Significance of Chain Transfer Agents in Holographic Photopolymers

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1. Introduction

Photopolymers have been widely used as holographic recording materials owing to their self-processing capability and low cost with high fidelity reconstruction and low loss. The non-local photopolymerization-driven diffusion (NPDD) model was introduced to explain the observed drop-off in the material's high spatial frequency (SF) response (> 2000 lines/mm) [1]. To understand the SF response characteristics further, Guo et al. considered the extension of the NPDD model that included the chain transfer mechanism [2, 3]. Their extended NPDD model includes the effects of: (i) the kinetics of the major photochemical processes; (ii) the temporally and spatially varying photon absorption; (iii) the kinetics of chain transfer; and (iv) the non-local material response. The extended NPDD model suggests that one possible way to improve the material's SF response at high SFs is indeed the addition of chain transfer agents (CTAs) [2, 3]. In this talk we describe the experimental characterization of volume holographic recording in a polyvinyl alcohol-acrylamide (PVA/AA) system doped with different types of CTAs to examine the prediction of the extended NPDD model and to extract material's polymerization kinetic parameters by using the model.

2. Experimental result

In order to experimentally examine the prediction of the extended NPDD model, we employed conventional PVA/AA photopolymer samples containing two different types of CTAs: sodium formate (CTA-1) and 1-mercapto-2-propanol (95%) (CTA-2). Experimental growth curves of the refractive index modulation n_1 of an unslanted transmission volume grating recorded at a wavelength of 532 nm were extracted from the measured diffraction efficiency data with the most suitable CTA concentration being identified by examining the resulting material SF response. The saturated refractive index modulation n_1^{sat} for a sample with each type of CTA were evaluated at various SFs. The effects of added CTAs on the extracted average polymer chain length were also examined. It was found that the addition of CTA led to a decrease in the average polymer chain length and thereby a reduction in the non-local response. This trend results in the improvement of the high SF response of the PVA/AA photopolymer system as is clearly seen in Table I.

Table I. Measured average values of n_1^{sat} at various SFs for a standard PVA/AA photopolyer system without and with either CTA-1 or CTA-2. MSE (mean squared error) values shown below correspond to deviations from the average value for n_1^{sat} among multiple measurements at one SF.

SF (lines/mm)	w/o CTA [<i>n</i> 1 ^{sat} ×10 ⁻³]	w/ CTA-1 [n ₁ ^{sat} ×10 ⁻³]	w/ CTA-2 $[n_1^{\text{sat}} \times 10^{-3}]$
500	2.07	1.90	1.97
1000	2.20	2.18	2.09
1428	2.36	2.39	2.38
2000	1.97	2.12	2.23
2500	1.56	1.87	2.03
3000	1.38	1.60	1.68
non-local length	61.3±6.7	47.6±3.4	39.8±2.2
MSE (×10 ⁻¹⁰)	1.59±1.13	2.41±1.24	2.18±3.35

3. Conclusion

We have demonstrated the improvement of the SF response of an AA/PVA photopolymer system by the addition of CTAs. This improvement, as predicted by the extended NPDD model, is attributed to the shortened average length of polymer chains formed. We have shown that the most effective materials combination results in an increase of 22% in n_1^{sat} at high SFs. The low MSE values of the curve fitting for extracted material parameters indicate the validity of the extended NPDD model.

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References

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