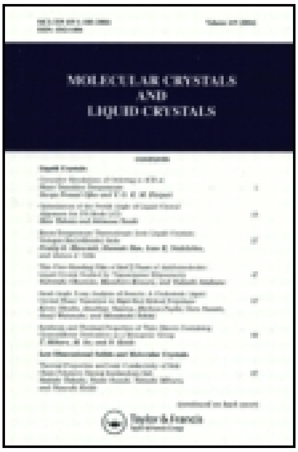

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Influence of the Continuous Application of an External DC Electric Field on Chromophore Orientations of Low T_g-photorefractive Polymers

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Influence of the Continuous Application of an External DC Electric Field on Chromophore Orientations of Low T_g-photorefractive Polymers

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The influence of the continuous DC electric field on the chromophore orientations is investigated in a typical PVK based photorefractive polymer. The result from the modulation measurement with stabilized Mach-Zehnder interferometer shows that the degree of the chromophore orientation is not deteriorated by the migration of carrier in the case of our sample.

Keywords Photorefractive polymer; Refractive index change; Mach-Zehnder interferometer; Coercive field; Carrier migration

Introduction

Recently, practical applications using photorefractive (PR) polymers have been proposed. For examples, a three-dimensional holographic imaging of living tissue with a near IR light source [1], and holographic three-dimensional telepresence [2], etc., are much attractive. To realize these applications, the modifications of the device configuration without degradation of the innate performance of materials have been required.

To make the polymer composite optically nonlinear-active, low-glass-transition PR polymers are normally used with the continuous application of a comparably high external DC electric field, i.e. a poling field, which is typically ~ 50 V/μm or more [3]. However, it has been reported that the charge injection and the migration of ionic carriers, which are electrically induced in polymers by the external DC electric field, degrade the performance of PR materials by the deterioration of chromophore orientation and space charge field formation [4].

In this work, in order to evaluate the influence of the continuous application of DC electric fields on the PR property, we investigated relationship between electrical current and chromophore orientation. The degree of chromophore orientation was evaluated through refractive index change using the interferometric modulation technique based on Mach-Zehnder interferometer (MZI).

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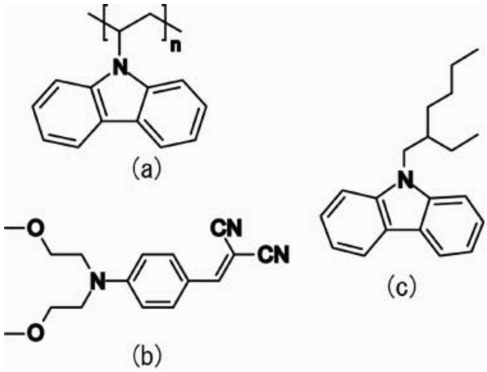

Figure 1. Photorefractive components: (a) PVK, (b) AODCST, (c) EHCz.

Experimentals

The typical photoconductive PVK based PR polymer was used in this experiment. The nonlinear optical chromophore AODCST [5] and plasticizer EHCz [6, 7] were dispersed in the host polymer PVK with the ratio of PVK:AODCST:EHCz = 50:30:20 wt%. The molecular structures are shown in Fig. 1. The composite was sandwiched by two glasses with ITO electrode. The thickness of the polymer layer was controlled by hot pressed technique with changing the temperature and the pressing time. In this experiment, we prepared the PR cell sample with the thickness of 30 μm under the condition that the temperature and time were 145°C and 8 minutes, respectively.

