Recent Progress in New Alignment Layers and its Applications

F. S. Y. Yeung, Y. W. Li, H. L. Cheung, K. K. Li and H. S. Kwok

Center for Display Research
Hong Kong University of Science and Technology
Clear Water Bay, Hong Kong

ABSTRACT

Variable pretilt angles can be obtained by a new alignment layer consisting of a mixture of polyimides. This process does not involve any untested new materials and it is compatible with existing manufacturing techniques. Recent progress of this new alignment layer will be discussed. Fast response color-filterless No-Bias-Bend (NBB) and Optically Compensated Bend (OCB) liquid crystal displays have been fabricated by using this high pretilt angles alignment layers.

INTRODUCTION

A new method for obtaining variable pretilt angles by using nano-structured alignment surfaces was proposed and demonstrated recently[1-3]. Variable pretilt angles from 0^0 to 90^0 can be obtained by mixing vertical polyimides and horizontal polyimides by the formation of nanodomains. However there are concerns about the processability and manufacturability of this technique because of the use of a mixture of two incompatible materials. In this study, we concentrate on the processing conditions, and repeatability of the alignment method. Various important process parameters are investtigated to see how critical they have to be. Results will be presented showing that the alignment is very stable and the pretilt angles obtained are very reproducible.

RESULTS ON PROCESSING CONDITIONS

The size of the domains and the relative area ratio of the nano-structured surfaces depend critically on the rate evaporation of the solvent and the relative solubilities of the polyimides.

Study of evaporation rate

The effect of evaporation rate of polyimide on the nano-structured surface is studied. When the samples are freshly soft-baked immediately, the evaporation rate is the fastest. Figure 1 shows the nano-domains of the alignment surfaces. The picture on the rightmost shows the domain size of the substrate which is waited for 20 minutes in air before soft-baking. From the Figure 1, the domain size decreases with faster evaporation rate. The measured pretilt angles also decrease slightly with a faster evaporation rate. Therefore, accurate control of evaporation rate is needed in order to obtain accurate value of pretilt angles.

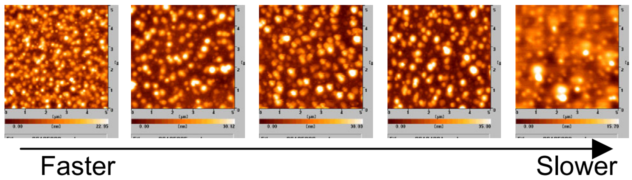

Fig. 1 Nano-domains of alignment layer under different evaporation rate.

Study of baking temperature

Different baking condition of polyimides results in different pretilt angles. We have studied the dependence of curing temperature against pretilt angles. Three samples with the same concentration of vertical polyimide are coated on the glass substrates. They were then put into an oven in vacuum and hard-baked under different temperature. The samples were then taken out and assembled into test cells.

Figure 2 shows the result of the studies. The pretilt angles increase with decreasing hard-baking temperature. As the curing temperature for horizontal polyimides and vertical polyimides is around 230^oC and 180^oC respectively, for a hard-baking temperature below 230^oC, most of the horizontal polyimides are not yet polymerized. Therefore, the pretilt angles and the alignment are not stable. In order to obtain a stable and repeatable result of pretilt angles, the curing temperature of 230^oC is fixed to use as the hard-baking temperature.

$$RS = NM\left(\frac{2\pi rn}{V} - 1\right) \quad (1)$$

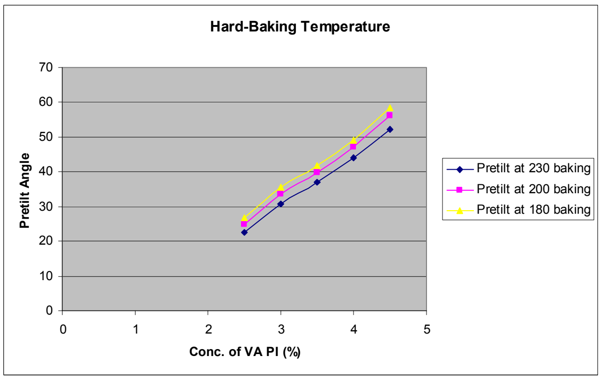

Fig. 2 Dependence of hard-baking temperature towards pretilt angles.

