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Liquid crystal alignment and pretilt angle generation on a photopolymer layer based on *N*-(phenyl)maleimide

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A photopolymer based on *N*-(phenyl)maleimide was synthesized and the liquid crystal (LC) alignment effects of the photopolymer layer on homeotropic alignment were studied. Good LC alignment with UV exposure of PMI5CA (*N*-(phenyl)maleimide with a 5-carbon chain cinnamoyl group) was obtained. However, defective LC alignment was observed for PMI3CA (*N*-(phenyl)maleimide with a 3-carbon chain cinnamoyl group) and PMIF (*N*-(phenyl)-maleimide including a fluoro-cinnamoyl group). Good LC alignment with UV exposure on the PMI5CA surface was observed with annealing temperature up to 150°C. It seems that the LC aligning ability of the photopolymer layers based on *N*-(phenyl)maleimide depends on the side chain length of the photopolymer.

1. Introduction

Liquid crystal displays (LCDs) require uniform alignment and stable pretilt angles on a substrate layer. Rubbed polyimide (PI) layers have been widely used to align LC molecules, and the effect of unidirectional rubbing on various alignment layers has been discussed by many investigators [1–6]. The rubbing method presents a number of obstacles, such as the generation of electrostatic charge and the creation of contaminating particles. In a previous paper, we reported the generation of electrostatic charges on various PI layers during rubbing [7]; thus, rubbing-free techniques for LC alignment are required in LCD technology. The photoalignment method is one of the most promising rubbing-free methods; photoalignment of LCs, with the use of a poly(vinyl)-cinnamate and other photopolymer layers, has been proposed by many researchers [8–17]. However, the thermal characteristics of acrylate material in the backbone photopolymer structure have not been satisfactory for good LC alignment capabilities.

In this work, we report the synthesis of new photopolymers based on *N*-(phenyl)maleimide and the LC alignment capabilities of the photopolymer layer.

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2. Experimental

Figure 1 shows the chemical structure and copolymerization of the photopolymers based on *N*-(phenyl)-maleimide. The three photopolymers are as follows.

(a) PMIF: *N*-(phenyl)maleimide including a fluoro cinnamoyl group;
(b) PMI3CA: *N*-(phenyl)maleimide with a 3-carbon chain cinnamoyl group;
(c) PMI5CA: *N*-(phenyl)maleimide with a 5-carbon chain cinnamoyl group.

The polymers were applied to indium tin oxide (ITO) coated glass substrates by spin-coating, and were cured at 130°C for 1 hr. The thickness of the monomer layer was 500 Å. The linearly polarized UV (mercury lamp, 500 W) exposure system is shown in figure 2. The substrates were exposed to UV at a wavelength of 365 nm; UV energy density was 5.8 mW cm^{-2}. The LC layer used was 60 μm thick. The NLC used is a fluorinated-type mixture ($\Delta = 8.4$; $T_c = 72$°C; MJ97359 from Merck Co., Ltd) and negative LC ($\Delta = -4$; MJ98468 from Merck Co., Ltd). The pretilt angle of the NLC was measured by a crystal rotation method.

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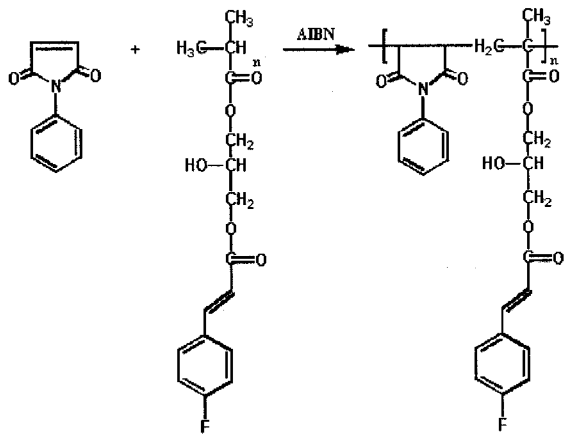
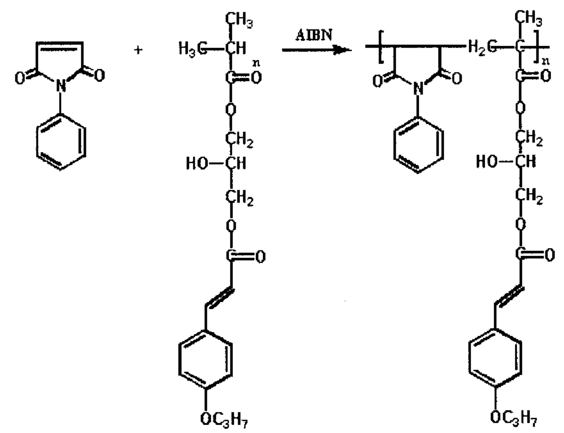
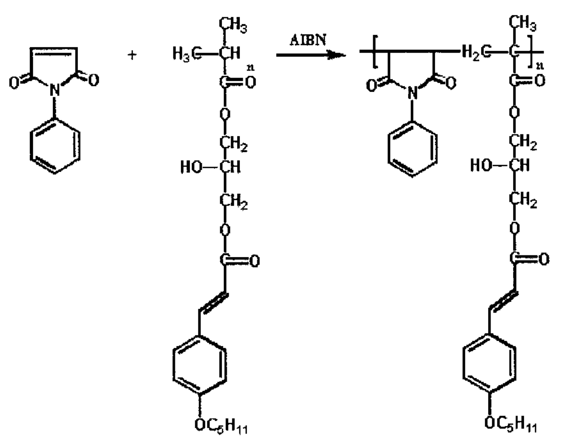


