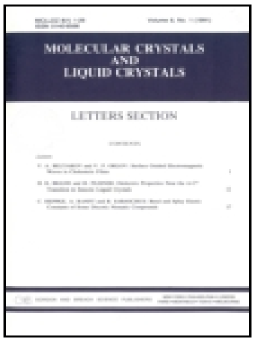

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Molecular Crystals and Liquid Crystals

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

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To cite this article: Chul Gyu Jhun & Jin Seo Gwag (2015) Four Domain Vertical Aligned Nematic Mode by Rubbing, Molecular Crystals and Liquid Crystals, 613:1, 16-22, DOI: 10.1080/15421406.2015.1032025

To link to this article: http://dx.doi.org/10.1080/15421406.2015.1032025

Mol. Cryst. Liq. Cryst., Vol. 613: pp. 16–22, 2015

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421406.2015.1032025

Four Domain Vertical Aligned Nematic Mode by Rubbing

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This paper presents a technique for producing a multi-domain VA mode using the conventional rubbing method, which is very simple LC alignment method with low cost. This method is characterized by an aluminum (Al) layer to block rubbing. The Al layer was deposited by low energy thermal evaporation that does not damage the polyimide surface. A simulation and simple experiments were performed to examine the possibility of a multi-domain VA mode using the conventional rubbing method. The proposed multi-domain VA mode will show a rapid response speed and high transmittance due to the lack of disclination formation in a LC cell, compared to the conventional VA modes.

Keywords Liquid Crystal Display; VA Mode; Rubbing method; 4-domain VA; High Transmittance; Fast Response speed

Introduction

A variety of flat-panel displays are being launched with the rapid increase in the display market. Among the many displays, liquid crystal displays (LCDs) have a dominant market share in all ranges from large panel sizes, such as LCD televisions, to small sizes, such as mobile applications [1–22]. For LCD TVs with high image quality, several LCD modes, such as fringe-field switching (FFS) mode [1], in-plane switching (IPS) mode [2], patterned vertical alignment (PVA) mode [3], and multidomain vertical alignment (MVA) [4] mode, have been introduced. The VA type modes have merits, such as high contrast ratio at normal direction and wide viewing angle with a compensation film. On the other hand, they show a slow rising speed and low transmittance because they produce transient disclination of the LC molecules due to the coincidence of the direction between the vertical electric field and initial negative LC alignment in the intermediate region between the top slit (or protrusion) and bottom slit (or protrusion). In addition, there is an undesirable electric field from the signal lines in the vicinity of the pixel edge. Therefore, the LC disclination in such LC cells are a prerequisite. The reduction of the transmittance and increase in response time is due to the existence of such disclination lines and defect points, of which the LC remains vertically aligned between the domains.

To solve these problems, Sharp Electronics suggested a photopolymer alignment technique with linearly polarized UV light to fabricate 4-domain VA-LCDs that produce very

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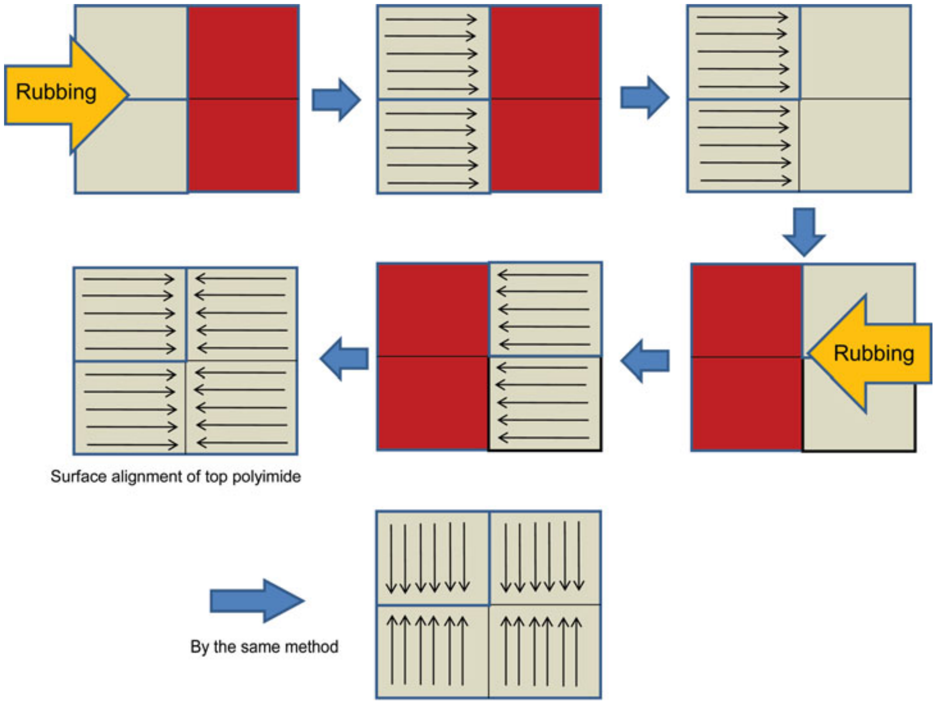

