New Photo-Alignment Materials for LCD as a Non-Rubbing Method.

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Abstract

We successfully developed new photo-alignment materials which can be treated with linearly polarized UV (LPUV) light in near UV region. The alignment films were also shown to provide with surface anchoring as strong as that on rubbed polyimide when exposed to the LPUV light with warming up the substrate. It can be also able to control pretilt angle by introduction of alkyl side chain.

1. Introduction

Photo-alignment is a new LC-alignment technology based on axis-selective photoreaction.[1] As a non-contacting method, photo-alignment has marked advantages over the conventional rubbing method, for example it is free from electro-static charge, rubbing dust, and easily applicable to multi-domain structures. This technology is expected as a future one for LCD devices of next generation.

However, the photo-alignment method has a number of technical problems, and has not been commercially adopted. Some of the major problems stem from use of LPUV light in deep UV region: LPUV light in deep UV region causes unfavorable degradation of the alignment film. Another problem is deficiency and instability of the surface anchoring.

We have developed new chalcone-based photo-alignment materials[2] which can be treated with LPUV light in near UV region at around 365 nm. The alignment film was also shown to provide with stable surface anchoring as strong as that on rubbed polyimide when exposed to the LPUV light with warming up the substrate.

In this paper, we summarize our research results, and exhibit the features of newly-developed photo-alignment materials.

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2. Experimental

2.1 Materials

Chemical structures of the photo-alignment materials are shown in Figure 1. Details of the conditions for the evaluation of the materials were described in previous publications[2-7].

