

# Performance of Fully Functionalized Photorefractive Polymer for Data Storage

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## Abstract

Both the photorefractive (PR) and holographic characteristics of 3-amino-9-ethyl carbazole (AEC) / Dispersed Orange 3 (DO3) / diglycidyl 1,2 cyclohexanedicarboxylate (DCD) main chain copolymer with the carbazole and the azo chromophore incorporated in a transverse way were investigated without external applied electric field. The recorded pattern exhibited good fringe contrast, the resolution of the recorded hologram was about 20  $\mu\text{m}$ . Problems such as dopant aggregation, fanning, and image distortion was not found in the system.

**Keywords** : holographic recording, storage, copolymer, resolution

## Introduction

Organic PR materials have held public attention since they were discovered<sup>1</sup>. PR polymers have been developed for applications such as optical computing<sup>2</sup>, optical correlator<sup>3</sup>, data<sup>4,5</sup> or image storage<sup>6</sup>. Peyghambarian et al<sup>6</sup> studied the performance of a new doped polymer composite for the dynamic holography and image storage. The composite made from the photoconductor poly-(N-vinylcarbazole)(PVK) doped with charge transfer molecule, nonlinear optical (NLO) azo dye, and

plasticizer. It showed high PR efficiency, good sensitivity and reasonably fast response time. However, a high voltage (1 ~ 10 KV) across the film was necessary. Recently, Yu et al<sup>7</sup> reported a fully functionalized polymer with large optical gain under zero electric field. In this study, a fully functionalized polymer in which photoconductor and NLO moieties reacted with the comonomer and became a copolymer was recorded without electric field.

### Experimental

Three monomer including DCD, AEC, DO3 were dissolved in cyclohexanone and added in to the three-necked round-bottomed flask under the nitrogen atmosphere with the molar ratio 2:0.5:1.5. The solid content of the solution is 30 wt%. The reaction mixture was refluxed at 105°C for 16 h and then vacuum dried. The dried polymer was grounded into fine powder. The chemical structure of the polymer was illustrated in Figure 1. The polymer and 1wt% of 2,4,7-trinitro-9-fluorenone (TNF) were dissolved in cyclohexanone. The solution with 20 wt% solid content was used for spin coating. The resulting polymeric film was 30  $\mu\text{m}$  thick and exhibited good optical clarity.

Degenerate four-wave mixing (FWM) as shown in Figure 2 was used to generate a diffraction grating in the polymeric PR film and to read the grating. Two mutually coherent s-polarized writing beams were spatially overlapped in the polymer film with an angle between them and form a diffraction grating. A p-polarized reading beam was counterpropagating to one of the writing beams at the Bragg matching condition. The angle between the writing beams was of 20°. A green beam laser ( $\lambda = 514 \text{ nm}$ ) and a red beam laser ( $\lambda = 632.8 \text{ nm}$ ) were applied as the writing and reading beam respectively. All the PR signals were measured without applying electric fields across the film.

Figure 3 illustrates the experimental setup used for the holographic recording and readout . A green light laser ( $\lambda=514$  nm) was selected as the light source . During holographic recording , the beam was expanded by a beam expander and then split into two writing beams, beam 1 and beam 2, by a beam splitter . Beam 1 passed through the center part of a test chart and then the pattern was imaged onto the photorefractive polymer film . The average power density measured at the polymer plane was about  $14 \text{ mW/cm}^2$ . Once beam 1 was cut , the hologram image was read by beam 2. The restored image was detected by a CCD camera. The recording time was 30 seconds. Again, all the hologram images were recorded without applying electric field .

### Results and Discussion

The UV/Vis absorption spectrum of the polymer was demonstrated in Figure 4. The main peak due to the absorption of the azo chromophore DO3 was at 500 nm . The other peak at 320 nm resulted from the carbazole unit of AEC. In order to exhibit the photorefractive properties, an appropriate absorption by the PR material at the wavelength of the applied laser is necessary . Then, enough charge carriers can be generated and at the same time the diffracted light can transmitted through the film without too much absorption by the polymeric material. The absorption at 632.8 nm was quite little for the polymer. So, the red light laser (632.8 nm) was used as the reading beam instead of the green one (514 nm) in the FWM measurement.