Figure 1. Schematic diagram of the rubbing directions in a pixel to produce the proposed multi-domain VA mode.

high transmittance and a fast response speed, and is now producing televisions using this technique. On the other hand, the fabrication process using photo-equipment is expensive.

This paper presents a multi-domain VA mode characterized by a conventional rubbing method, which is a very simple LC alignment technique, and a layer blocking the rubbing. As the blocking layer, Al was deposited by low energy thermal evaporation to prevent damage to the LC alignment layer (polyimide). Simulation and simple experimental studies were conducted to test the possibility of multi-domain VA mode produced by the conventional rubbing method. The proposed multi-domain VA mode showed a rapid response speed and high transmittance due to the lack of disclination formation in the LC cell unlike that observed with conventional VA modes.

Method

The production of a 4-domain with a simple rubbing process in two steps was first examined through a simulation. Fig. 1 shows the rubbing directions at a pixel in LC simulator. Each substrate requires two rubbings. A layer blocking the surface alignment covered half of the area of the surface of the polyimide, as shown in Fig. 1. When rubbed to a direction on this substrate, only the other half of the area without the blocking material will be aligned by the rubbing. In the next step, the previously aligned area is covered by a blocking material and the previous area blocked by the material is then exposed. At this time, it is rubbed in opposite direction. After removing the blocking layer by using a NaOH solution, two

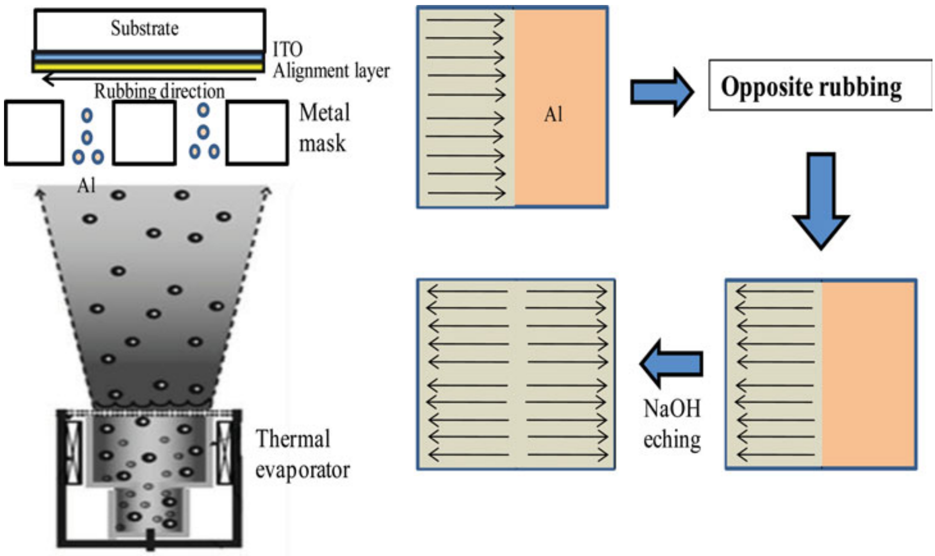

Figure 2. Schematic diagram of Al deposition by thermal evaporator and rubbing process.

alignments on the substrate are generated in mutually opposite directions. In the same manner, two alignments can be produced on another counter substrate in mutually opposite directions but perpendicular to the aligned direction of the previous substrate, as shown in Fig. 1. The pretilt angle in the present case was 88° with respect to the each rubbing direction. A simulation was also performed using the commercial LCD simulator, Techwiz 3D-LCD.

