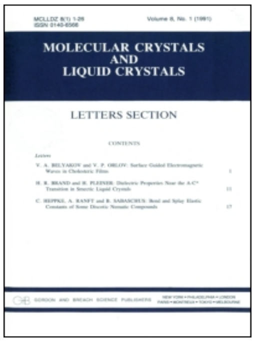

Molecular Crystals and Liquid Crystals

ISSN: 1542-1406 (Print) 1563-5287 (Online) Journal homepage: http://www.tandfonline.com/loi/gmcl20

Fabrication of a fast-switching liquid crystal device using reactive self-assembled polyimide alignment layer

Ji Yong Yoo, Intae Son, Jae Hong Kim, Byungsun Lee, Chunho Kim & Jun Hyup Lee

To cite this article: Ji Yong Yoo, Intae Son, Jae Hong Kim, Byungsun Lee, Chunho Kim & Jun Hyup Lee (2016) Fabrication of a fast-switching liquid crystal device using reactive self-assembled polyimide alignment layer, Molecular Crystals and Liquid Crystals, 635:1, 127-132, DOI: 10.1080/15421406.2016.1200379

To link to this article: http://dx.doi.org/10.1080/15421406.2016.1200379

Published online: 01 Nov 2016.

Submit your article to this journal

Article views: 15

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
http://www.tandfonline.com/action/journalInformation?journalCode=gmcl20

Download by: [College of Business Education] **Date:** 21 December 2016, At: 14:35

MOLECULAR CRYSTALS AND LIQUID CRYSTALS
2016, VOL. 635, 127–132
http://dx.doi.org/10.1080/15421406.2016.1200379

Taylor & Francis
Taylor & Francis Group

Fabrication of a fast-switching liquid crystal device using reactive self-assembled polyimide alignment layer

Ji Yong Yoo, Intae Son, Jae Hong Kim, Byungsun Lee, Chunho Kim, and Jun Hyup Lee

Department of Chemical Engineering, Myongji University, Yongin , Korea

ABSTRACT
We proposed a new vertical alignment method for simultaneously improving the alignment force and electro-optical properties. The key point of the new method is the self-assembly of the reactive monomer via hydrogen bonding with the polyimide alignment layer and the formation of pre-tilt using the reactive monomer on an alignment layer. Through the self-assembly of the reactive monomer and the generation of the pre-tilt, it is possible to obtain a higher alignment force and a fast response time. As a result, through a simple additional step, we can fabricate a fast-switching liquid crystal device using a reactive self-assembled alignment layer.

KEYWORDS
Liquid crystals; polyimide alignment layer; reactive monomer; self-assembly

Introduction

Liquid crystals (LCs) afford advantages such as high picture quality and low power consumption, and have been used extensively in display devices such as mobile phones, laptops, and televisions. For such applications involving LC display (LCD), it is important that the LC devices have excellent electro-optical properties, which depend on the alignment and reorientation of LC molecules. Many types of LCD modes such as twisted nematic (TN), in-plane switching (IPS), fringe field switching (FFS), and vertical alignment (VA) have been developed for high display performance [1–7]. Among LCD modes the VA is a very useful mode for such purpose owing to high contrast ratio, wide viewing angle, and fast falling time characteristics that can be achieved with this mode [8]. In general, a polyimide (PI) alignment layer with long aliphatic side chains is coated on to the electrode substrate to obtain the uniform initial vertical alignment of LCs. However, this vertically aligned layer might lead to some problems such as slow rising time and uncontrolled LC texture owing to the imprecise control of the reorienting direction of LCs [9–11].