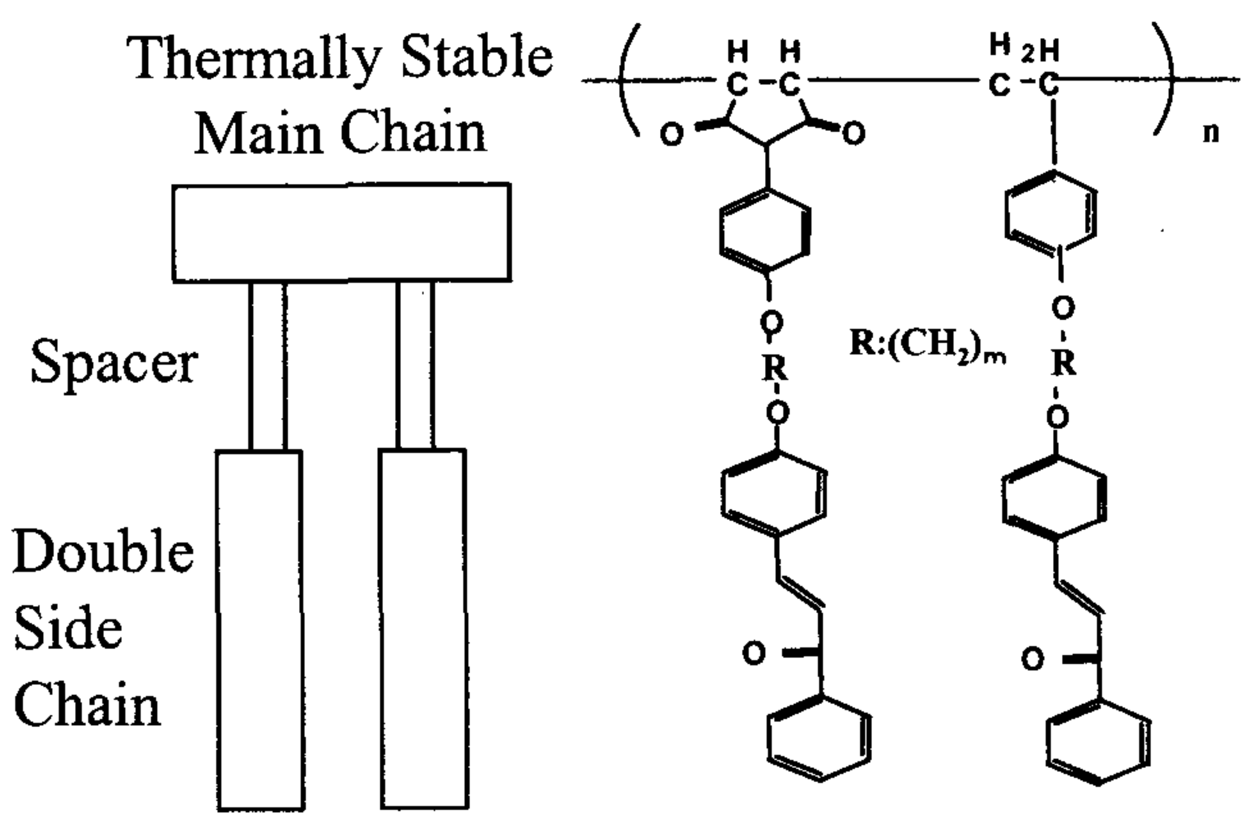

Figure 1. Chemical structure of photo-alignment material with chalcone unit.

2.2 LC cell preparation for characterization

Alignment films were spin coated and baked on glass plates, and then which were obliquely exposed to LPUV light as shown in Figure 2. They

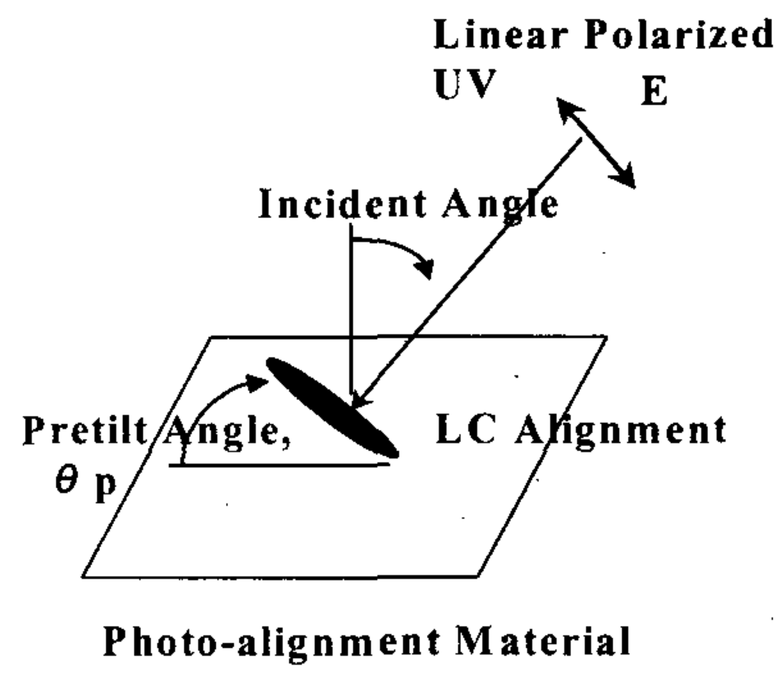

Figure 2. Photo-irradiation method for photo-alignment material.

were made into LC cells with a gap of 5.5 μm. The easy axis of the alignment films is arranged in an anti-parallel manner. The cells were filled with LC, and treated above the N-I point of the LC.

3. Results and Discussion

3.1 Near-UV sensitivity and thermal stability of 4-chalconyl compounds

When we started a research, it had been known that several kinds of photo-sensitive polymers, like polyvinyl cinnamate(PVCi)[8], polymers containing azobenzene units[9], and some polyimdes[10], can perform as a photo-alignment film. However, they did not show both the near-UV sensitivity and stability of LC alignment.

For example, PVCi films provided with stable LC alignment attributed to dimerization of the cinnamate groups, but needed exposure to LPUV light with an wavelength less than 320 nm. Azobenzene derivatives, on the other hand, had sensitivity to near UV light, but the LC alignment on the films was essentially unstable because of reversible nature of *trans-cis* photo-isomerization.

We investigated that polymers with 4-chalconyl groups as shown in Figure 1 met our requirements.[2] First, the 4-chalconyl compound has a longer conjugation than PVCi, and thus has sensitivity to near UV light.[11] Second, the 4-chalconyl compound proceeds photo-dimerization selectively,[11] and stable LC alignment was obtained when the exposed light was linearly polarized.