Using a stabilized MZI, we evaluated the temporal change of refractive index induced by a DC electric field with the long time scale modulation measurement. The experimental setup is shown in Fig. 2. The polarized He-Ne laser oscillated at the wavelength of 633nm was used as a light source. The laser beam was divided into two by the non-polarized prism beam splitter (B.S.), then, one of which passed through the sample and the other through the phase sifter (P.S.). Then the two beams combined together with another B.S. resulting

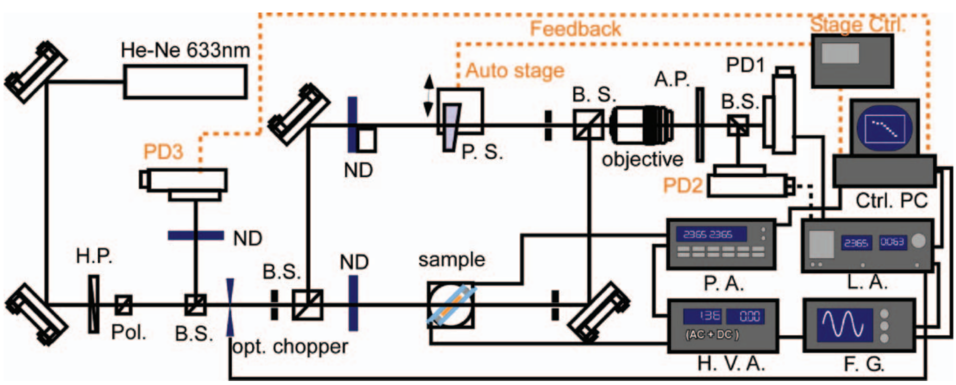

Figure 2. Experimental setup for Mach-Zehnder Interferometry, where, H. P. : half wave plate, Pol. : polarizer, B. S.: beam splitter, ND: ND Filter, P. S. : phase shifter, A.P. :aperture, PD: amplified photodiode, P. A.: pico-ammater, L. A.: lockin amplifier, H. V. A. : high voltage amplifier, F. G.: function generator. Dashed line shows feedback circuits for stabilization of measurement system.

in the formation of interference pattern on the aperture (A.P.). The light powers of both beams were modified with ND filters (ND) to be equal so that the contrast of fringe was to be maximum. The interferometric fringe intensity pass through the aperture, the size of which was much smaller than the fringe spacing, was detected by the photo detector (PD1). Application of a modulated electric field to the sample changed the refractive index and then modulated the fringe intensity, which was measured with Lockin amplifier (L.A.).

In modulation measurements, the modulated amplitude was obtained at the work point where the non-modulated phase difference between the two beams equaled to $+\pi/2$ or $-\pi/2$. [8] However, the phase difference was easily deviated from the work point by fluctuation of environment, since the two divided beams were experienced different optical path installing some optics or mirrors. Therefore, the stabilizing technique for phase retardation was required, especially for the long time scale measurement. In this setup, we installed two stabilizing mechanisms. One was the auto phase tracking technique, which adjusted the phase difference to $\pm\pi/2$ by tuning the position of the phase shifter. The other was the power monitoring of the laser source. We considered the power fluctuation in determining the optimum position of the phase shifter in the auto tracking. Using these techniques enabled us to carry out the modulation measurement with the high sensitivity of sub milli-radian, prolonged time of a few hours, and low frequency of sub Hertz. Moreover, in order to measure the change of the electrical current in a sample during the modulated measurements, we installed a pico-ammeter on the electrical circuit which applied the external voltage to the sample.

Using this setup, we measured the effects of the continuous DC field on the changes of refractive index and electric current. We applied the DC field $E_{DC}(0)$ of 60 V/μm and measured a refractive index change $R(\omega)$ by the modulated AC field $E_{AC}(\omega)$with the amplitude of 1 V/μm and the frequency of 120 Hz, that was enough small to ignore the influence of $E_{AC}(\omega)$ on $R(\omega)$.

