angle, to characterization of molecule force between additive and substrate.The contact angle of SiOx substrate which contains amount of hydroxyl is smallest. Due to the substrate of real panel is also tin oxide (ITO), various of ITO substrate treatment method study were carried out, as shown as **figure 2.** Extreme Ultra Violet (EUV) shows optimal performance, compared with water cleaning, plasma(AP), neutral detergent. Two types of real panels were fabricated, one substrate is SiOx, the other one is ITO. By compared with two treatment methods, dark lines were improved, shown as **figure 3**. Therefore, we presume the mechanism of substrate influence alignment state is quantity of surface hydroxyl groups on the surface of substrate. Because it will affect the strength of hydrogen force on solid-liquid interface, shown as **Scheme 2.**



Scheme 2. Schematic diagram of mechanism of intermolecular force between additive molecule and substrate at solid-liquid interface.

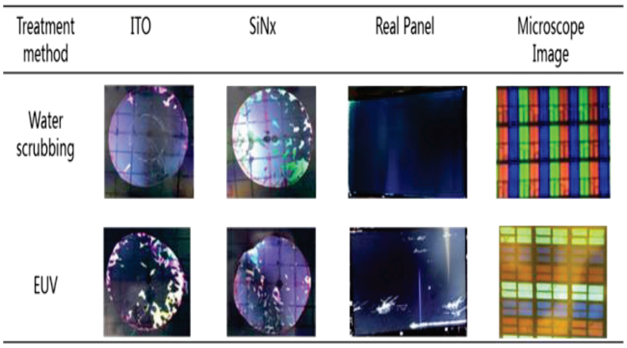


Fig. 3 Optical and microscope images of different real panel substrate, ITO and SiNx with adjusting treatment methods, such as water scrubbing, EUV. and bright state, and vertical alignment images at edge and middle area.

As **figure 4 a- c** shown, three types of LC cells (G1, 2.5*2.5 cm2, G2, 1.0*1.0 cm2, 5.0*5.0 cm2) were employed to test alignment force at different concentration of additive. As additive concentration increasing (1 %, 2 %, 3 %), edge light-leaking and alignment state significantly improved, clearly shown as figure 1 d. By compared diffusion time at different conditions, as shown as **figure 5**, additive diffusion time increased as LC cells size get bigger at the same additive concentration, additive diffusion time also increased as additive concentration get higher at the same cell size.

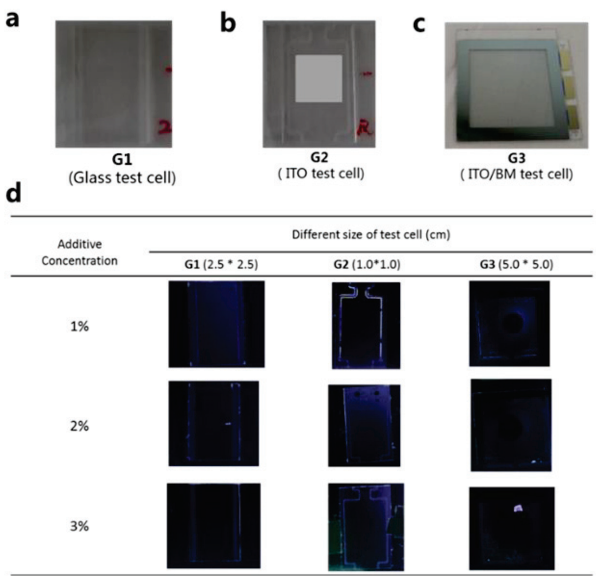


Fig. 4 a,b,c, images of test cells with different sizes; d, observation dark vertical alignment states with varies additive concentration and cell size.

To further improve alignment state, innovation process was applied in this study, added heating process before UV light irradiation. As shown as figure6, it can be clearly observe edge light-leaking and light spot before heating. After heating at 120 oC for 1 h, LC cells' light spots were significantly reduced and present well alignment state. Adjusting additive concentration from 1 % to 3 %, light spots and alignment state can be improve before heating. After heating, light spots and alignment state can all further improve, LC cells present well vertical alignment state.

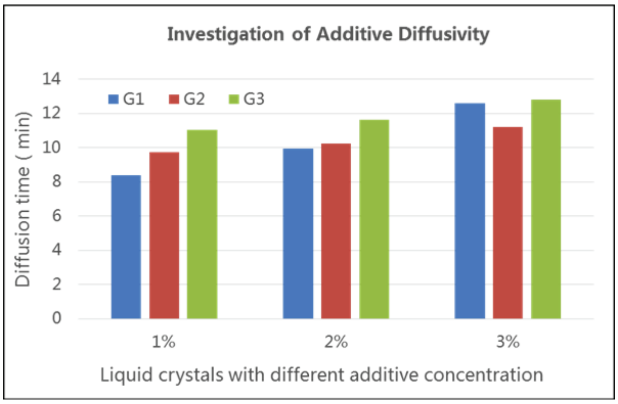


Fig. 5 The variation of additive diffusion time with adjusting additive concentration and cell sizes.

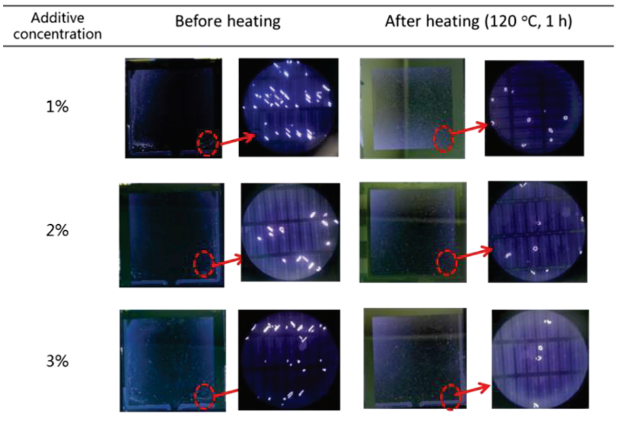
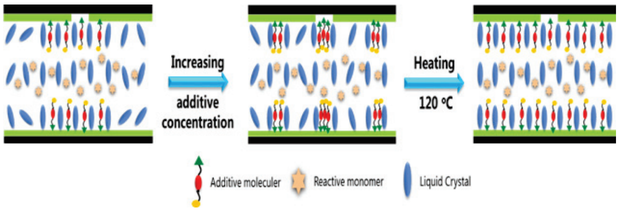


Fig. 6 The comparison images of vertical alignment state before and after heating with different concentration additive.

The presume mechanism which significantly improved alignment state is the arrangement of additive is the key influence factor to maintain LC molecule vertical alignment state, shown as scheme 3. With increasing additive concentration, more LC molecule will maintain vertical alignment with the additives' help. The alignment force become stronger with additive concentration increasing. Then, molecule and additive will rearranged during heating process. The high concentration additive will be equally distributed in LC cells, each LC molecular will esthetic vertical alignment force and maintain vertical alignment state. In a word, additive concentration increasing and heating process prompt LC molecule esthetic balance and strong vertical alignment force, thus LC cells represent well alignment state.



Scheme 3. Schematic illustrations of synthetic procedure of vertical alignment LC cell.

3. Conclusion

In this report, we systematically investigated the influence of types of substrate, different treatment method, the concentration of additive, the routes and temperature of possess on the polyimide-free liquid crystal display (SVA). We presume the inner relationship among alignment state, additive concentration, and hydrogen groups. The self alignment force will increase with additive concentration and surface's hydrogen groups increasing .

4. Acknowledgements

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5. References

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