By contrast with the 4-chalconyl compounds, 4'-chalconyl compounds proceeded both dimerization and isomerization when exposed to near UV light.[11] As a result, LC alignment on the LPUV-exposed was thermally unstable.[3]

3.2 Improvement of surface anchoring by a "warming up" process

A feature of our photo-alignment material is that the surface anchoring can be improved by "warming-up" exposure process.[4] This process is to expose the alignment film to LPUV light with warming up the substrate above the T_g of the film. The polar anchoring energy of the alignment film thus obtained was comparable to that of rubbed polyimide film as shown in Figure 3.[4]

It was shown that chalcone residue in the alignment films was markedly reduced when the "warming-up" process was applied as shown in Figure 4.[4] This result is ascribable to easier molecular motion in the warmed film.[4] We think this high conversion of the photo-reaction led to the stronger surface anchoring.[4]

Figure 5 shows a schematic illustration of a proposed mechanism of our photo-alignment material by photo-reaction below and above Tg.

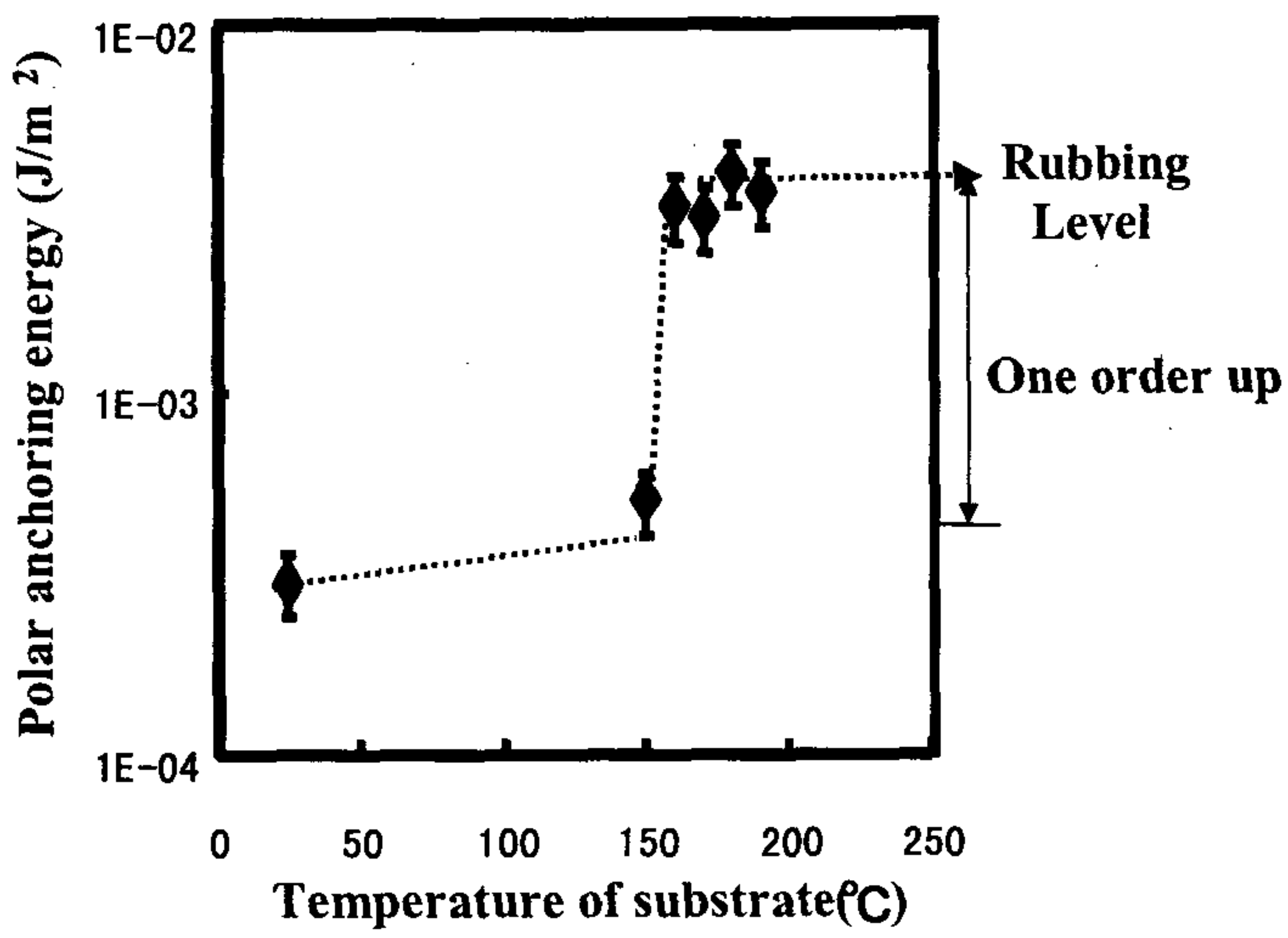

Figure 3. Effect of the warming-up procedure on the polar anchoring energy.