Hence, in order to resolve these problems and improve the response time of LCs without any disclination defects, a new VA method should be developed for obtaining good vertical alignment and fast-switching at the same time. In this study, we report a novel VA method by utilizing the self-assembly between the reactive monomer and PI owing to hydrogen bonding. In this method, when the mixture of PI and reactive monomer of 2-carboxyethyl acrylate (2-CA) is coated on to the substrate, the reactive monomer is hydrogen-bonded with PI to achieve an improved vertical alignment, as shown in Fig. 1. Thereafter, the monomer can be

CONTACT Prof. Jun Hyup Lee junhyuplee@mju.ac.kr Department of Chemical Engineering, Myongji University, 116 Myongji-ro, Cheoin-gu, Yongin, Gyeonggi-do, 449-728, Korea.
Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/gmcl.
© 2016 Taylor & Francis Group, LLC

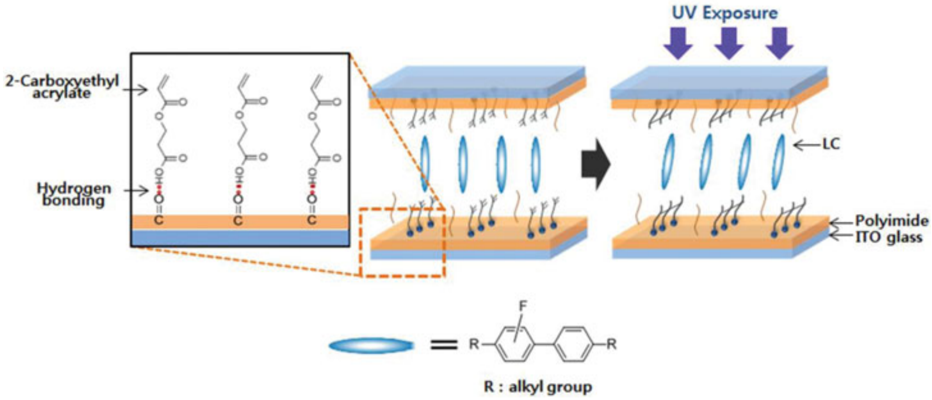

Figure 1. Schematic diagrams of the proposed VA mode with reactive self-assembled polyimide alignment layer.

polymerized by ultraviolet (UV) exposure under an applied voltage, leading to the pre-tilt for LC molecules. The polymerized monomer can memorize the switching direction on the alignment layer and improve the response time owing to pre-tilt. As a result, the LC device fabricated by the proposed method is expected to show a fast response time and a good orientation force simultaneously.

Experimental

A glass substrate coated with indium tin oxide (ITO) was used for electrode. For the LC alignment, the conventional PI (JSR, AL607XX, PI solid content = 5 wt% in N-methylpyrrolidone and gamma-butyrolactone, viscosity = 20 cP) was mixed with the UV-curable monomer of 2-carboxyethyl acrylate (Sigma-Aldrich) at 5, 10, and 15 wt% concentrations. After the resulting mixed alignment material was spin-coated on the ITO electrodes, the cell was assembled with a UV sealant (Sekisui Chemical Co., Ltd., SD-25XX) and hardened under 3.0 J cm^{-2} UV irradiation (Daihan Labtech Co., Ltd., WUV-L50). The cell gap was maintained at 5.25 µm using a spacer (Sekisui Chemical Co., Ltd., SP-205XX). Then, the nematic LC ($T_{NI} = 75°C$) was filled into the ITO cell through capillary action. The fabricated LC cell was annealed for 60 min at 100°C. In order to provide the pre-tilt to LC device, the LC cell was exposed to UV light (20 mW cm^{-2}) for 500 s under 7.5 V.

The vertical alignment of LCs was checked with a polarized optical microscopy (POM, Olympus BX51). The hydrogen bonding between the polyimide and 2-CA monomer was confirmed by using Fourier-transform infrared spectroscopy (FT-IR, Jasco FT/IR-460 Plus). The electro-optical characteristics were measured using a 632-nm He–Ne laser (JDSU, 1135P), a photodetector (EOT, ET-2000), an oscilloscope (Tektronix, TBS1062), and a function generator (Agilent, 33210A).