(a) PMIF



(b) PMI3CA



(C) PMI5CA

Figure 1. Chemical structure and copolymerization of the photopolymer based on *N*-(phenyl)maleimide.

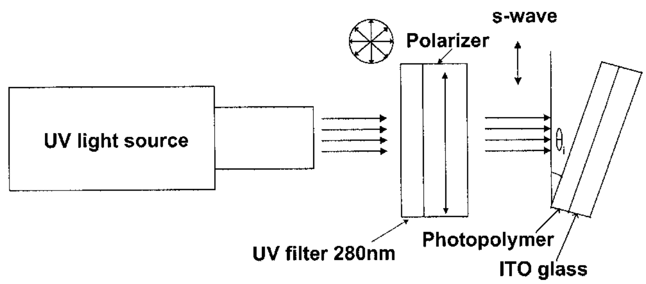


Figure 2. Schematic diagram of UV system.

3. Results and discussion

Figure 3 shows the thermogravimetric analysis (TGA) characteristics of the photopolymers based on *N*-(phenyl)-maleimide. TGA measurement revealed that the synthesized photopolymers have satisfactory thermal stabilities up to 350°C.

Figure 4 shows the UV absorption spectra of the three new kinds of photopolymer. UV absorption was observed at 250 ~ 350 nm, it decreased with increasing UV exposure time. It is considered that the low UV absorption is attributable to the [2+ 2] cycloaddition reaction by broken C=C bonds. The UV absorption shifted to longer wavelengths as the alkyl chain length increased.

Photomicrographs of the LC cell with UV exposure on the three kinds of photopolymer layer based on *N*-(phenyl)-maleimides are shown in figure 5; in (*a*) and (*b*), LC alignment defects were measured for UV exposure on the PMIF and PMI3CA layers. However, good LC alignment for the PMI5CA layer was observed. Therefore, good LC alignment can be obtained on the photopolymer layer based on *N*-(phenyl)maleimide with a 5-carbon

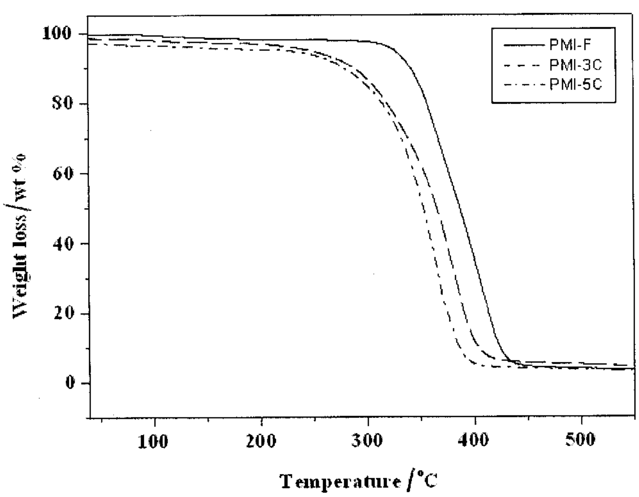


Figure 3. TGA characteristics of the photopolymer based on *N*-(phenyl)maleimide.