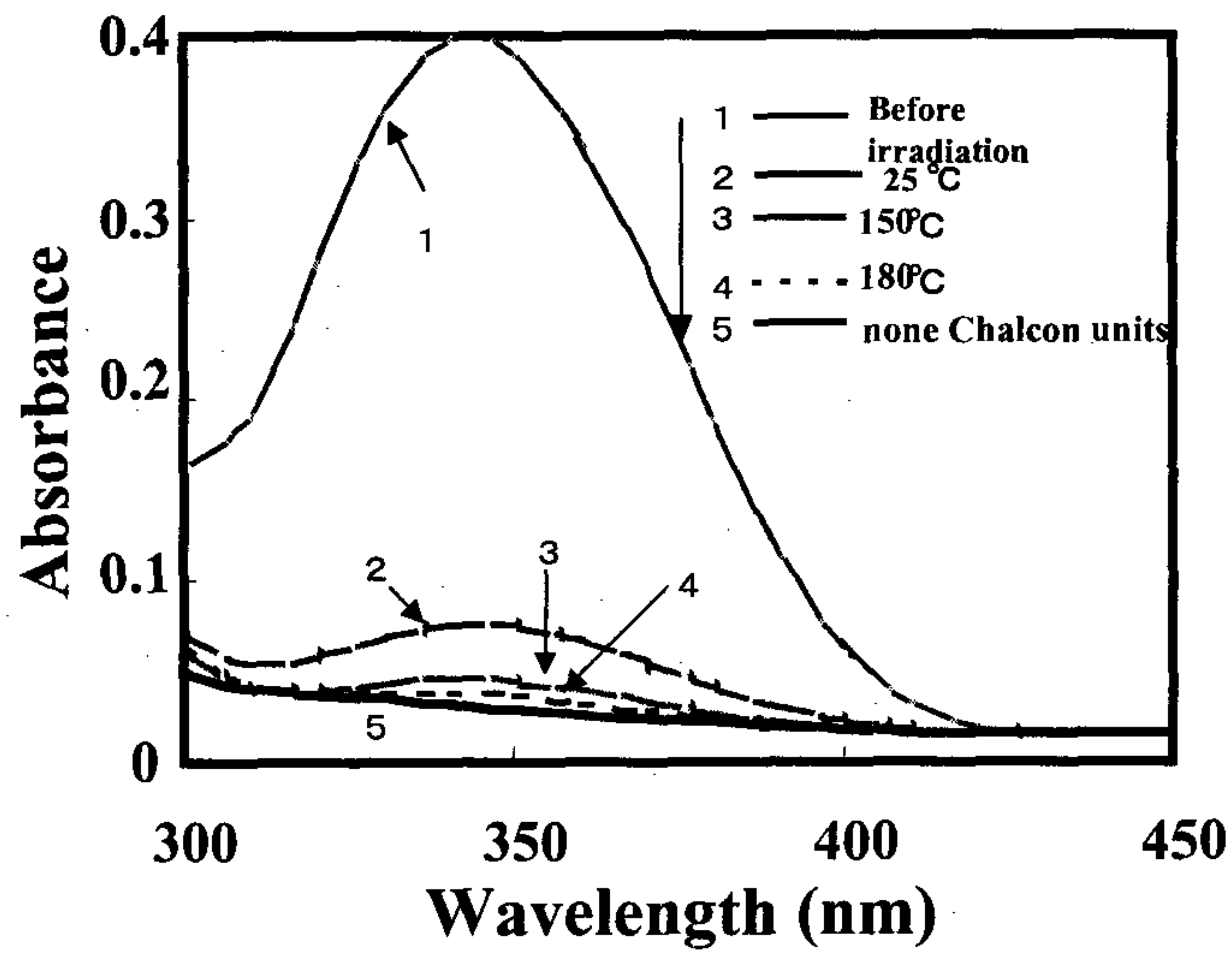

Figure 4. UV absorption spectra of photo-alignment material upon LPUV irradiation at several temperatures.