The hologram growth speed was studied by the FWM measurement , as shown in Figure 2. Figure 5 showed the temporal dependence of the FWM diffracted signal measured without external electric field. The rise time ( $T_r$ ) and the decay time ( $T_d$ ) were 110 and 100 seconds respectively. The diffraction efficiency was  $3.26 \times 10^{-3}$  .

A resolution test chart was utilized to evaluate the resolution of the reconstructed hologram images

recorded in the PR film. The chart is correspondent to the USAF 1951 resolution target standard except the group number. For example, the fifth group in this test chart is equal to the third group of the USAF resolution target standard, and the fourth group in this test chart is equal to the second group of the USAF resolution target standard, ... etc. Figure 6(a) shows the image of the original resolution chart transmitting through a filter, and Figure 6(b) illustrates a reconstructed image of the resolution chart written in the DCD/AEC/DO3 film. In figure 6(a), the fourth element of the fifth group was distinguishable. The corresponding element was perceptible in the restored image, as shown in Figure 6(b). The recorded image was more clear when the recording time reached 30 seconds. The hologram growth rate was slower than that of the doped polymeric system. Since the image demagnification in our optical system was two, the resolution of the recorded hologram was about 20  $\mu\text{m}$ . Besides, the recorded pattern exhibited good fringe contrast, problems such as fanning and image distortion were not found in the case.

### **Conclusions**

This study has provided a new PR copolymer with the azo dye and carbazole moieties. We have demonstrated its potential applications such as the holographic information storage. In the doped polymer system, higher concentration of the dopant lead to crystallization and made the film opaque. However, the concentration of each component in the PR copolymer could be adjusted without limitation. Hologram image could be written and read in the copolymer by a low power laser without applying external electric field. The resolution of the recorded hologram was about 20  $\mu\text{m}$  and the image showed good fringe contrast. Our system has shown a great potential in the storage application because no electric field is required.

## References

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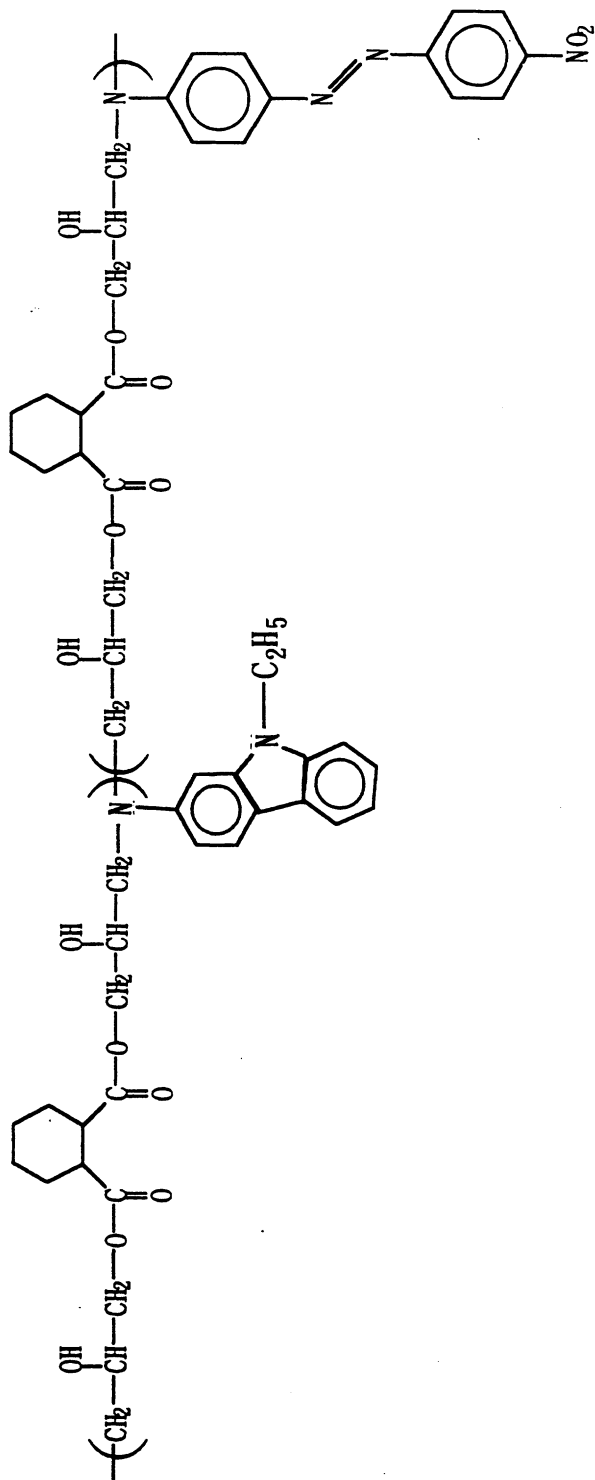


