Assessment of nonlinear optical properties of polyurethane/MgO nanocomposites

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Abstract
   The third-order optical nonlinearities of polyurethane open cell (PUOC)/MgO nanocomposites, dissolved in dimethylformamide are characterized by Z-scan technique with continuous-wave (CW) Nd:YAG laser at its second harmonic frequency of 532 nm with TEM_{00} Gaussian profile. The synthesized samples are also characterized by scanning electron microscopy imaging. The nonlinear refractive indices and nonlinear absorption coefficients of the synthesized samples are obtained in the order of 10^{-8} cm^2/W with negative sign and 10^{-5} cm^2/W, respectively. The origin of optical nonlinearity in this case may be attributed due to the presence of strong saturable absorption effect. All the results suggest that the nonlinear coefficients of the synthesized samples can be controlled by the nanoparticles contents into PUOC. Furthermore, the results show that PUOC/MgO may be helpful candidate for the application in nonlinear optical field in the visible region.
Keywords: Nano powder, Polyurethane, MgO, Nonlinear, Z-scan.

تخمين الخواص البصرية غير الخطية للمادة المتراكبة النانوية (بولي يورثان – اوكسيد المغنيسيوم)

الخلاصة

ان خلية البولي يورثين المفتوحة (PUOC)/MgO المتراكبة ذات الخصائص البصرية اللاخطية من الدرجة الثالثة و المذابة في مادة داي مثيل فورمايد تم دراسة خصائصها بواسطة تقنية Z-scan باستخدام ليزر الندميوم ياك ذات الموجة المستمرة (CW) Nd:YAG عند التردد الثنائي بطول موجي 532 nm ذات التوزيع الكاوسي المستعرض TEM_{00} وايضا تم دراسة العينات المحضرة باستخدام تقنية الماسح الالكتروني SEM وقد لوحظ ان معاملات الانكسار اللاخطية ومعاملات الامتصاص اللاخطية للعينات المحضرة تساوي بحدود cm^2/W 10^{-8} مع الاشارة السالبة و cm^2/W 10^{-5} بشكل متوالي. ويعود اصل البصريات اللاخطية في هذه الحالة الى ظهور تاثير امتصاصي قوي وان كل النتائج تستنج ان معاملات اللاخطية للعينات المحضرة يمكن السيطرة عليها من خلال كمية الجسيمات النانوية لمادة PUOC.بالاضافة الى ذلك اظهرت النتائج ان مادة PUOC/MgO النانوية يمكن ان تساعد في كثير من التطبيقات اللاخطية في منطقة الضوء المرئي .

INTRODUCTION

In the last few decades, great efforts have been made in the field of nonlinear optics (NLO) and it has been developed as a promising area of research with wide range of potential applications [1–3]. There is considerable interest in finding materials having large yet nonlinearities. This interest, that is driven primarily by the search for materials for all-optical switching and sensor protection applications, concerns both nonlinear absorption (NLA) and nonlinear refraction (NLR) [4].

In the present work, we will evaluate the effects of MgO nanoparticles (NPs) in PUOC matrix by considering the third-order nonlinear optical properties by using the closed-aperture (CA) and open-aperture (OA) Z-scan techniques with the Nd:YAG laser at a 532 nm wavelength with continuous-wave (CW).
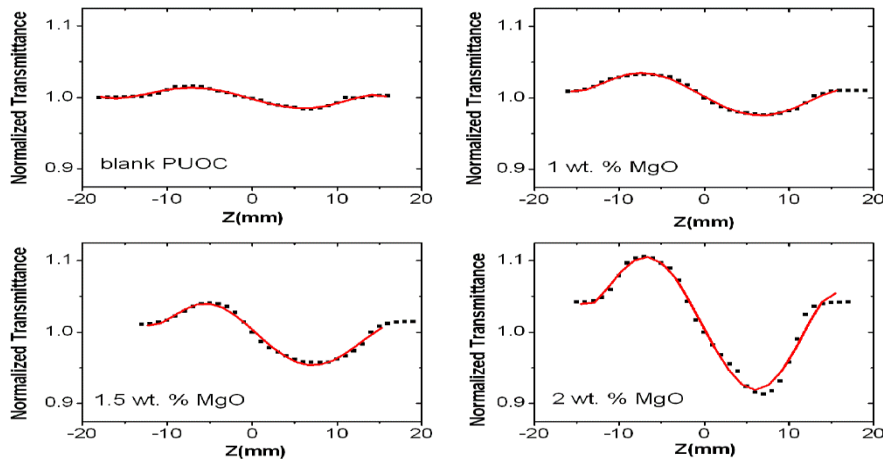
Experiment

The PU foam material composed of two commercially reactants: component A and component B in the form of liquid supplied by Exxon Panah Co., Iran without any commercial filler. The polyisocyanate employed was diphenylmethane diisocyanate (MDI, ρ=1.23 gcm^{-3}) as component A. Component B consists of polyol (based on polyether, ρ =1.1 gcm^{-3}), blowing agent, catalyst, and surfactant. For blank PU foam, two components mixed at a 1:1 ratio at 2000 rpm for about 10 seconds in an open cylindrical mould at room temperature. No heating was necessary. The polymerization reaction then takes place and simultaneously foaming begins due to CO_2 gas generation.

