

# Advanced Photo-Alignment Method with Fast Response Time

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## ABSTRACT

*We propose an advanced photo alignment method for uniform liquid crystal alignment by using UV curable reactive mesogen (RM) mixed in alignment layer through double step UV exposure process. Through the polymerization of RM monomers, we obtained faster response time than conventional rubbing process.*

## 1. INTRODUCTION

In liquid crystal displays (LCDs), the uniform orientation of LC directors is one of the most important factors for high display performance. A lot of alignment methods have been developed to obtain the consistent alignment of LCs.

Among these methods, rubbing method is the most widely used because of the simplicity of manufacturing process and their good thermal stability [1, 2]. However, the rubbing process has many problems such as particles from fabricating process, lack of controllability, failure to achieve multiple domain alignment, contamination of electrons and/or ions on polyimide (PI) layer and inducing electrostatic charge which can cause residual DC voltage [3].

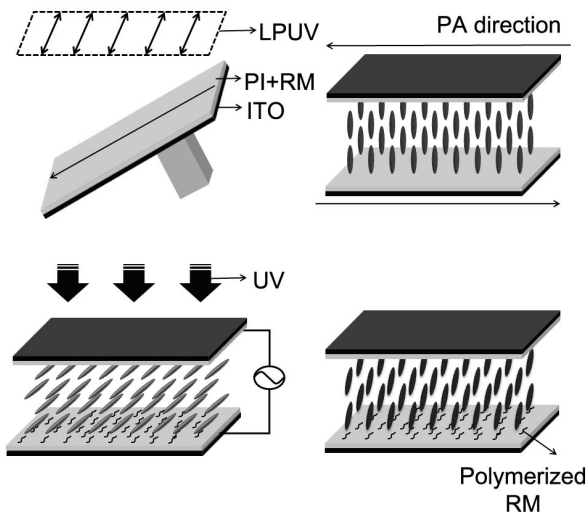
To overcome these problems, non-contact alignment methods have been developed such as oblique evaporation of SiO<sub>2</sub> on substrates [4], photopolymerized film through UV exposure [5], ion beam treatment on polymer substrates [6], etc. Among them, many kinds of photo alignment (PA) methods have been proposed with various advantages in comparison with the usual rubbing treatment of the substrates for LCDs. An anisotropic distribution of the molecules of the PA layer is generated by using the dependence of the polarization direction of the absorption of UV light by the molecules. Therefore, the PA method is free

from problems induced by rubbing. In PA method, however, it is difficult to obtain strong surface anchoring energies [7] and stable pretilt angle [8] which are crucial factors to avoid inferior alignment property, slow response time, and reverse tilt or twist domains [9]. In our previous work, we report the surface controlled patterned vertical alignment (SC-PVA) mode with fast response time using PI-RM alignment layer [3]. As the SC-PVA sample with PI-RM layer is exposed to UV light with applying field, RM monomers are polymerized and anchor LC molecules near the alignment surface LC in the certain polar direction, simultaneously. As a result, the pretilt angle was generated and then the response time could be enhanced.

In this letter, we demonstrate the advanced PA method with a strong anchoring energy as well as fast response time through double step UV exposure processes by using the polyimide (PI) alignment material and reactive mesogen (RM) mixture.

## 2. EXPERIMENTAL

Figure 1 shows the schematic diagrams of a proposed PA method process. In our study, we used cleaned glass substrates coated indium tin oxide (ITO) for electrodes. For alignment materials, we prepared the mixture of conventional positive type vertical polyimide (VPI) material (AL60101, JSR) whose chemical bonds are dissociated in the direction of linearly polarized UV (LPUV) light, proper amount of RM monomer (BASF), and photo initiator (IRGACURE 651 from Ciba chemical) which can enhance the photo reactivity according to UV light. The mixture was spin coated on both ITO glasses at the rate of 1000 rpm for 10 sec and then 3000 rpm for 20 sec. The alignment layer was pre-baked at 80 °C for 10 min followed by curing at 180 °C for 1 hour.