Figure 1. Chemical structure of the photorefractive DCD/AEC/DO3 polymer

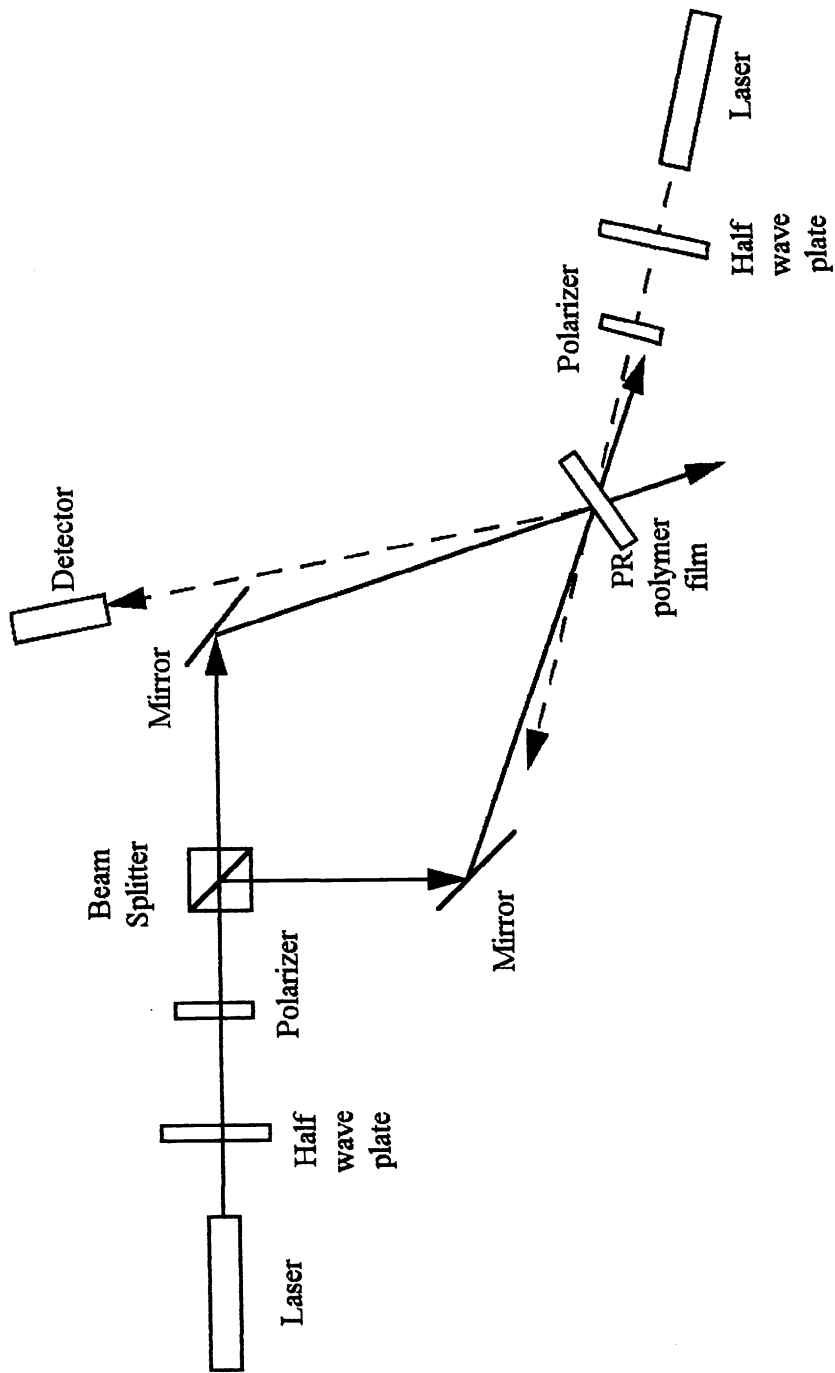


Figure 2. Experimental setup of the degenerated