A 2-domain VA-LC cell was made to check 4-domain VA mode with the rubbing process in a small laboratory level. The vertical LC alignment material, AL60101 (JSR), was spin-coated on ITO and baked on a hot plate at 100 °C for 5 min to remove the solvent and baked on a hot plate at 200 °C for 90 min for polymerization. The polyimide was rubbed using a velvet cloth. In general, many studies have used a photo resist to make a multi-domain by conventional rubbing, which is adopted for forming surface patterns by protecting the material of a specific area from the etching solvent. On the other hand, the applications of the photo resist have been limited to the patterning of inorganic materials because it does not affect the surface of the inorganic materials due to the weaker bonding at the interface between the photo resist and the inorganic materials. In addition, when a photo resist is applied to the polyimide, which is an organic material, it can leave some residue on the surface of the polyimide in developing or stripping processes because of the stronger interaction due to bonding between similar chemical components. Therefore, it may have a deleterious effect on the surface alignment of LCs.

In this experiment, to remove any influence on the surface, Al metal was used as a blocking layer instead of the photo resist. The Al was deposited by a thermal evaporator with low energy to prevent damaging the surface of the polyimide. Al was deposited as a metal mask blocking half of the polyimide area, as shown in Fig. 2. The film thickness was approximately 50 nm. The polyimide was rubbed in the opposite direction with respect to the previous rubbing direction, as shown in Fig. 2. The Al was removed for 1 min in a 7% NaOH solution. The LC material used for the simulation and experiment was MLC-6610 (Merck), which has $\Delta n = 0.9$ and $\Delta\varepsilon = -3.1$. The cell thickness was 3.5 μm.

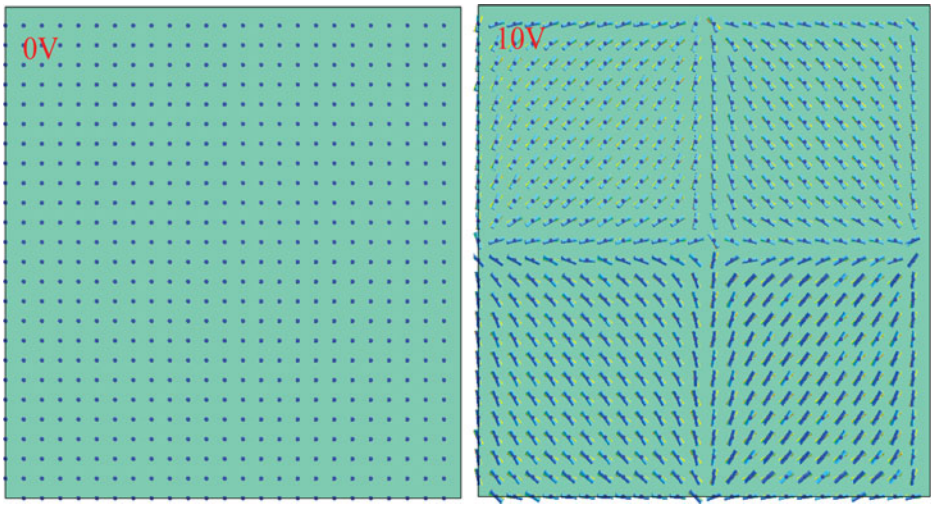

Figure 3. Simulated LC director profile at the top view when the voltages are 0 V and 10 V at the proposed multi-domain structure.

Results

Figure 3 shows the simulation results of the LC director profile at top view under 0 V and 10 V when LCs on the treated surface are aligned, as shown at Fig. 1. At 10 V, the LC directors in bulk were tilted down to $\pm 45^\circ$ with respect to the top and bottom rubbing directions, even though some twisted states were observed. As a result, the pixel with a simple two step rubbing process can produce a 4-domain at the homeotropic LC alignment layer through the simulation.

Figure 4 (a) presents a cross-sectional diagram of the simulated LC director behavior and transmittance at 8 V. Fig. 4 (b) also shows the V (voltage) - T (transmittance) curve of the proposed 4-domain VA mode. As expected, it shows very high transmittance.