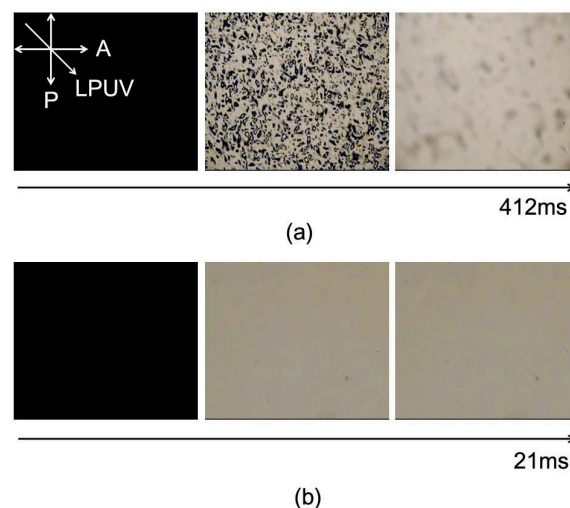


**Fig. 1** The schematic diagrams of proposed PA method.

As shown in Fig. 1, the prepared VPI-RM layers were irradiated to the obliquely incident LPUV with  $30^\circ$  for 15 min as the 1<sup>st</sup> step UV exposure to induce in-plane and out-of-plane surface anisotropy. Subsequently, the rubbed VPI substrates and VPI-RM substrates exposed by LPUV are assembled with  $3\ \mu\text{m}$  glass spacer and the nematic LC, MLC 6610 ( $\Delta\epsilon < 0$ , Merck), was injected to VPI and VPI-RM samples. At this state, the VPI-RM sample has a pretilt angle induced by 1<sup>st</sup> LPUV exposure but the reverse tilt domains was observed when the voltage is applied because the induced pretilt angle is very small as conventional PA methods do. To increase the pretilt angle, we exposed the 2<sup>nd</sup> step UV to the VPI-RM sample with applied voltage, the RM monomers are completely polymerized and anchor the LC molecules near the alignment layer surface depending on an applied voltage. Therefore, the photoaligned VPI-RM samples have an increased pretilt angle.

### 3. RESULT AND DISCUSSION

In our studies, the used VPI is positive type whose photosensitive bonds are dissociated in the parallel direction of LPUV polarizing axis. Non-dissociated PI molecules generate the anisotropy which induces a particular alignment of LC molecule near the layer. Therefore, the LPUV exposed PI can orient the LC molecule perpendicularly to the direction of LPUV.



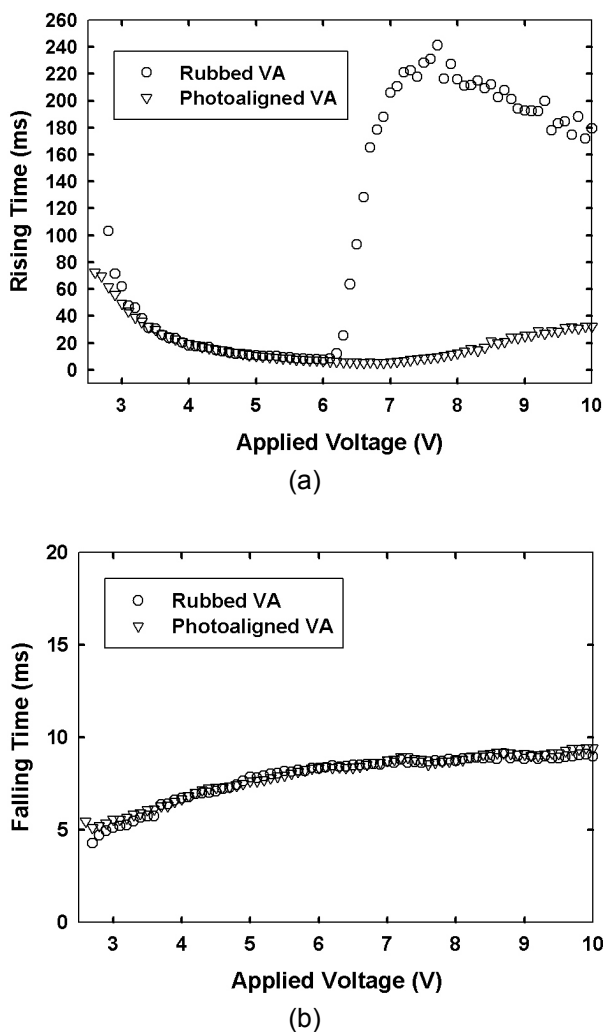
**Fig. 2** Time-resolved microscopic textures for photoaligned VA mode sample (a) before 2<sup>nd</sup> UV exposure and (b) after 2<sup>nd</sup> UV exposure with XX V.