Results and discussion

2-CA as the reactive monomer forms dimeric structure by forming double self-hydrogen bonds in the bulk state, but adopts single hydrogen bonds when in contact with the spin-coated PI. Figure 2 shows the FT-IR spectra of pure PI, 2-CA, and self-assembled polyimides with different concentrations of 2-CA monomer. The carbonyl peak of pure 2-CA was observed at 1704 cm^{-1}, because the double self-hydrogen bonding of carboxylic acid

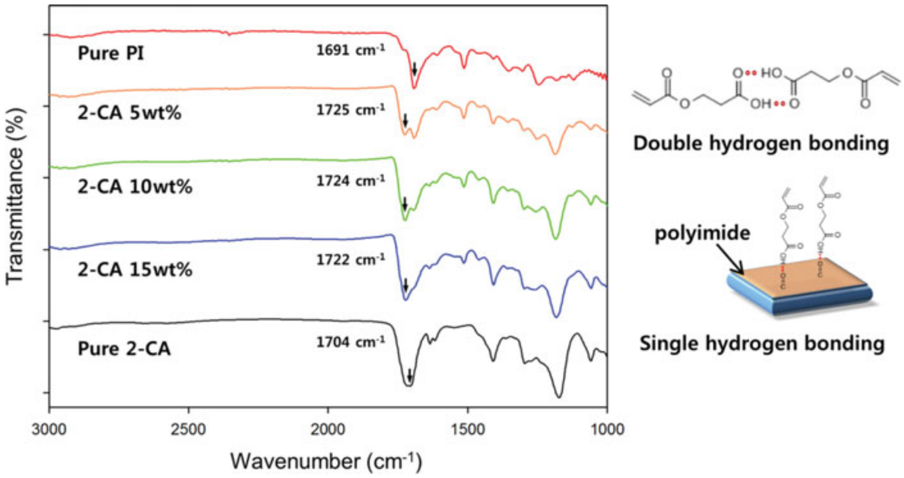

Figure 2. FT-IR spectra of pure PI, 2-CA, and self-assembled polyimides with different concentrations of 2-CA monomer.

groups restricts the C=O stretching vibration resulting in a lower wavenumber of carbonyl peak. Pure PI was observed at 1691 cm^{-1} owing to the presence of an imide ring structure [12]. In contrast, when the polyimide is mixed with 2-CA, the stretching band of carbonyl group of 2-CA shifted to higher wavenumber of about 1725 cm^{-1}, which is attributed to single hydrogen bonding between 2-CA and PI, which does not restrict the C=O stretching vibration of carboxylic acid groups of 2-CA [13]. Moreover, the absorbance of the shifted band increased as the concentration of 2-CA increased. These results confirm the formation of the self-assembled alignment layer via hydrogen bonding of the reactive monomer and the PI material.

To examine the difference in the vertical alignment state of the fabricated LC cells, we measured the POM images of the cells under crossed polarizers before carrying out the UV treatment, and they were compared with those obtained after the UV treatment. Because the main alignment component of the self-assembled alignment layer is PI, the effect of 2-CA concentration on vertical alignment can be confirmed. A comparison of the POM images shows that there is no significant difference between the LC cells containing various concentrations regardless of UV treatment (Fig. 3). Hence, it is confirmed that the vertical alignment of the

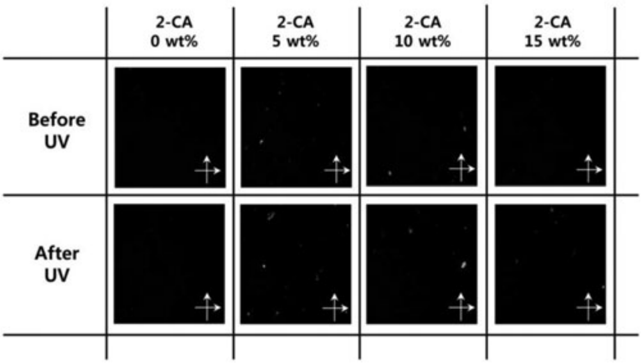

Figure 3. POM images of the fabricated LC cells before and after UV treatment.

