

# Alignment of smectic liquid crystals on newly synthesized photo-reactive polyimide with chalcone moiety

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## Abstract

*Benzylideneacetophenones are known as chalcones[1]. The chalcone has been known to be a photo-isomerizable and photo-dimerizable chromophore. The chalcone derivatives were prepared by base-catalyzed condensation of aldehydes and acetophenones, which were substituted with various alkyl chains. The synthesized chalcone was introduced into the t-BOC protected diamine through William synthesis reaction. Photocrosslinkable polyimide was prepared via one-step imidization reaction of DOCD A (5-(2,5-dioxotetrahydro furyl)-3-methyl-3-cyclohexene-1,2-dicarboxylic anhydride) and the chalcone introduced diamine using isoquinoline (5 wt%) in m-cresol. The polyimide solutions were spin-coated onto the quartz, silicone wafer and glass substrates and the obtained thin films were irradiated obliquely with linearly polarized UV light.*

## 1. Introduction

The merits of ferroelectric liquid crystal (FLC) molecules, such as fast response time, wide viewing angle, and memory effect make ferroelectric liquid crystal devices (FLCD) as alternative display devices [2,3]. FLC is existed in a chiral smectic C phase (SmC\*) with dipoles normal to long molecular axis. FLC molecules in SmC\* have a layer structure and are tilted in a regular angle to each layer forming a helicoidal structure with a pitch through layer by layer. Therefore it is difficult to make well-aligned FLC cells. Good alignment of layers and a planar alignment of FLC are need. In general, the layers of FLC have defects like zigzag defects, which affect the display quality. In order to make uniformly aligned FLC cell without defects, many researches have been tried

efforts such as application of electric field [4], the application of magnetic field [5], and controlling temperature [6].

In our work, we designed the new photo-reactive polyimides containing the chalcone moiety to apply to the FLC cell. To understand the effect of the difference of structure, we synthesized the various kinds of polyimides, which have the different alkyl chain length and content of chalcone moiety respectively.

## 2. Experimental

The chalcone derivatives were prepared by base-catalyzed condensation of aldehydes and acetophenones, which were substituted with various alkyl chains. The synthesized chalcone was introduced into the t-BOC protected diamine through William synthesis reaction. Photocrosslinkable polyimide was prepared via one-step imidization reaction of DOCD A (5-(2,5-dioxotetrahydro furyl)-3-methyl-3-cyclohexene-1,2-dicarboxylic anhydride) and the chalcone introduced diamine using isoquinoline (5 wt%) in m-cresol. The structure of the synthesized polyimide is depicted in figure 1.

The polyimide solutions were spin-coated onto the quartz, silicone wafer and ITO-coated glass substrates and the obtained thin films were irradiated obliquely with linearly polarized UV light. After assembling these two ITO-coated glass substrates, we injected the nematic LC (ZLI-3449, Merck) and FLC (FeIIX-015/100, clariant) for the measurement of pretilt angles and the observation of the alignment properties in FLC cell respectively.

