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Research Article

Nonlinear Optical Properties of deoxyribonucleic acid DNA doped Rhodamine B/PVA films using Z-scan technique

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Abstract

In this work, we present the nonlinear optical properties from the measurements of third order nonlinearity in DNA doped Rhodamine B/PVA films achieved through Z-scan technique at a wavelength of 1064nm. The films demonstrated negative nonlinear refractive index (n_2) with magnitudes of (8.66-16.7) $\times 10^{-7} cm^2/W$ with varying weight concentrations of DNA. While, the largest magnitude (7.64×10^{-7}) cm^2/W with a positive (n_2) was observed at different concentrations of RhB/PVA films. Open aperture data demonstrated a strong two-photon absorption with a magnitude of $26.8\times10^{-3} cm/W$ for films doped with (6Wt. %) of DNA. However, a nonlinear absorption coefficient (β) with a magnitude $4.77\times10^{-3} cm/W$ at the concentration 1×10^{-4} Ml of RhB/PVA film was recorded. Reverse saturable absorption (RSA) behavior at 1064 nm for RhB/PVA films was observed and by adding DNA, a strong completely switchover from RSA to SA behavior. These data indicate to the addition of DNA enhanced the nonlinear optical properties of the solid films. Therefore, suggests that DNA is promising material for photonics applications.

Keywords: *Nonlinear optics, DNA, Rhodamine B, Z-scan technique, Biomaterial.*

1. Introduction

Nonlinear optics is the study of effects and phenomena that occur when the response of a material system to an applied optical field depends in a nonlinear manner on the strength of the optical field. Typically, nonlinear optics is observed with only laser light which have a sufficiently intense to modify the optical properties of a material system. (Robert Boyed *et al*, 2007) The invention of lasers, a concentrated source with a high degree of monochromatic and directed light has revolutionized photonics. Photonics are taken to be applications in which light (consisting of photons) is used to transmit, or process information, or to modify materials physically. (Richard *et al*, 2006) A new extension of photonics is biophotonics, which includes a fusion of photonics and biology. Biophotonics deal with interaction between light and biological matter. (Paras *et al*, 2003) At the recent, biomaterials are of particular interest as they have unusual properties that are not easily replicated in conventional organic or inorganic materials. Moreover, biomaterials are a renewable resource and biodegradable. (Andrew *et al*, 2007) Deoxyribonucleic acid (DNA) is the most important and famous biomaterials known to man. The DNA polymer in solid- state thin films has an individual combination of optical and electronic properties which have formed the basis of the new field of DNA photonics, such as optical switching, laser structures, optical waveguides and OLEDs. (A.J. Steckl *et al*, 2011) DNA is one of the possible host materials for functional molecules (such as fluorescent and laser dyes molecules), because of its unique double helix structure. These molecules are called as DNA binding dyes. (N. Kitazawa *et al*, 2012) Rhodamine B is one of the Xanthene dye's family and a widely used to detect metal ions in luminescent analysis and in biotechnology to study fluorescence microscopy and fluorescence correlation spectroscopy (Md. Maidul *et al*, 2013).

We have used poly vinyl alcohol (PVA) for dissolving DNA and Rhodamine B dye for carrying out most of the experiments. Since DNA and PVA are water soluble, it is very easy to make films of DNA/PVA mixture. Rhodamine B is also soluble in water. Therefore, we have incorporated RhB dye in DNA/PVA films (Sasidharan *et al*, 2012). To evaluate parameters which may be relevant for photonic device application of DNA and the material derived from it. It is important to determine third order nonlinearity for evaluation of the properties of the materials containing DNA. The nonlinear optical properties of dyes doped polymer films (RhB/PVA) and DNA doped RhB/PVA films can be demonstrated by using a simple technique called Z-scan. This technique is a sensitive single- beam for measuring both of the nonlinear refractive index and

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nonlinear absorption coefficient for a wide variety of materials (Mansoor *et al*, 1990). The aim of this work was the investigation of the nonlinear optical properties of DNA/RhB/PVA films, as they promising systems for photonic devises.

