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ضریب شکست غیر خطی تنظیم پذیر در لایه نازک PVP شامل نانوسیم نقره

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چکیده- کنترل ضریب شکست غیر خطی در نانوساختارها به منظور استفاده از آنها در زمینه های مختلفی مانند لیزر، جفت شدگی اکسیتون پلاسمون، پیزوفوتونیک و مانند آن از اهمیت ویژه ای برخوردار است. از این رو در این مقاله، نانوسیم های نقره در بستره پلیمری PVP با غلضت های مختلف آماده شده و تحت اندازه گیری ضریب شکست غیر خطی قرار گرفتند. نتایج نشان دهنده افزایش چشم گیر میزان ضریب شکست غیر خطی با افزایش غلظت نانوسیم هاست که می تواند در زمینه افزایش بهره در محیط ها بسیار کاربردی باشد.

کلید واژه- ضریب شکست غیر خطی، نانوسیم های نقره، روش روبش **z**.

Controllable Nonlinear refractive index of PVP thin film doped with silver nanowires

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Abstract: In the present work, the nonlinear refractive index of silver nanowires (Ag NWs) doped with PVP polymer films is determined using z-scan technique. This work was particularly done utilizing a close aperture placed in front of the detector to show the effect of the Ag NWs on the nonlinear refractive index of the PVP films. It’s found experimentally that the nonlinear refractive index of the films can be varied by changing the compositional percentage of Ag NWs in PVP films. The obtained nonlinear refractive index of the samples indicated that Ag NWs can act as a good material for controlling the third order nonlinear coefficient in gain media due to its large nonlinear optical properties.

Keywords: Ag nanowires, nonlinear refractive index, PVP films, z-scan technique.

1. Introduction

The adjustment of the optical properties of materials by the presence of laser light, leads to a promising field with significant applications in the area of optical and photo-electronics [1, 2]. One of these optical properties is nonlinearity, but in metallic nanostructures dispersed in a dielectric medium [3-5]. Insulator materials containing of metal nanoparticles, exhibit large nonlinear optical effects, because of their fast response and high value of nonlinear optical parameters such as nonlinear absorption and nonlinear refractive index [6]. These materials are perfect candidates for the creation of new photonics devices, for example, all optical switching and routing units. Several techniques have been used to measure the third order nonlinearity such as z-scan, which is an easy procedure, also a delicate and direct technique for determination and characterization of the nonlinear optical properties of materials. According to the previous literature, there are a lot of papers which focus on the study the silver nano wires (Ag NWs) in polymer films [7-16], but there are few works which focus on the change in the nonlinear properties for metal nanostructures in polymers by using the z-scan technique. In the present study, we have investigated nonlinear refractive index of polymer films containing Ag NWs by using Z-scan technique.

2. Materials and method

2.1. Materials

The materials used in this work, the silver nanowire (>99 %) were purchased from Sigma-Aldrich, it's length and width 1um, 100nm respectively. Poly vinyl pyrrolidone (PVP) (Mw= 55000 g/mol) was purchased from Merck.

2.2. Sample preparation

The samples investigated in this studying are a mixture of Ag NWs and PVP at different percentages, the polymer with a mixture of 3% PVP and deionized water dissolved using a magnetic stirrer. Our samples are prepared by adding the PVP films doped Ag NWs at five different compositional percentages (2%,4%,8%,12%, and 16%) and then stirred in an ultrasonic bath for about 15 min. The last step is preparing the thin films layer on glass by a spin coating method.

2.3. Z-scan technique

The nonlinear refractive index (n_2) of all the samples are measured by z-scan technique. We utilized the closed aperture z-scan technique using a continuous wave Nd:YAG laser at λ =532 nm as the light source. A Gaussian beam of the CW laser with a well-defined vertical polarization and the power of 10 mW. The convex lens with a focal length of 18 cm, was used to focus the laser beam on the sample, the samples were excited at normal incidence geometry for the laser beam. In order to measure transmittance as a function of the sample position, the sample was moved back and forth along the z-axis around the minimum beam waist of the laser during the z-scan measurement. We managed to analyse the distortions of beam wave front associated with distinct effects nonlinear variation of the refractive index, by controlling the diameter of the aperture (S=0.1–0.3). The schematic of the setup for the z-scan experiment, is shown in Fig.1.

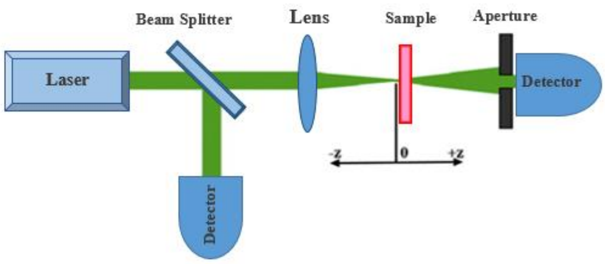

Fig. 1: Schematic diagram of the experimental setup for closed aperture z-scan technique.