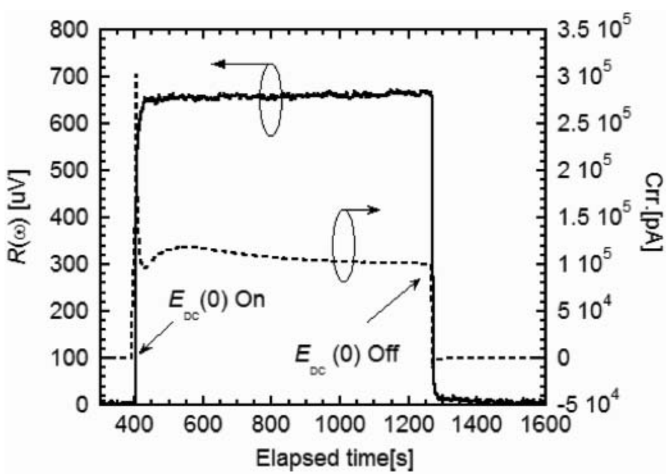

Figure 3. The temporal modulation response and current change when the DC electric field was applied at t = 400 s and removed at t = 1270 s. The solid and dotted line showed the modulation signal and electrical current, respectively.

Results and Discussions

The temporal changes of the modulation signal and electrical current are shown in Fig. 3. We started the application of modulation field at $t = 0$. Then, E_{DC} (0) was superimposed to $E_{AC}(\omega)$ at $t = 400$ sec and removed by short-circuiting after the electrical current was stable (∼1200sec). When $E_{DC}(0)$ was applied on the sample, the fundamental component of modulation signal $R(\omega)$ detected by L.A., the amplitude of which was linearly proportional to the change of refractive index $\Delta n(\omega)$, appeared immediately and then, reached steady state level R_{max}. On the other hand, comparably slow electrical current change was observed during the application of $E_{DC}(0)$. Here, the first peak was associated with the chromophore orientation and the next peak originated from the ionic charge carrier [4]. This result showed that the stable response of modulated signal was still remained despite the current was changed with time. However, the current curve involving the ionic migration signal implies that the different distribution of charges between before and after applying $E_{DC}(0)$ was induced in the polymer. In order to see the decay of the modulation signal, the ratio $R(\omega)/R_{max}$ after $E_{DC}(0)$ removal versus time after off the voltage is shown in Fig. 4. Here, initial 50 second was ignored by considering the time constants of L.A. and auto phase tracking system. This figure shows that the small $R(\omega)$ signal is still remained after removing $E_{DC}(0)$ and it implies the coercive field seems to be formed in the material due to the re-distribution of charges. The single exponential fitting curve of the decay of $R(\omega)/R_{max}$ is shown by the solid line in Fig. 4, where we assumed a simple capacitor model for the temporal decay induced by the charges. It should be noted that the short circuit response time of the electrical circuit was 60 μsec, which faster than the response in Fig. 4. Extrapolating to the initial time, the magnitude of signal was estimated to be 3.5% of R_{max}. It corresponded to that the coercive field of 2.1 V/μm was formed by applying $E_{DC}(0)$ of 60 V/μm. It means that, in the case of our sample, no effective coercive field enough large to degrade the ability of chromophore orientation was induced.

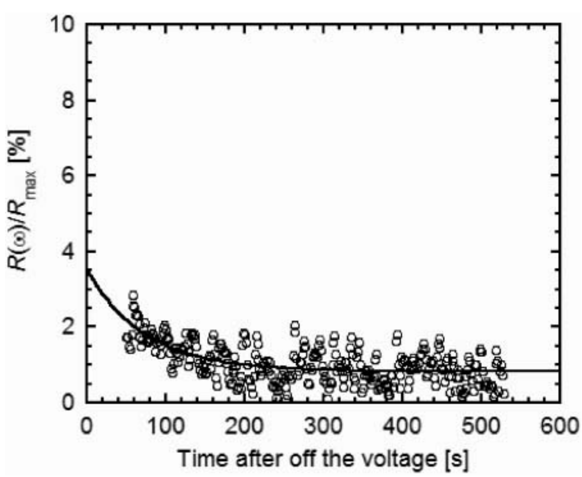

Figure 4. The modulation signal decay after off the voltage. The solid line showed fitting curve by single exponential.

Conclusions

We evaluated the influence of DC electric field on the chromophore orientation in a typical PR polymer. We observed ionic current and confirmed the formation of coercive field due to the migration of ionic charges inside the polymer. It was found, however, the chromophore orientation was not seriously affected by the coercive field.

Acknolegment

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