3.3 Electro-optical and electrical properties of TN cells prepared with photo-alignment film

Using the photo-alignment film, we could prepare TN cells without defects.[4] Figure 6 exhibits the T-V curve of a cell.[4] VHR of the cells was >95%.

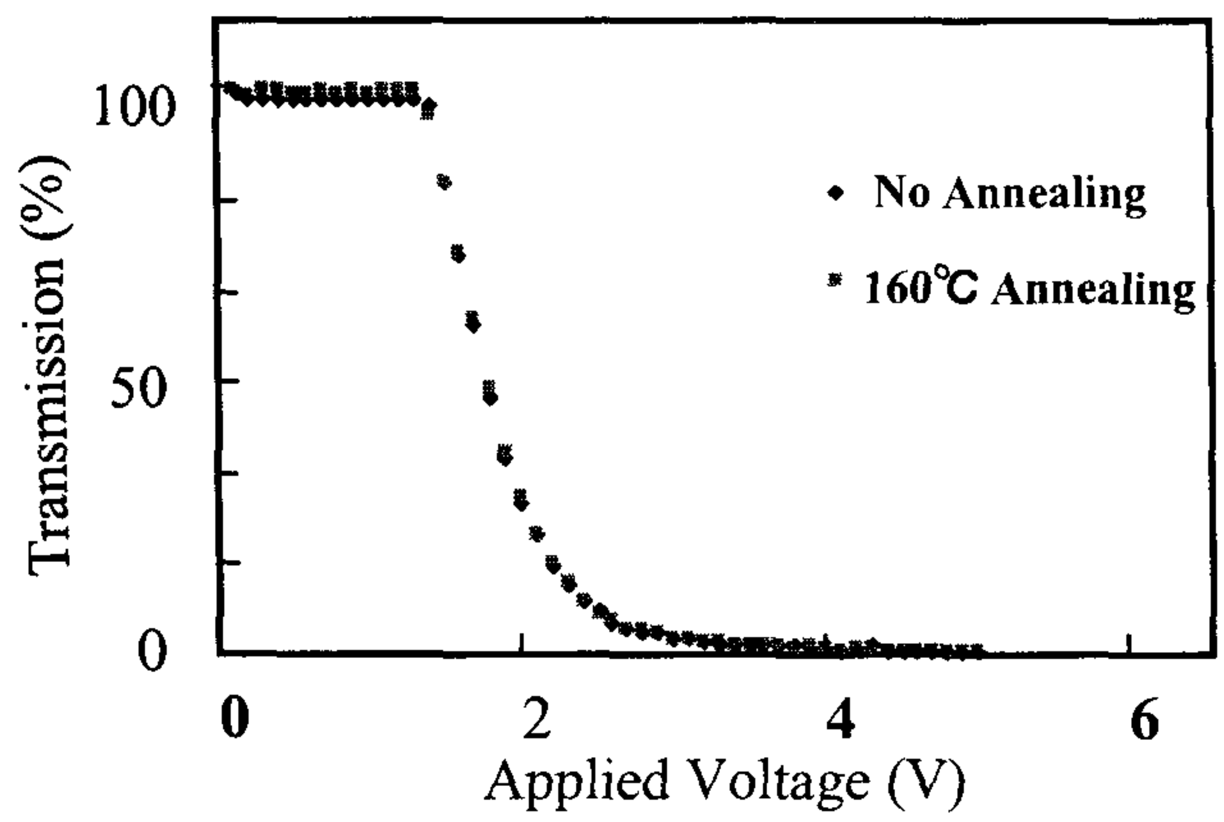

Figure 6. T-V curve of TN cell made with photo-alignment material.

3.4 Pretilt angle generation by one-step slantwise LPUV exposure

Pretilt angle generation by photo-alignment was considered from a viewpoint of symmetry by Kobayashi et. al.[12] and by Schadt et. al.[13]. As Kobayashi et. al.[12] noted, pretilt angle can not be generated by one-step exposure of LPUV light when the easy axis was perpendicular to the electric vector of the LPUV light ("perpendicular" manner). In contrast, pretilt angle generation by the one-step exposure is possible when the easy axis is parallel to the electric vector ("parallel" manner), as Schadt et. al.[13] suggested.