3. Results and discussion

The UV-VIS absorption spectra of the samples used in this work are shown in Fig. 2. We can clearly observe the absorption spectrum changes accordingly to their Ag NWs ratio. In addition, the absorption spectrum of this sample indicates that the intensity peak becomes stronger as Ag NWs quantity increases. Moreover, the absorption spectra of the samples containing three distinct peaks at wavelengths of 285nm indicates absorption PVP polymer, as well two peaks at 300nm and 330nm indicates absorption Ag NWs.
Measurements of the nonlinear refractive index of samples revealed by using the z-scan technique. The scan started from a distance near the focus until out of focus.

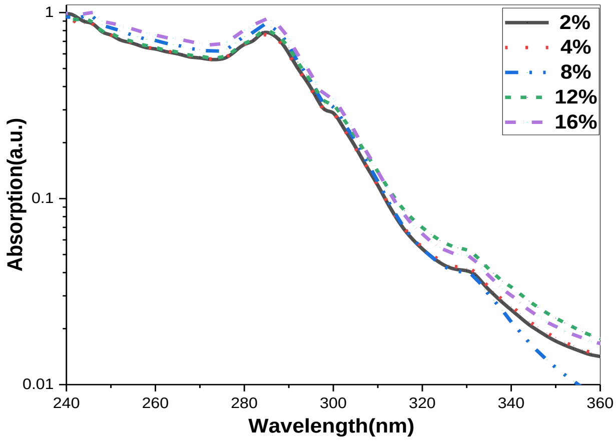

Fig. 2. Absorption spectra of different samples by concentrations set to 2, 4, 6, 8 and 16 percent.

A nonlinear refractive index has been observed, the peak-valley pattern of the normalized transmittance curve configuration indicates the positive sign in which the peak comes after the transmittance valley for all the samples, as are shown in Fig.3.

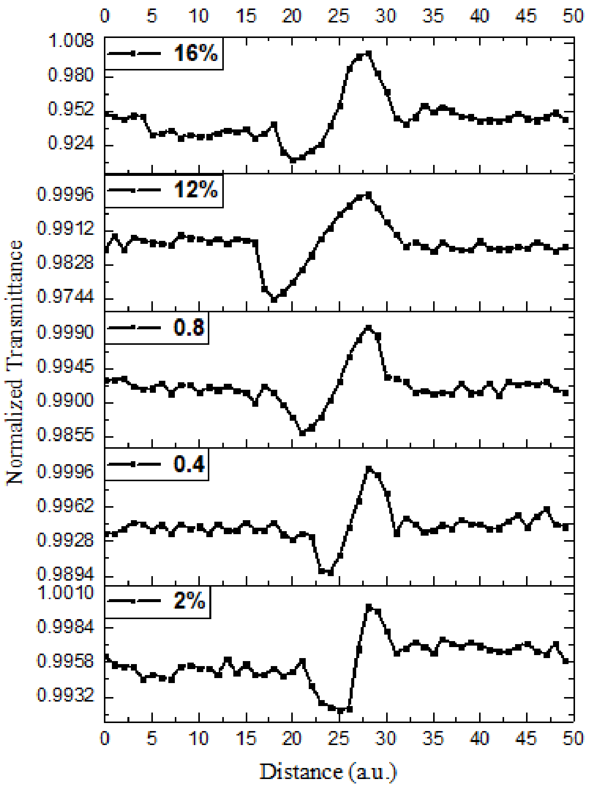

Fig. 3. Transmittance with closed aperture z-scan for all samples.

Using of the peak-valley position shown in Fig.3, the nonlinear refractive index values can be calculated using the equations shown in our previous work [17].

Table 1: The linear and nonlinear optical parameters for all the samples.

Compositional percentages of the samples	Linear absorption coefficient α (cm^{-1})	ΔTP-V	$\Delta\emptyset_0$	n_2 (cm^2/watt)
2%	0.24	0.0078	0.019	1.89E-11
4%	0.14	0.0105	0.026	2.54E-11
8%	0.23	0.014	0.034	3.40E-11
12%	0.20	0.0258	0.064	6.27E-11
16%	0.28	0.0879	0.216	21.1E-11

A nonlinear refractive index of PVP films is observed to increase when the Ag NWs ratio increases, as shown in Table 1. Our results are explained, the n_2 of the PVP films can be controlled by adding different ratios for Ag NWs to polymer. These important results can help us in the designing of optical devices in the domain of applications.

4. Conclusion

In summary, the nonlinear responses of Ag NWs in PVP mixtures are determined. We studied the effect of PVP of the nonlinear refractive index of Ag NWs, using z-scan technique. In addition, the linear optical properties of the prepared samples using UV-VIS spectrophotometer is presented. In the closed aperture, a strong variation of n2 can be observed when the pure Ag NWs were dispersed in PVP in order 10-11 cm2/ watt. Such results suggest that PVP doped with Ag NWs can be a good candidate for such a dielectric medium and it can be useful for gain enhancement applications.

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