four wave mixing measurement

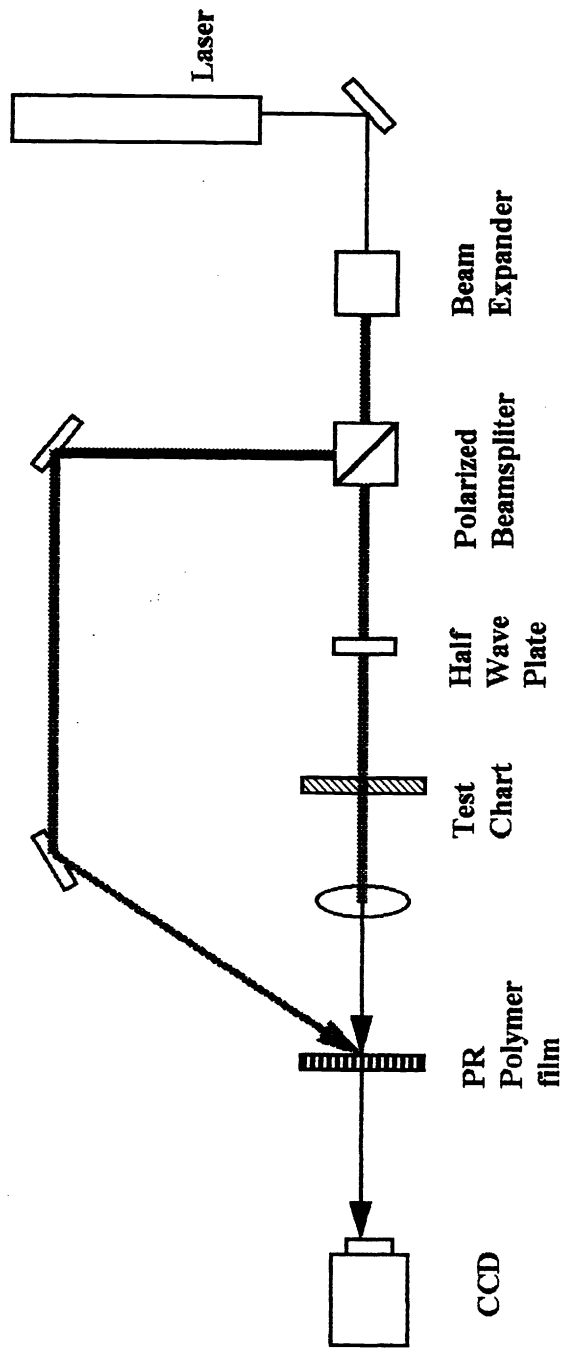


Figure 3. Experimental setup of the holographic recording and readout measurement



