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THE NON-LINEAR RESPONSE OF DYE-SENSITIVE PHOTOPOLYMERS IN REAL TIME HOLOGRAPHY

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ABSTRACT

Photopolymers are considered today one of the most promising recording materials for Holography because with them it is possible to achieve high diffraction efficiencies and low signal-to-noise ratios, while working in real time. Moreover, they are self-developing materials. In this communication we propose a non-linear model that, using the accepted mechanism of most photopolymerization reactions as a starting point, justifies the non-linear response of the diffraction efficiency curve, when these recording materials are analysed in real time.

PHOTOPOLYMERIZATION MODEL

Photopolymers are holographic recording materials which store information through refractive index variations under irradiation. This index changes according to the composition of the materials used and to the mechanism of the photopolymerization reaction involved. If a photochemical polymerization changes the concentration of the initial monomer A, producing polymer B, the relation between the concentration of A and B at any time, t, is:

\[ C(B,t) = C(A,t)(1 - \exp(-kt)) \]

where \( k \) is the overall reaction rate, a constant related to the photochemical quantum yield and to the absorbed radiation intensity. Assuming that refractive index and concentration are related through the Lorentz-Lorenz expression, it is possible to deduce the behavior of the modulation index as a function of the parameters above defined (expression (1)). Figure 1 shows an example of this relation.

\[ \Delta n(t) = \frac{(n^2 + 2)^2 - C(A,0)(R(B) - R(A))(1 - \exp(-kt))}{6000n} \]  \[ \text{[1]} \]

\( R(A) \) and \( R(B) \) are the molar refractivities of monomer and polymer and \( n \) is the refractive index of the photopolymer. As it is seen, a clear non-linear relation is established between exposure and modulation index. Previous studies have shown that this function is possible\(^1\), but the relation between the photochemical reaction and its form has not been justified.

DIFFRACTION EFFICIENCY

Taking into account that that diffraction gratings are stored in real time in photopolymers, and that the diffraction efficiency for phase holograms follows the equation proposed by Kogelnik\(^2\), this diffraction efficiency, \( \eta \), for non-linear responses of photopolymers can be expressed by (2):

\[ \eta = \sin^2\left( \frac{\pi d}{\lambda \cos \theta} \Delta n(t) \right) \]  \[ \text{[2]} \]

Figure 2 shows that the diffraction efficiency does not have a periodic response as predicted by Kogelnik's model, because the behavior of the modulation index is non-linear. At high exposures,
diffraction efficiency remains constant. The equation described above also indicates the existence of a clear relation between composition and properties of the materials on one hand, and the diffraction efficiency obtained on the other. Likewise, it allows the optimization of the material according to its composition, quantum yield and irradiation intensity.

CONCLUSION.

Using Kogelnik’s theory and introducing the non-linear response of refractive index modulation caused by the concentration changes in photopolymerization reactions, we have proven that photopolymerizable materials have non-linear behavior when working in real time Holography.

Figure 1

Figure 2

REFERENCES


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