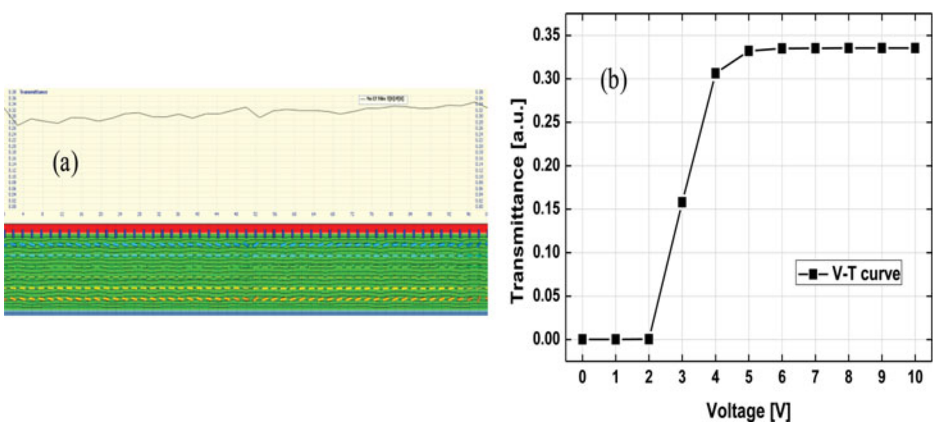

Figure 4. (a) Cross-sectional diagram of the simulated LC director behavior and transmittance at 8 V and (b) simulated V-T curve of the proposed 4-domain VA.

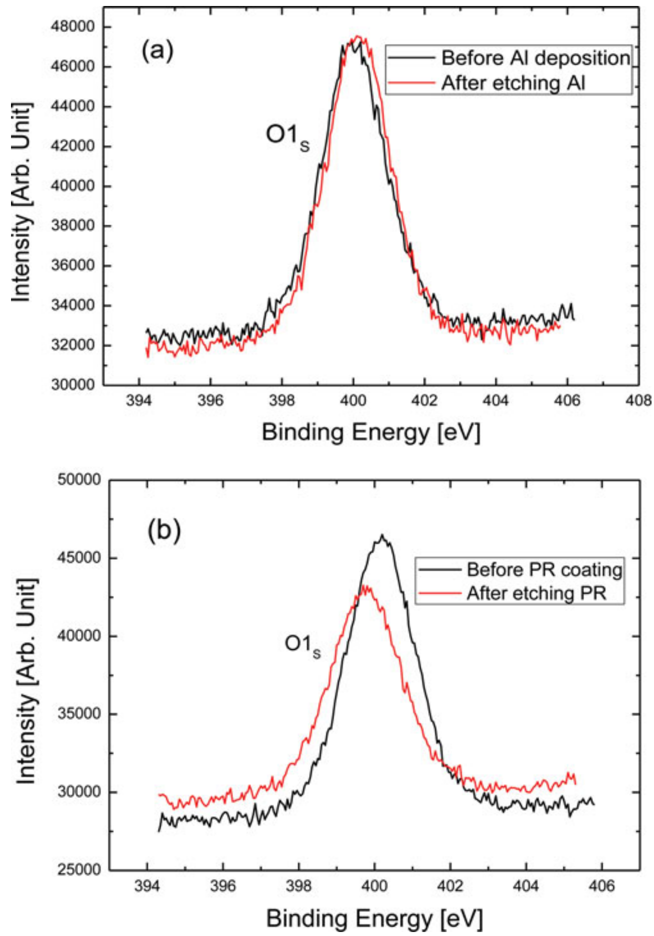

Figure 5. XPS results of (a) the surface of the polyimide before Al deposition and after etching the Al surface and (b) the surface of the polyimide before the PR coating and after etching PR.

The surface of the polyimide before Al deposition and after etching the Al layer were examined by x-ray photoelectron spectroscopy (XPS) to determine if Al deposition by the thermal evaporation method affects the surface of the polyimide. For comparison, the surface of the polyimide spin-coated by a photo resist also was analyzed. The $O1_S$ XPS peak for the molecules in the polyimide showed that the surface of the polyimide was similar before Al deposition to that after etching the Al layer (Fig. 5 (a)). As expected, low energy thermal evaporation did not affect the surface of the polyimide. On the other hand, in the case of the photo resist (PR), the surface of the polyimide was changed significantly, as shown in Fig. 5 (b). This shows the surface had been damaged after etching the PR. Consequently, the proposed technique is superior to the conventional method.

Finally, a two domain VA cell was fabricated using the proposed technique to confirm the concept of multi-domain VA. Fig. 6 shows the photo images taken at the front side, the left side, and right side of the fabricated LC cell at 0 V and 3 V. As expected, the two domain structure was formed clearly through a symmetric image of two domains at the side pictures.

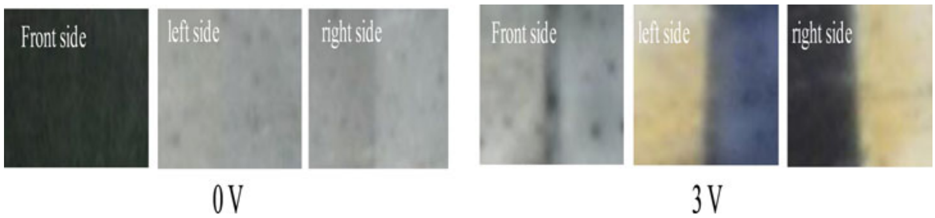

Figure 6. Photo images taken at the front side, left side, and right side of the fabricated LC cell.