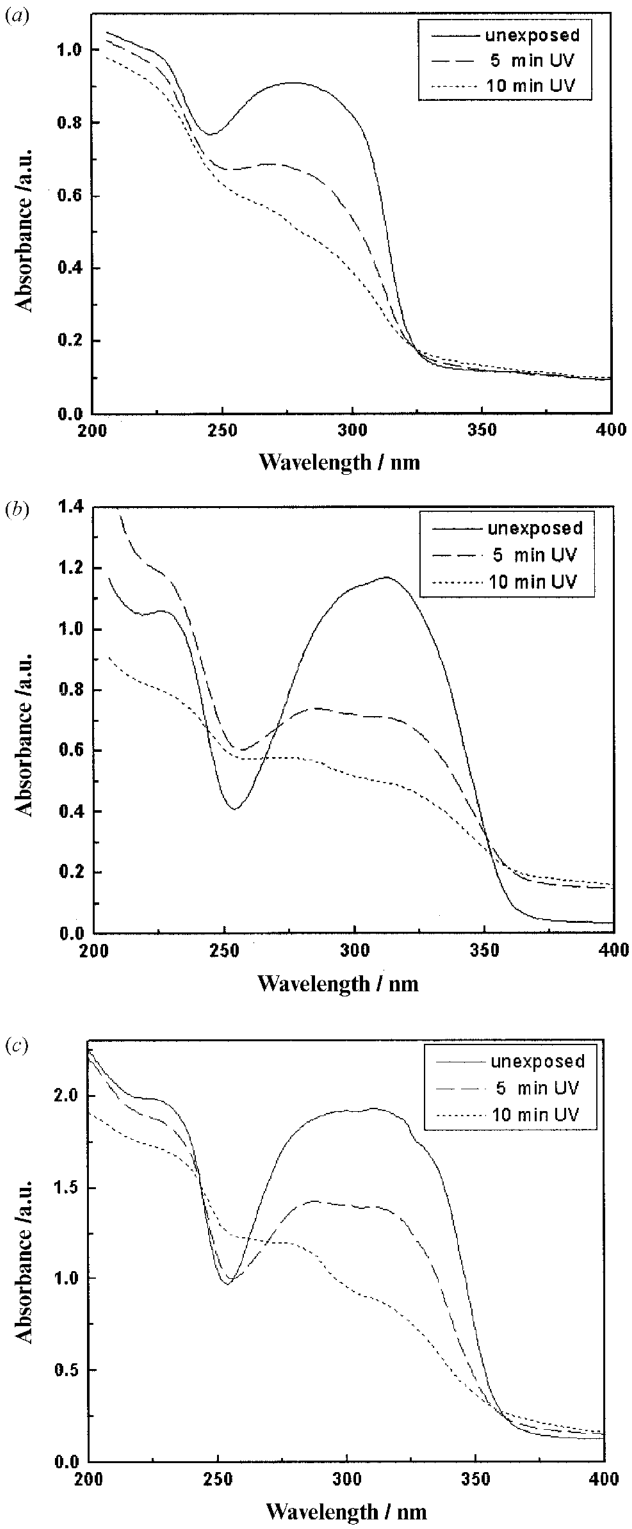


Figure 4. UV absorption spectra of photopolymers based on *N*-(phenyl)maleimide: (*a*) PMIF, (*b*) PMI3CA, (*c*) PMI5CA.

chain cinnamoyl group; LC alignment thus strongly depends on the alkyl chain length of the photopolymer for *N*-(phenyl)maleimide materials.