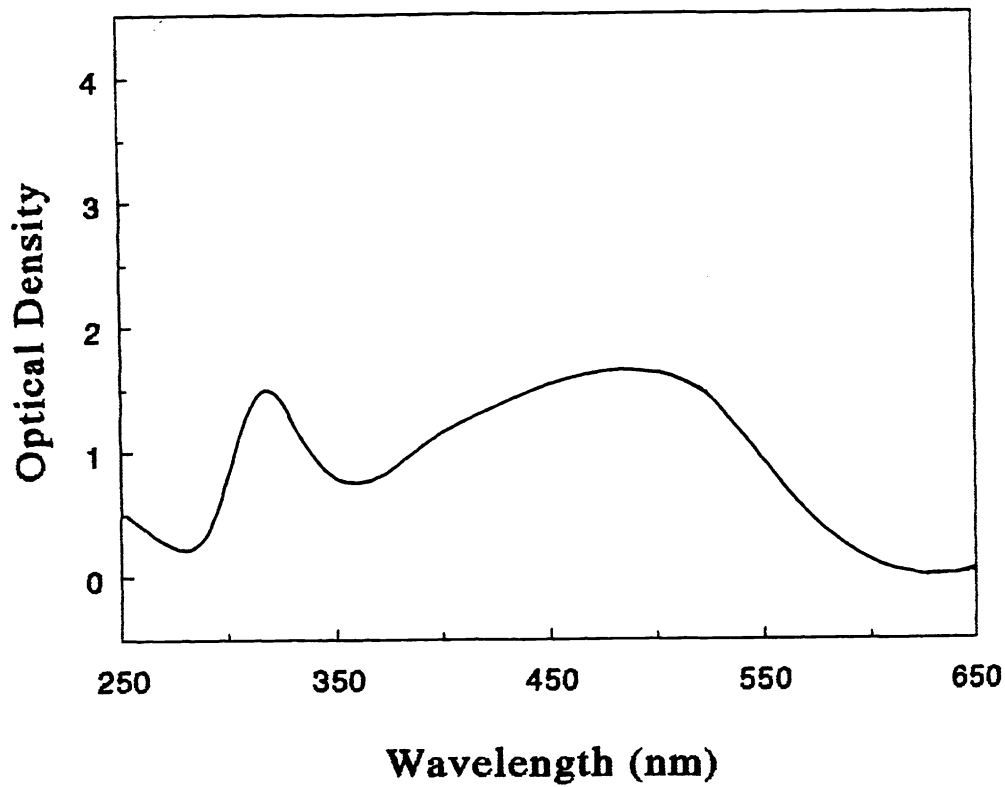


Figure 4. The UV/Vis absorption spectrum of the DCD/AEC/DO3 film.