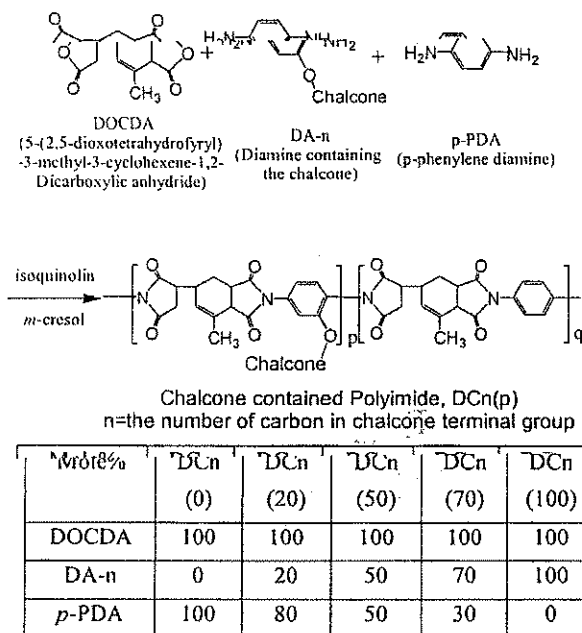


Figure 1. Synthesis of photo-reactive polyimides

### 3. Results and discussion

Various kinds of Chalcone derivatives were synthesized by William's synthesis and photo-sensitive polyimides (DCn(p)) were prepared from 5-(2,5-dioxotetrahydrofuryl)-3-methyl-3-cyclohexene-1,2-dicarboxylic anhydride and chalcone containing diamine by one-step imidization. These synthesized materials were confirmed with FT-IR spectroscopy and H-NMR. Figure 2 shows the UV-visible spectra of the DC8 film depending on the exposure time of linearly polarized UV light (LPUV). The decrease of absorbance at near 240nm means that the C=C-C=O bond constituting the chalcone derivatives (n=8) disappears with LPUV irradiation (the intensity of UV lamp: 10mWcm<sup>-2</sup>) and chalcone introduced polyimide shows more great reactivity than the polyimide having no chalcone.

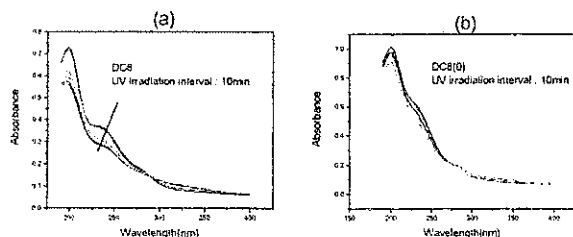


Figure 2. UV-visible spectra of the DC8 film depending on the exposure time of LPUV

By FT-IR spectroscopy, as shown in Figure 3, we observed that the C=O carbonyl peak conjugated with the C=C double bond of the chalcone moiety decreased and shifted to high energies state and the intensity of the C=C double bond also decreased with irradiation of LPUV. This means that the conjugated system of the chalcone is broken and a new bond is formed.

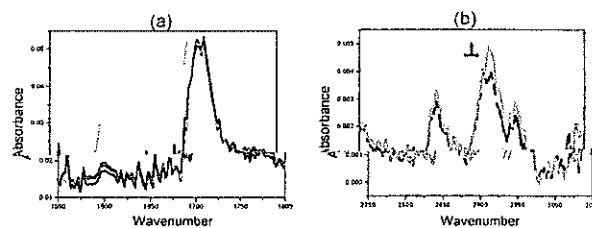


Figure 3. FT-IR spectra of the DC8 film (a) and absorbance perpendicular and parallel direction to the polarization (b) after LPUV exposure.

Figure 3(b) also shows the alkyl groups of chalcone moieties were reoriented perpendicular to the LPUV irradiation.

To make sure these materials align liquid crystal molecules actually, the birefringence was measured as a function of the angle of rotation for the DC8 PI film exposed to LPUV. Figure 4 shows that the birefringence of DC8 film increases drastically upon exposure time and is induced to the direction perpendicular to the polarization axis. This result is consistent with the previous FT-IR study (see figure 3(b)).

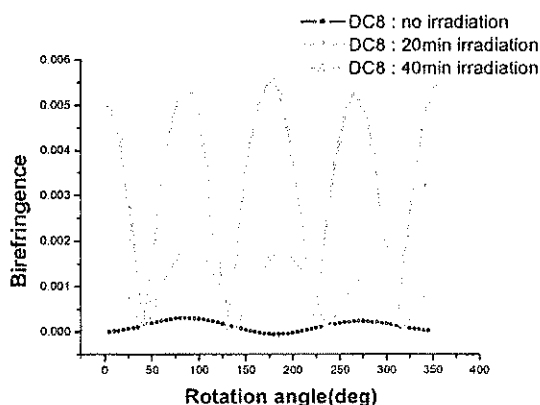


Figure 4. The angular dependence of the optical anisotropy for the LPUV irradiated DC8 film.

To understand the effect of the number of carbon in chalcone moiety on pretilt angle, we fabricated the LC cells with polyimides having the various length of chalcone moiety and measured the pretilt angles by crystal rotation method. As shown in figure 5, the pretilt angles are 1-2° for DC3 and 90° for DC16, but those for the other polyimides were not obtained. It is believed that the pretilt angles of these polyimides (DC8 and DC12) are out of range as much as possible by crystal rotation method. Short alkyl chain of DC3, that is, induces a low pretilt angle and planar alignment.