Figure 2 shows the time resolved textures of the proposed VPI-RM samples after 1<sup>st</sup> LPUV exposure and 2<sup>nd</sup> UV exposure under crossed polarizers. After 1<sup>st</sup> UV exposure, the long reorientation time of LC directors is need because of the low pretilt angle. The measured pretilt angle's value was about  $88.5^\circ$ . Therefore, when the voltage is applied, it is easy to observe disclination lines and reverse tilt domains in the whole area of sample.

After stabilization of LC directors with applied voltage, the RM monomers in the alignment layer are aligned along the director of LC molecules. That is because the RM monomers have some fluidity and the alignment characteristics of LC phase, so they are aligned along with LC molecules to reduce the exclude volume. At this state, the cell was exposed the 2<sup>nd</sup> UV light and the RM monomers are polymerized. The polymerized RM generated the pretilt angle on the surface and it can enlarge the surface anchoring energy. These effects are resulted in microscopic textures, as shown in Fig. 2(b). We could get uniform texture without any disclination lines and reverse tilt domains and the reorientation time for stabilization of LC molecules was dramatically enhanced. In the experience, the response time of PA sample before and after 2<sup>nd</sup> UV exposure was 412ms and 21 ms, respectively, and the measured pretilt angle was  $87^\circ$ .

To evaluate the improved characteristics of samples fabricated by our proposed PA method, we compare the response time of our proposed VPI-RM sample after 2<sup>nd</sup> UV exposure and rubbed VPI sample. Figure 3 shows the measured rising and falling time characteristics of both samples. When the applied voltage is less than 6V, the rising time is

almost same between rubbed VPI and proposed VPI-RM samples, as shown in Fig. 3(a). On the contrary, when the applied voltage is larger than 6V, the rising time is definitely improved due to the high pretilt angles which can defined the falling direction of LC molecules. The falling time characteristics are almost same between both samples, as shown in Fig. 3(b). This means that the surface anchoring energy of proposed VPI-RM sample is sufficiently high to get the excellent display performance even comparing to rubbed VPI sample.



**Fig. 3 The response time characteristics for rubbed VA and photoaligned VA sample after 2<sup>nd</sup> UV exposure as a function of the applied voltage: (a) the rising time and (b) the falling time.**

We estimate that our PA method can achieve the strong anchoring energy sufficiently compare to conventional PA method. In the near future, we will study the polar and azimuthal anchoring energy of samples fabricated by our PA method and certificate our deduction that anchoring energy is enhanced.

#### 4. CONCLUSION

We propose the advanced PA method which can overcome problems of conventional PA method such as unstable pretilt angle, slow response time, and insufficient anchoring energy. The RMs which be mixed in the PI alignment layer are polymerized by double step UV exposing process in the presence of an electric field. At this process, we can be achieved enough high pretilt angle for uniform alignment of LCs as well as anchoring strength for fast response time by PA method.

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