Study of baking conditions

In order to check the stability of the nano-structured alignment layer, hard-baking under different medium is studied. Five samples with different pretilt angles as shown in Figure 3 were put into three different 230°C ovens in vacuum, filled with nitrogen and filled with air respectively. It was found that the pretilt angles remained almost unchanged under three different conditions as shown in Figure 3. It clearly shows that the pretilt angle is stable on different baking environment.

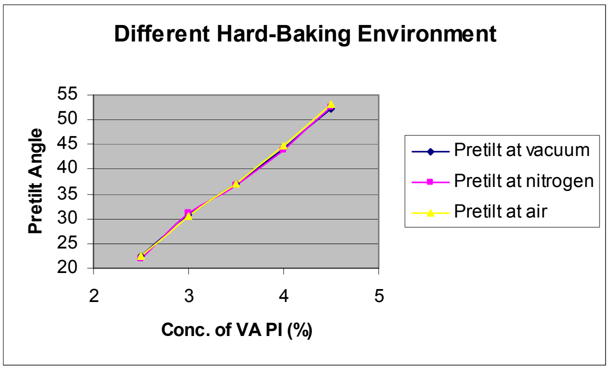

Fig. 3 Dependence of hard-baking environment towards pretilt angles.

Study of rubbing strength

The pretilt angles of the nano-structured alignment layer are directly proportional to the Rubbing Strength (RS)[4].

Where N is the number of the repeated times for the rubbing, M is the depth of the deformed fibers of the cloth due to the pressed contact (mm), n is the rotation rate of the drum (1500/60s), V is the speed of the substrate (15.0mm/s) and r is the radius of the drum (100mm).

The polyimide film is rubbed using a drum which wrapped with a nylon cloth. Different combination of rubbing times and rubbing depth of the rubbing cloth are studied. The result is shown in Figure 4.

When RS increases, pretilt angles decreases. As the number of repeated times for the rubbing process increases, the damage to the coated polyimides increases. Therefore, the best way to obtain a good alignment layer is to rub the alignment layer for one time only.

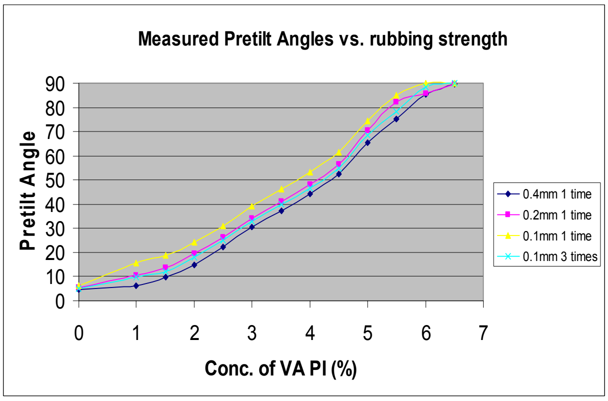

Fig. 4 Measured pretilt angles under different rubbing strength.

APPLICATIONS

The major applications of this high pretilt alignment layers are fast response color-filterless NBB and OCB LCDs.

Principle of color sequential LCD

The principle of color sequential LCD is shown in Figure 5. The driving of such color sequential LCD includes three sub-frames. The response time of the LCD needs to be very fast in order to fit the field sequential driving method.

Suppose that are 60 frames per second, then there is 16.67ms per frame. Each sub-frame will have 5.5ms. Again, each sub-frame has to further divide into three parts. The first one is the data loading time which is about 0.5ms. Secondly, it comes to the LC response time which is about 2.1ms. Finally, the LED illumination time is around 2.9ms.