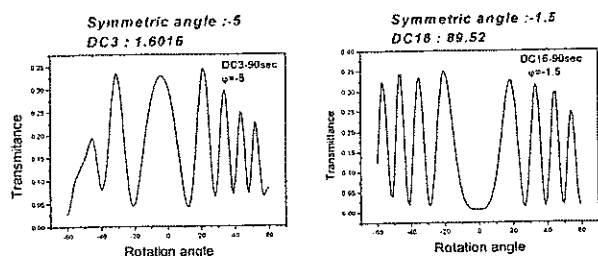


Figure 5. Pretilt angles of LC cells (DC3 and DC16)

Instead, the alignment layers have the high pretilt angles under the increasing number of carbon in chalcone moiety. Also we studied the influence of the content of the chalcone moieties on the pretilt angle.

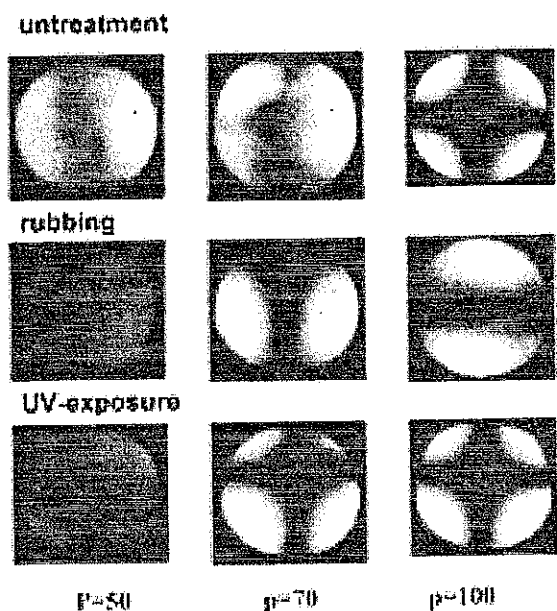


Figure 6. Conoscopic images for the LC cells of DC12(p) (p = the content(%) of chalcone moiety)

Figure 6 shows the texture of LC cells fabricated with DC12(p). From the first row, the textures of untreated, rubbing and LPUV-exposed LC cells are arranged. Before some treatments, the cells of much content of chalcone moieties have high pretilt angles. By rubbing, the pretilt angle have a tendency to decrease, but the cell of DC12(100) shows the uniform vertical alignment with LPUV-exposure. In general, the pretilt angles become higher in proportion to the content of chalcone moieties. In order to get a high pretilt angle, photo-alignment technique is needed.

We applied these polyimides to align FLC (FeIX-015/100, clariant). The textures of FLC cells were shown in figure 7. These images show the similar uniformity in both photo-alignment and rubbing technique. The alignment properties however become worse on increasing the content of chalcone moieties.

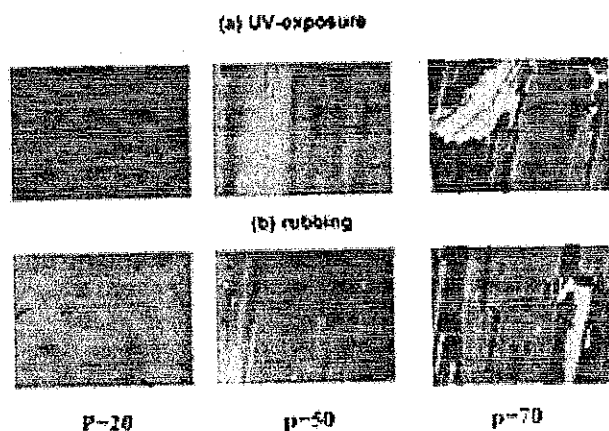


Figure 7. Texture of FLC cells (DC12(p)) (p = the content(%) of chalcone moiety)

#### 4. Conclusion

We synthesized the photo-reactive polyimides and characterized the reactivity with UV-visible and FT-IR spectroscopy. In the LC cell, we have investigated the effect of the structure of these materials on pretilt angles and alignment properties. As the number of carbon in chalcone moiety increases, the alignment layers have the high pretilt angles and the increased content of chalcone contributes to the high pretilt angle. In FLC cell, the similar uniformity is observed in both photo-alignment and rubbing technique, but the alignment properties become worse on increasing the content of chalcone moieties.

### 5. Acknowledgement

This work was performed Advanced Backbone IT technology development project supported by Ministry of Information & Communication in republic of Korea.

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