Since the easy axis of the photo-alignment film was formed parallel to the electric vector,[7] pretilt angle can be generated by the one-step exposure in principle. Our experiment indicated that pretilt angle was thus generated with the photo-alignment film, although it was less than 1 degree.[3]

It is noteworthy here that the direction of easy axis is related to the chemical structure of the photo-sensitive side groups. LC alignment on the polymers with spacer units in the photo-sensitive side chain was "parallel" manner, while that on polymers without spacers was "perpendicular" manner.[5] Obi et. al. reported similar results with coumarin derivatives.[14]

The small pretilt angle of our photo-alignment material was supposed to be ascribed to high surface tension of the material. Accordingly, we tried copolymerization of a monomer with alkyl group to decrease the surface tension (Figure 7).[6] In the case of photo-alignment material with alkyl chain, its pretilt angle increased with the alkyl chain content. Pretilt angle also depended on substrate temperature during the exposure, LPUV light dose, and LC type. We showed that these dependence of pretilt angle can be explained as an effect of surface tension.[7]

Another factor affecting the pretilt angle was incident angle of the LPUV light (Figure 8).[6] Obviously, pretilt angle was set to be zero when the normal incidence was employed. Figure 10 shows that increase in the incident angle resulted in monotonical increase in the pretilt angle.

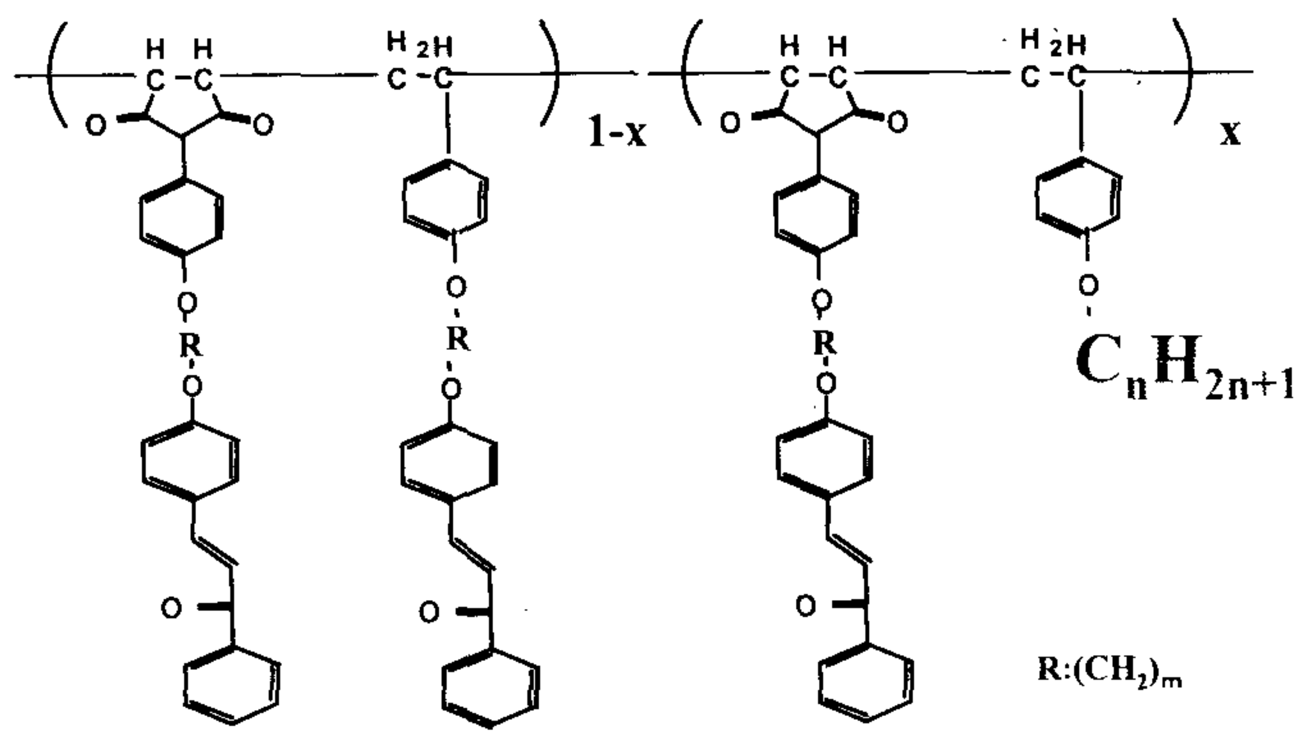

Figure 7. Chemical structure of photo-alignment material with alkyl chain.