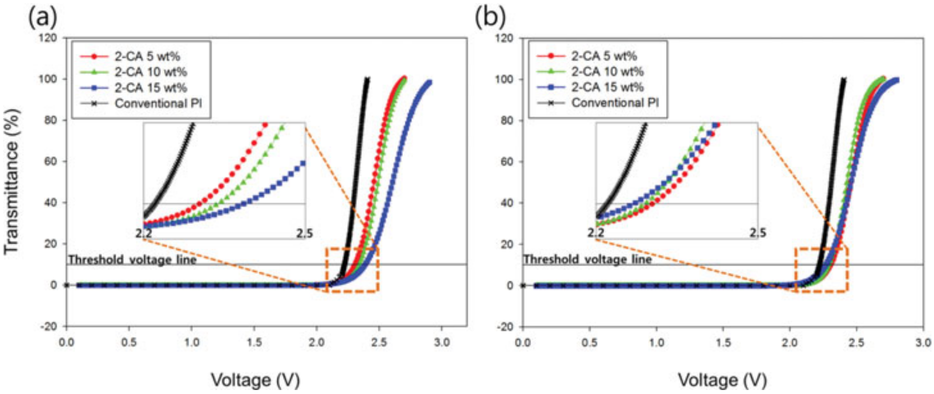

Figure 4. V-T curves of the fabricated LC cells (a) before and (b) after UV exposure.

LC can be stably maintained even after doping with a high concentration of 2-CA and subsequent UV treatment for pre-tilt.

Figure 4 shows the *V-T* curves of the fabricated cells obtained before and after the UV treatment. From Fig. 4(a), the *V-T* curve of the cells shifts to the right with increasing 2-CA concentration. In addition, it is clear that the threshold voltage (V_{th}) value of the cell with the added 2-CA monomer is higher than that of the cell with pure PI; moreover, it increases on increasing the concentration of 2-CA. Generally, the V_{th} defined as the voltage at transmittance of 10% provides information on anchoring force of alignment material, and high V_{th} value corresponds to high anchoring ability for LCs. This anchoring force is commonly governed by van der Waals interaction between the alkyl group of LC molecules and the alkyl side chains of the PI [14,15]. In addition to base PI, the alkyl moiety of 2-CA hydrogen-bonded to PI can interact with the alkyl group of LC molecules via van der Waals interaction. Therefore, these results indicate that the vertical alignment ability of the proposed LC cell increases with increasing content of the 2-CA monomer due to hydrogen bonding between the 2-CA and PI, leading to better vertical alignment than conventional PI. In contrast, after the UV treatment, the *V-T* curve of the cells shifts to the left with increasing 2-CA concentration (Fig. 4(b)). Furthermore, the V_{th} value of the fabricated cell after the UV treatment decreases on increasing the concentration of 2-CA. Since UV treatment on reactive monomer of 2-CA in self-assembled alignment layer generates the pre-tilt for LC molecules, the value of V_{th} is decreased according with 2-CA concentration. Interestingly, the V_{th} value obtained after the UV treatment is higher than that of the conventional PI, indicating that superior vertical alignment is maintained even after the formation of pre-tilt. These results suggest that the fabricated cell has a strong alignment force and can simultaneously give a high-speed response owing to the generated pre-tilt.

To analyze the response time of the LCs, we measured the response time of the cells before and after UV treatments (Fig. 5). Because the pre-tilt is not present before the UV treatment, the rising time of the cell was relatively slow with about 200 ms and the cell could not show high-speed switching control of LCs. In contrast, after the UV treatment, the rising speed abruptly increases owing to the pre-tilt. The proposed LC cells containing 5, 10, and 15 wt% of 2-CA exhibited the lower values of 12.5, 6.4, and 1.2 ms, respectively, after UV treatment. Similarly, the rising time decreases with increasing concentration of 2-CA. Hence, it is confirmed that the self-assembled alignment layer formed by hydrogen bonding between reactive monomer and PI leads to a high-speed response characteristic. Finally, the LC cell fabricated