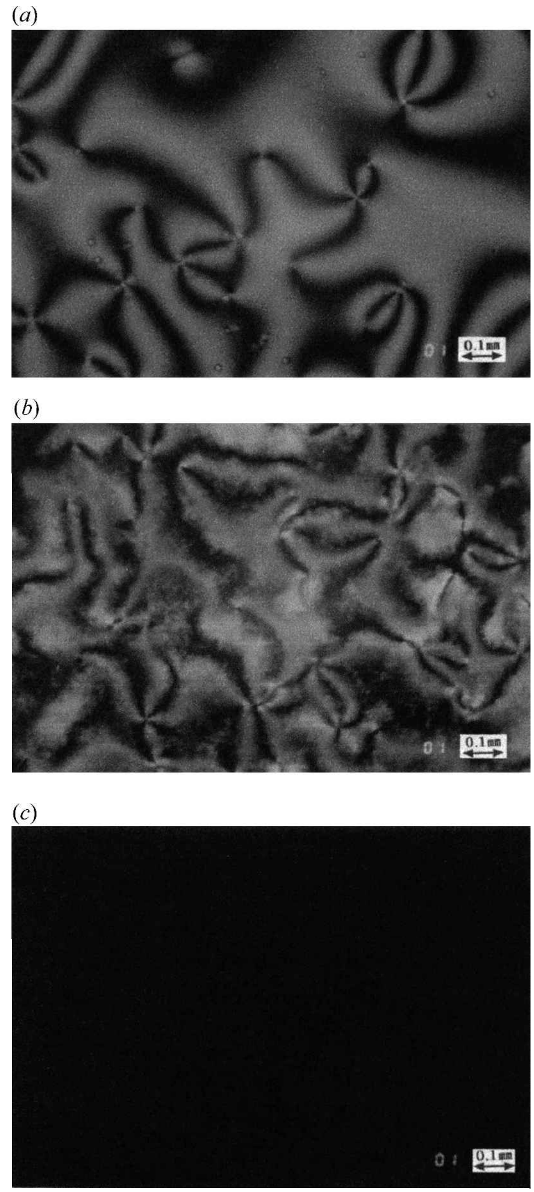


Figure 5. Microphotographs of photoaligned LC cells on photopolymer layers based on *N*-(phenyl)maleimide (in crossed Nicols): (*a*) PMIF, (*b*) PMI3CA, (*c*) PMI5CA.

Figure 6 shows the LC tilt angles with polarized UV exposure for 5 min on the PMI5CA layer as a function of the incident angle. It can be seen that the NLC tilt angles were about 90° for all incident angles. It is considered that homeotropic alignment can be achieved by using the 5-carbon chain cinnamoyl group on the photopolymer layer. Also, the LC tilt angle depends on the side chain length of the photopolymer.

Figure 7 shows the photomicrographs of the aligned LC with 1 min polarized UV exposure on PMI5CA for various annealing temperatures (in crossed Nicols). In figures (*a*) and (*b*), good LC alignment was observed

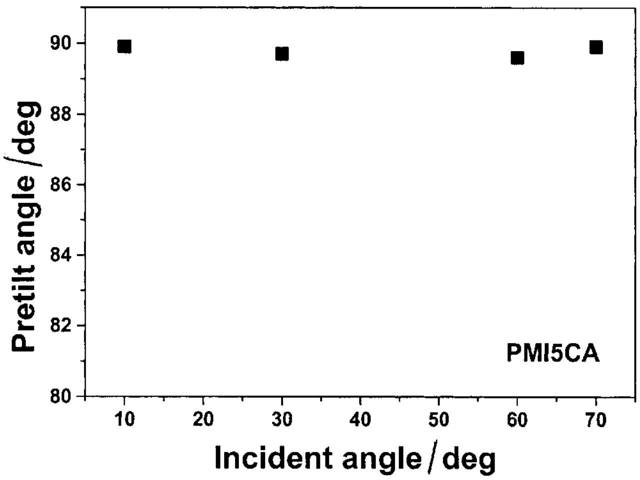


Figure 6. LC pretilt angles with polarized UV exposure on PMI5CA for 1 min as a function of incident angle.

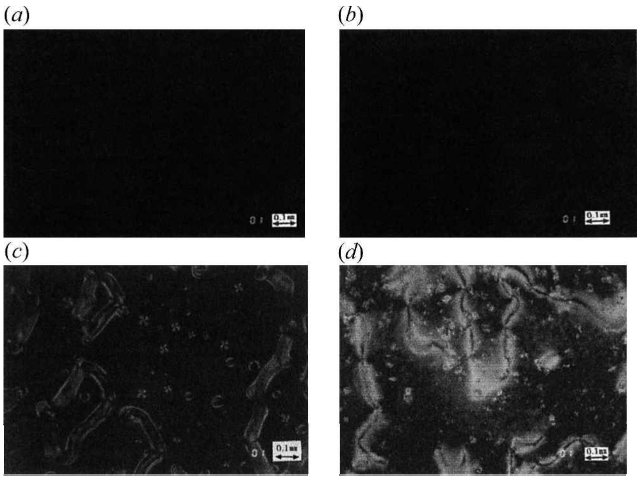


Figure 7. Photomicrographs of aligned LC cells with polarized UV exposure on PMI5CA photopolymer layers for 10 min at various annealing temperatures (in crossed Nicols): (*a*) 100°C, (*b*) 150°C, (*c*) 180°C, (*d*) 200°C.

upto an annealing temperature of 150°C; defective alignment was observed above this annealing temperature, (*c*) and (*d*). Therefore, good LC alignment and thermal stability through UV exposure of the PMI5CA layer with a 5-carbon chain cinnamoyl group can be achieved. The thermal stability of the LC alignment after UV exposure of the PMI5CA layer was almost the same as that of a rubbed PI layer.

4. Conclusion

We have studied the synthesis of photopolymers based on *N*-(phenyl)maleimide, and investigated LC alignment effects of the photopolymer layers. Good LC alignment with UV exposure on a PMI5CA layer with a 5-carbon chain cinnamoyl group was obtained. Good LC alignment was also observed upto 150°C annealing temperature of the layer. The LC aligning ability on the photopolymer layer based on *N*-(phenyl)maleimide depends on the side chain length of the photopolymer.

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