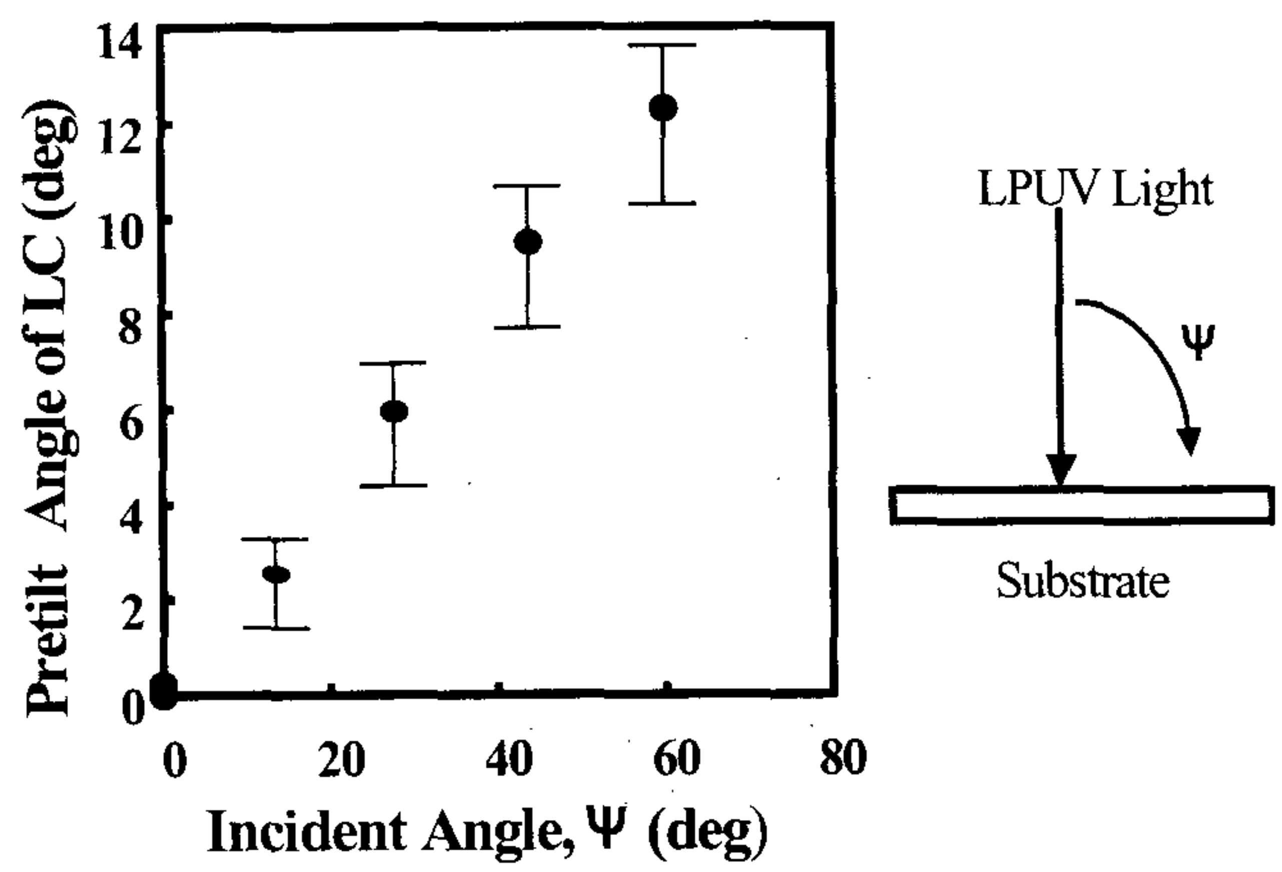

Figure 8. Pretilt angle of LC as a function of a incident angle of LPUV.

3.5 Characteristics for VA alignment property

According to the amount of incorporated alkyl chain unit, the pretilt angle increased and came close to 90 degree.[6] It is of interest if the photo-alignment film with a pretilt angle close to 90 deg. is applicable as a VA alignment film.

In order to confirm this, we observed electro-optical response of a VA cell prepared with phto-alignment material with alkyl chain. When electric field was applied to the cell, pretilt angle of which was about 89 deg., LC alignment along the easy axis was seen.