For preparing PUOC/MgO nanocomposites, three different weight percentages of MgO NPs (1.0, 1.5 and 2.0 wt.%) were dissolved into polyol component solution individually for 20 seconds with 3000 rpm in an open cylindrical mould at room temperature until a homogenized solution was reached. Then MDI part was added to the solution by doing vortex at 2000 rpm for 10 seconds. After 10–12 seconds reaction was ended by formation of foams in the samples. The ratio of polyol:MDI was 1 (2ml):1(2ml) in all the synthesized samples. For detecting NLO properties blank PUOC and PUOC/MgO nanocomposites dissolved in N, N Dimethylformamide (DMF).

Results and discussion

Fig. 1 shows pure closed Z-scan data of different percentages of MgO NPs in pure PUOC. As it can be seen in the normalized curves of closed aperture Z-scan exists a pair of peak and deep valley which can be identified as a self-defocusing material with negative sign of NLR index because the valley comes after the peak of the transmittance [5]. The order of NLR indices coefficients are 10^{-8} cm^2/W.

Figure(1) Closed aperture curve of PUOC/MgO nanocomposite

However, because of using continuous-wave laser it is expectable that we detect thermo-optical (thermal) effects in the samples. Furthermore, by considering related research, it is more probability that thermal effect occurs for linear absorption in the order of 1 cm^{-1} [6].

It is seen that in Fig. 2 the open aperture transmittance is symmetric with respect to the focus $(z = 0)$, where has a maximum transmittance. The values of β cm^2/W or NLA can be obtained from eq. (1).

$$T_{norm}(z) = Ln(1 + q_0(z,t)) / q_0(z,t) \qquad \ldots(1)$$

Where

$q_0(z,t) = \beta I_0 L_{eff} /(1 + z^2 / z_0^2)$, $z_0 = k\omega_0^2 / 2$ is the diffraction length of the beam, and $k = 2\pi / \lambda$ is the wave vector [5-7].
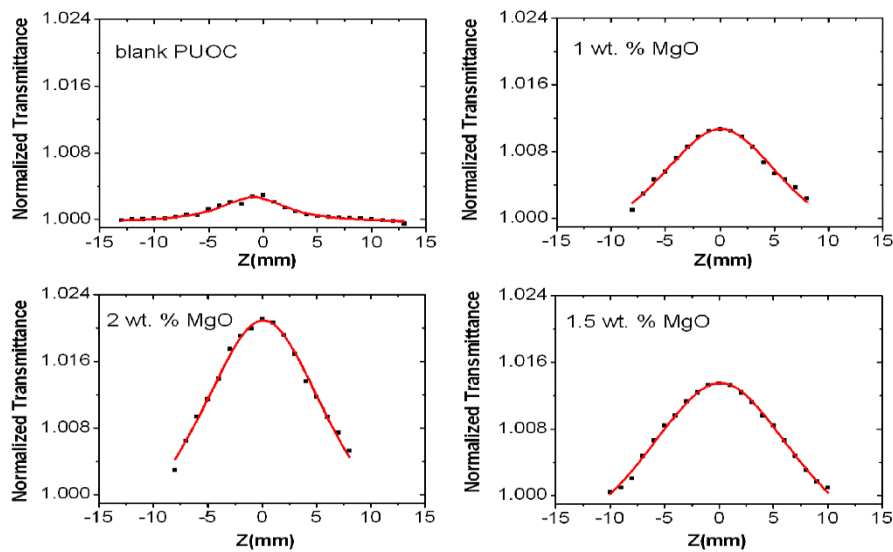

Figure (2) Open aperture curve of PUOC/MgO nanocomposite

The NLA coefficients of the synthesized samples were obtained in the order of 10^{-5} cm^2/W with positive sign that shows the presence of strong saturable absorption (SA) [8]. It is clear that by adding MgO NPs into polymer matrix, the amount of β has increased. As a result, by adding NPs into blank PUOC from 1.0 wt.% to 2.0 wt.% the NLR indices and the NLA coefficients of the synthesized samples increased gradually. By adding MgO NPs into blank PUOC, the polarity of the system will be increased that tends to rising of the NLO properties.

Conclusion:

By controlling the optimum ratio of MgO into PUOC, it can be suggested as a promising and helpful candidate for applications in real optical systems by controlling the amount of NPs, the nonlinear coefficients of samples can be adjusted. The nonlinear refractive index of the samples was obtained from CA Z-scan in the order of 10^{-8} cm^2/W with negative sign. By adding NPS into polymer matrix, the nonlinear refractive index has increased. The nonlinear absorption coefficients of the samples were obtained from OA Z-scan in the order of 10^{-5} cm^2/W with positive sign. By adding NPs into polymer matrix, the amount of β is increased. The origin of β is the presence of strong saturable absorption (SA) effect.

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