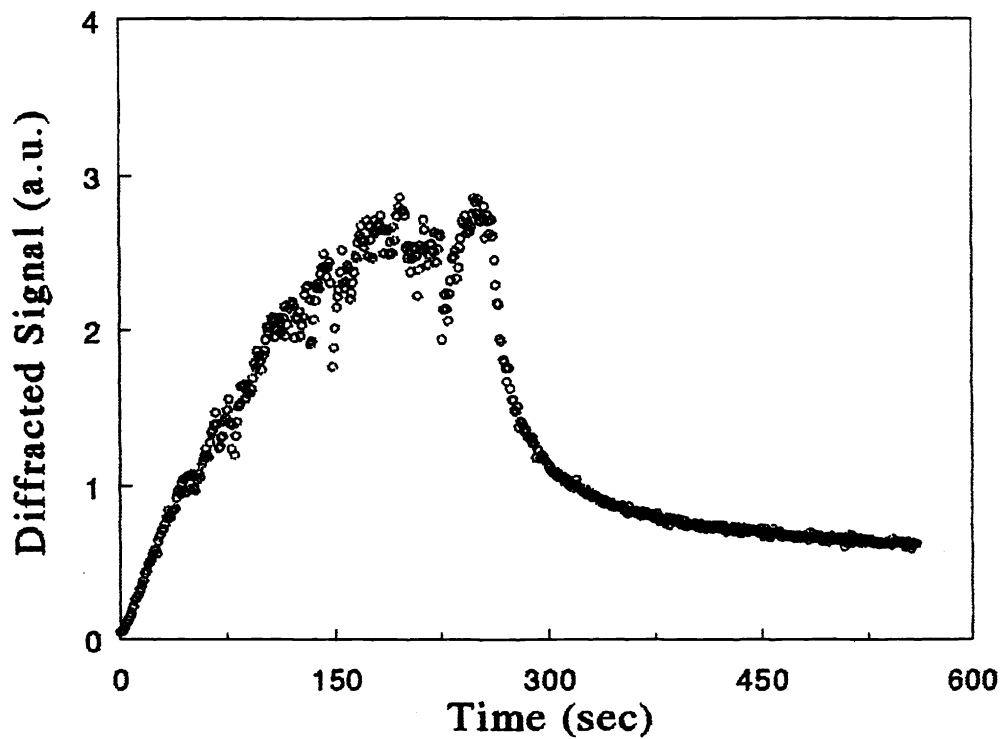


Figure 5. The temporal dependence of the FWM diffracted signal measured without external electric field.

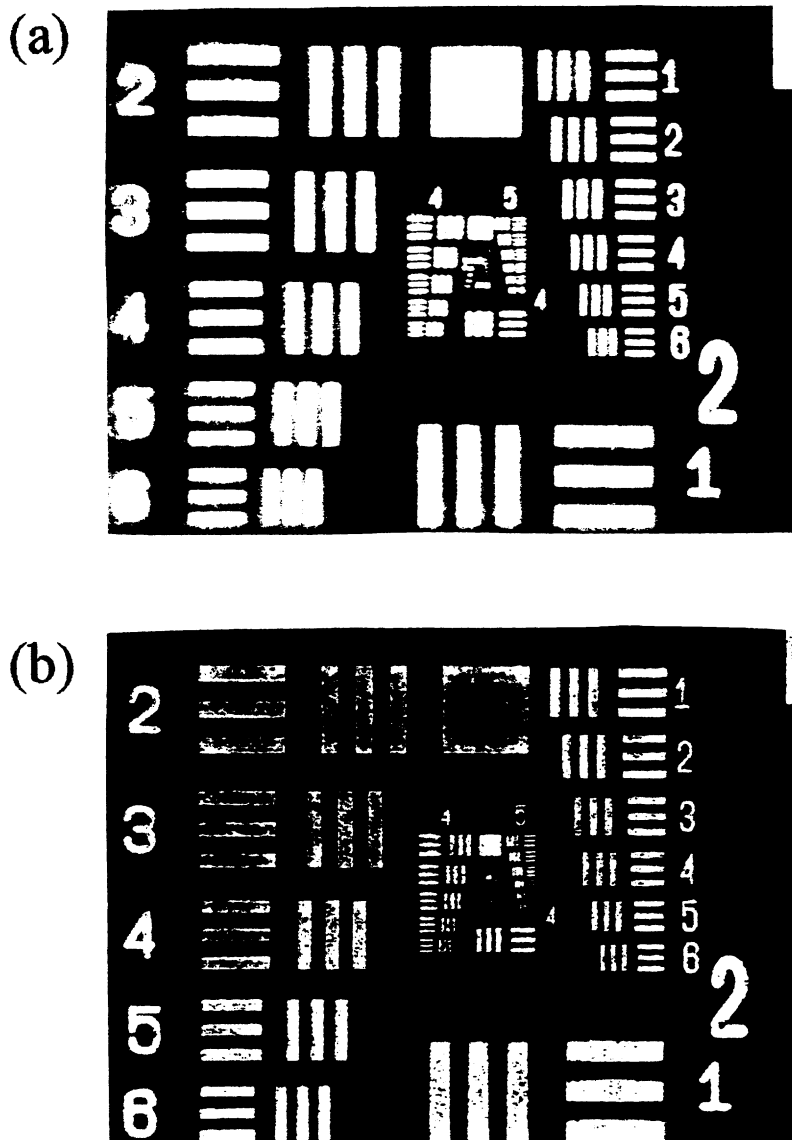


Figure 6.(a) The image of the original resolution chart transmitting through a filter (b) the restored image of the resolution chart written in the DCD/AEC/DO3 film under zero electric field. The average power density at normal incidence was about  $14 \text{ mW/cm}^2$ .