4. Conclusion

We developed new photo-alignment materials with the following features:

1) Sensitivity to near UV light
2) Stable LC alignment
3) Surface anchoring as strong as on rubbed polyimide
4) VHR >95%
5) Pretilt angle generation (0-90 deg.) by one-step exposure of LPUV light

5. Acknowledgment

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6. References

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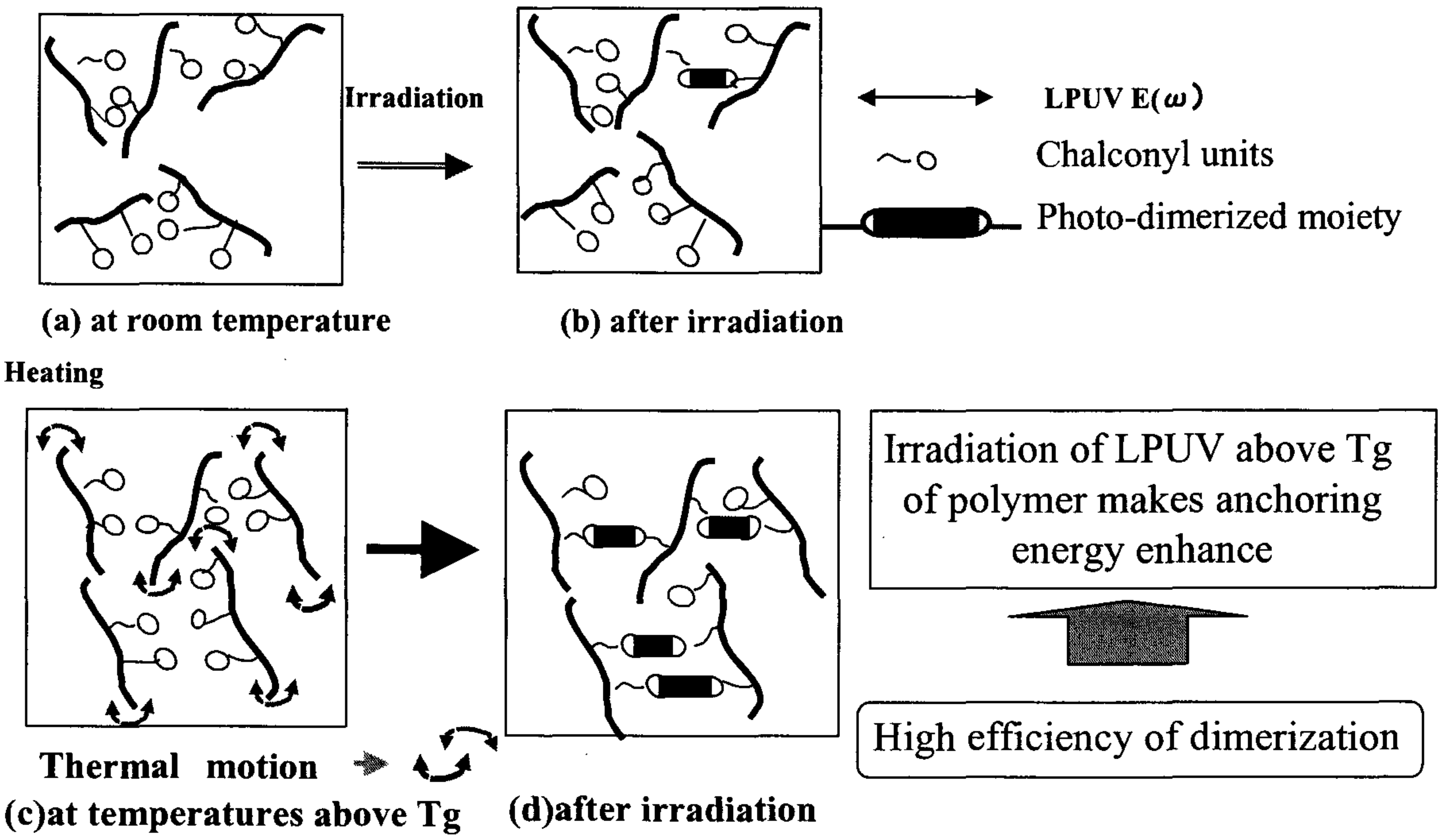

Figure 5. Schematic illustration of LC alignment mechanism by photo-irradiation reaction.