Conclusion

A simple technique for producing multi-domains in VA mode was developed using the conventional rubbing method with the addition of an Al blocking layer deposited by thermal evaporation at low energy, which does not damage the polyimide surface used as the LC alignment layer. The multi-domain VA mode using the conventional rubbing method may be useful for application to transmissive type LCDs because of its many merits, such as good image quality due to the rapid response speed, high transmittance, simple fabricating process, and low cost. Consequently, the multi-domain VA mode generated using the proposed technique has excellent electro-optical properties.

Funding

This study was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science, ICT and Future Planning (No. 2013R1A1A1A05006783) and the Human Resources Development Program (No. 20124030200100) of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korean Government Ministry of Trade, Industry and Energy.

References

[1] Lee, S. H., (1998). *Appl. Phys. Lett.*, *73*, 2881.
[2] Oh-e, M., & Kondo, K. (1995). *Appl. Phys. Lett.*, *67*, 3895.
[3] Kim, K. H., Lee, K., Park, S. B., Song, J. K., & Souk, J. H. (1998). *The. 18th. IDRC*, 383.
[4] Takeda, A., Kataoka, S., Sasaki, T., Chida, H., Tsuda, H., Ohmuro, K., Sasabayashi, T., Koike, Y., & Okamoto, K. (1998). *SID.*, *1998*, 1077.
[5] Wu, S. T., & Wu, C. S. (1996). *Appl. Phys. Lett.*, *68*, 1455–1457.
[6] Miyashita, T., Yamaguchi, Y., & Uchida, T. (1995). *J. Appl. Phys.*, *34*, L177–L179.
[7] Chen, S. H., & Yang, C. L. (2002). *Appl. Phys. Lett.*, *80*, 3721–3723.
[8] Yeung, F. S., Li, Y. W., & Kwok, H. S. (2006). *Appl. Phys. Lett.*, *88*, 041108.
[9] Gwag, J. S., Park, K. H., Lee, J. L., Kim, J. C., & Yoon, T. H. (2005). *Jpn. J. Appl.*, *44*, 1875–1878.
[10] Park, S., Choi, S. W., Kim, K. H., Song, D. H., Shim, Y. R., Lee, S. Y., Kang, S. G., Yoon, J. H., Kim, B. K., & Yoon, T. H. (2013). *J. Opt. Soc. Korea.*, *17*, 200–204.
[11] Gwag, J. S., Fukuda, J., Yoneya, M., & Yokoyama, H. (2007). *Appl. Phys. Lett.*, *91*, 073504.
[12] Gwag, J. S., Lee, Y. J., Kim, M. E., Kim, J. H., Kim, J. C., & Yoon, T. H. (2008). *Opt. Exp.*, *16*, 2663–2668.
[13] Wu, S. T., & Yang, D. K. (2001). Wiley; New. York.
[14] Lee, G. D., Kim, G. H., Yoon, T. H., & Kim, J. C. (2000). *Jpn. J. Appl. Phys.*, *39*, 2716–2719.
[15] Yoon, T. H., Lee, G. D., & Kim, J. C. (2000). *Opt. Lett.*, *25*, 1547–1549.

[16] Son, P. K., Yi, J., Kwon, J. H., & Gwag, J. S. (2011). *Appl. Opt.*, *50*, 1333–1337.
[17] Tang, S. T., Yu, F. H., Chen, J., Wong, M., Huang, H. C., & Kwok, H. S. (1997). *J. Appl. Phys.*, *81*, 5924–5929.
[18] Son, P. K., Yu, S. H., Yi, J., & Gwag, J. S. (2011). *J. Appl. Phys.*, *50*, 1333–1337.
[19] Kim, S. G., Kim, S. M., Kim, Y. S., Lee, H. K., & Lee, S. H. (2007). *Appl. Phys. Lett.*, *90*, 261910.
[20] Lee, Y. J., Kim, Y. K., Jo, S. I., Gwag, J. S., Yu, C. J., & Kim, J. H. (2009). *Opt. Exp.*, *17*, 10298–10303.
[21] Choi, Y., Park, M. S., Kwon, J. H., & Gwag, J. S. (2012). *J. Appl. Phys.*, *112*, 074513.
[22] Gwag, J. S. (2013). *J. Opt. Soc. Korea.*, *18*, 78–81.