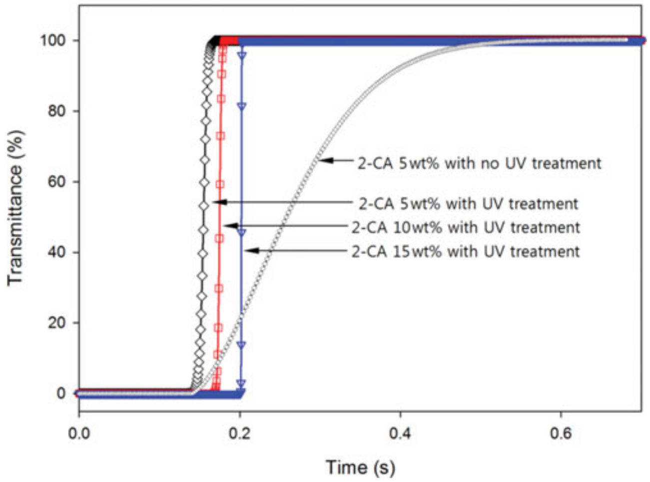

Figure 5. Response time curves of the fabricated LC cells before and after UV treatment.

by the proposed method simultaneously affords an ultra-fast response and a stable vertical alignment.

Conclusions

We proposed a new method to improve the vertical alignment and the electro-optical properties of LCs by utilizing hydrogen bonding of the reactive monomer polymerized by UV exposure with PI material. The conventional PI layer for VA mode might cause some problems such as uncontrolled LC texture and a slow rising time. Our proposed method can prevent these problems by a simple mixing of the reactive monomer capable of hydrogen bonding with PI and subsequent UV treatment. The proposed method affords superior vertical alignment to the conventional PI, and fast response time at the same time with a low cost.

Acknowledgments

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2014R1A1A2057947).

References

[1] Gooch, C. H., & Tarry, H. A. (1975). *J. Phys. D: Appl. Phys.*, *8*, 1575.
[2] Shimomura, T., Mada, H., & Kobayashi, S. (1976). *Jpn. J. Appl. Phys.*, *15*, 1815.
[3] Choi, T. H., Kim, J. W., & Yoon, T. H. (2014). *Jpn. J. Appl. Phys.*, *53*, 081701.
[4] Chen, Y., Luo, z., Peng, F., & Wu, S. T. (2013). *J. Display Technol.*, *39*, 319.
[5] Yu, I. H., Song, I. S., Lee, J. Y., & Lee, S. H. (2006). *J. Phys D: Appl. Phys.*, *39*, 2367.
[6] Tadeda, A., Kataoka, S., Sasaki, T., Chida, H., Tsuda, H., Ohmuro, K., Sasabayashi, T., Koike, Y. & Okamoto, K. (1998). *Soc. Inform. Display Technical Disgest.*, *29*, 1077.
[7] Lee, G.-D., Son, J.-H., Choi, Y.-H., Lyu, J. J., Kim, K. H., & Lee, S. H. (2007). *Appl. Phys. Lett.*, *90*, 033509.
[8] Kim, S. G., Kim, S. M., Kim, Y. S., Lee, S. H., Lee, G. D., Lyu, J. J., & Kim, K. H. (2007). *Appl. Phys. Lett.*, *90*, 261910.
[9] Kim, K. H., Park, B. W., Choi, S. W., Lee, J. H., Kim, H., Shin, H. S., & Yoon, T. H. (2013). *Liq. Cryst.*, *40*, 391.

[10] Galabova, H. G., Allender, D. W., & Chen, J. (1998). *Phys. Rev. E.*, *58*, 3295.
[11] Kimura, M., Nakata, S., Makita, Y., Matsuki, Y., Kumano, A., Takeuchi, Y., & Yokoyama, H. (2001). *Japan. J. Appl. Phys.*, *40*, L352.
[12] Maurer, M. L., Tooker, A. C., & Felix, S. H. (2014). *LLNL.*, 659320.
[13] Kung, G., Jiang, L. Y., Wang, Y., & Chung, T. S. (2010). *J. Membr. Sci.*, *360*, 303.
[14] Chae, B., Kim, S. B., Lee, S. W., Kim, S. I., Choi, W., Lee, B., Ree, M., Lee, K. H., & Jung, J. C. (2002). *Macromolecules*, *35*, 10119.
[15] Lee, S. B., Shin, G. J., Chi, J. H., Zin, W. C., Jung, J. C., Hahm, S. G., Ree, M., & Chang, T. (2006). *Polymer*. *47*, 6606.