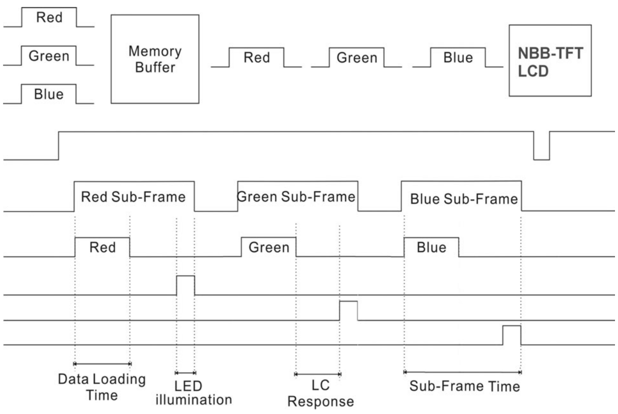

Fig. 5 Working principle of color sequential LCDs.

Recent results of color sequential LCD

A color sequential TFT-LCD is successfully fabricated and tested with the above principle.

Figure 6 shows the response time of the NBB TFT-LCD. The rise time is 1.78ms and the fall time is 310µs. Average switching time is around 1ms which is fast enough to be integrated into a color sequential LCD.

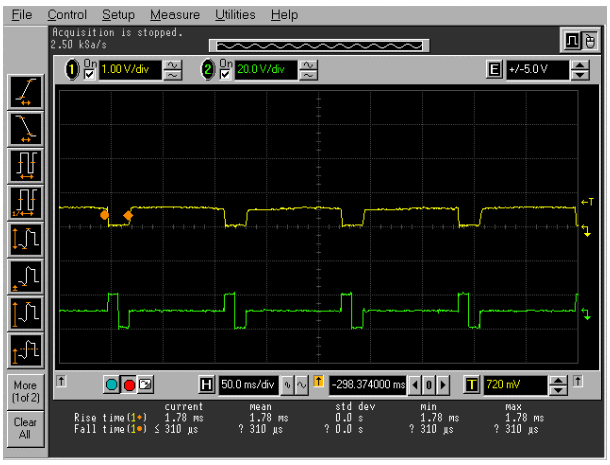

Fig. 6 Measured response time of the color sequential TFT-LCD.

Figure 7 shows a working color-filterless NBB TFT-LCD. Color mixing is clearly shown in the picture.

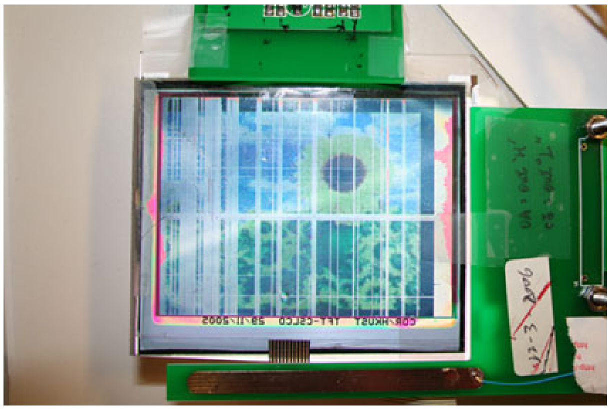

Fig. 7 A sample of the color sequential TFT-LCD.

CONCLUSION

By using the nano-structured alignment surfaces, any pretilt angles can easily be obtained. Pretilt angles can be controlled precisely through the studies of different fabrication processes. Many new LCD devices such as fast response NBB TFT-LCD can be fabricated using high pretilt angles.

ACKNOWLEDGEMENT

This research was supported by the Hong Kong Government Innovation and Technology Fund abd the Research Grants Council.

REFERENCES

[1] F. S. Y. Yeung, F. C. Xie, J. Wan, O. Tsui, P. Sheng and H. S. Kwok, SID Symposium Digest, 36, pp. 1080, (2005).

[2] F. S. Y. Yeung, F. C. Xie, J. Wan, O. Tsui, P. Sheng and H. S. Kwok, Eurodisplay 2005, pp. 514, (2005).

[3] F. S. Y. Yeung, J. Y. Ho, Y. W. Li, F. C. Xie, O. Tsui, P. Sheng and H. S. Kwok, Appl. Phys. Lett., 88, 051910, (2006).

[4] D. Seo, S. kobayashi and M. Nishikawa, Appl. Phys. Lett., 61, pp. 2392-2394, (1992).