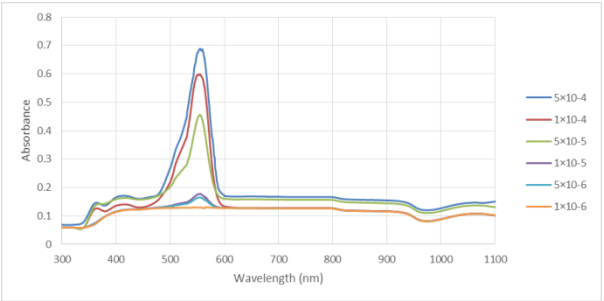
2. Experimental details

PVA solutions (8%) were prepared by dissolving appropriate amount of PVA in a distilled water under a continuous stirring. Weighed DNA powder [extracted from fish milt, Supplied from (BDH Chemicals Ltd Poole, England)] was added to the prepared PVA solution. Rhodamine B dye was then added to PVA/DNA solution in desired concentration. After stirring the solution, the films were fabricated by casting method with average thickness of ~150µm. The sold films preparation which involves two groups were studied, the first group is Rhodamine B dye doped PVA polymer at different concentrations (1×10^{-6}, 5×10^{-6}, 1×10^{-5}, 5×10^{-5}, 1×10^{-4}, 5×10^{-4}) Ml, and the second group is 1×10^{-4}Ml of Rhodamine B dye doped PVA polymer with (1, 2, 3, 4, 5 and 6) Wt.% of DNA. The absorption spectra of prepared films were characterized by using a double-beam UV-Visible spectrophotometer (Metertech SP8001, Taiwan). Nonlinear optical measurements were performed on the films by using Z-scan technique with a wavelength of 1064nm. The Z-Scan measurements were performed using CW Nd-YAG laser (MIL-111, Changhun new industry, china) with a wavelength of 1064 nm. The output beam was focused onto the sample by using a convex lens with a focal length of 10 cm, giving a spot size of ~ 60µm. The transmittance of the sample as it is moved between ~ $\mp5Z_0$.

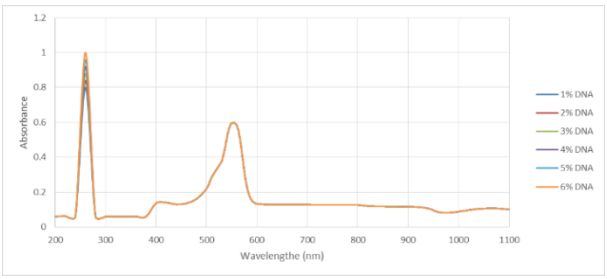
3. Results and discussion

3.1 Linear absorption spectra

Figure (1, a) shows the linear absorption spectra for different concentrations of RhB/PVA films. Absorption peak of RhB is prominent in the visible region around 555nm. By increasing concentration of RhB, the absorption peak values increased due to the increase of the number of the absorbing species according to Beer's law. This behavior was in agreement with literature.



(a)



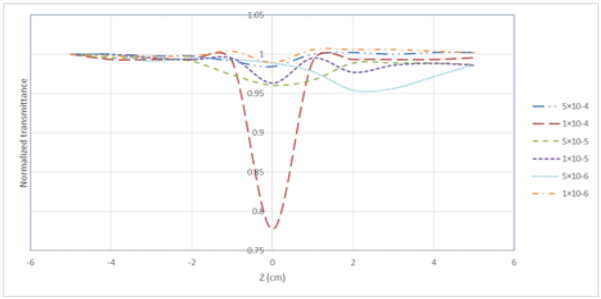
(b)

Figure 1: UV-Visible Absorption Spectrum of (a) PVA with Rhodamine B at different concentrations and (b) Rhodamine B Dye doped PVA with DNA at different Weight ratio

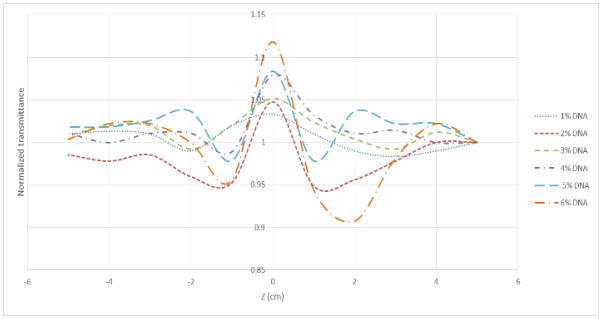
Figure (1, b) above shows absorption peak at 260 nm for all the samples of (DNA/RhB/PVA) films, which is the characteristics of DNA absorption and this is due to π-π* transition of the electrons of C=C bond in DNA (where π represents bonding orbitals and π* represents anti-bonding orbitals). This behavior was in agreement with literature. By increasing weight percent of DNA, significant increasing in the light absorbance at 260 nm of the samples can be observed.

3.2 Nonlinear optical properties

In this part we present the nonlinear optical properties, the nonlinear refraction and the nonlinear absorption in term of nonlinear refractive index n_2 and nonlinear absorption coefficient β, respectively. Figures (), () show Open and closed aperture Z-scan curves at 1064 nm at six concentrations of Rhodamine B doped PVA and 1×10^{-4}Ml of Rhodamine B doped PVA with different weight concentrations of DNA at a fixed peak intensity of 1.77 W/cm^2. The values of n_2, β are calculated from Z-scan theory (real and imaginary) parts of the third order nonlinear susceptibility χ^3, as listed in table (1) and (2). From these tables we can see the changes in the nonlinearity of the samples according to the effect of DNA, this enhancement can be attributed to the intercalation interactions into base pair stack at the core of double helix and/or insertion into the minor groove of DNA are recorded to have strong influence on the optical characteristics. Furthermore the increase of charge transfer, which occurs in the system due to the presence of many highly polarizable conjugated π electrons of DNA.

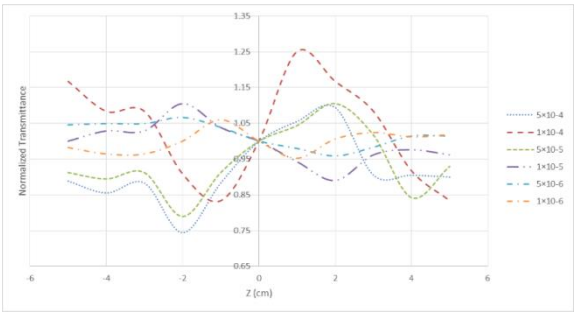


(a)

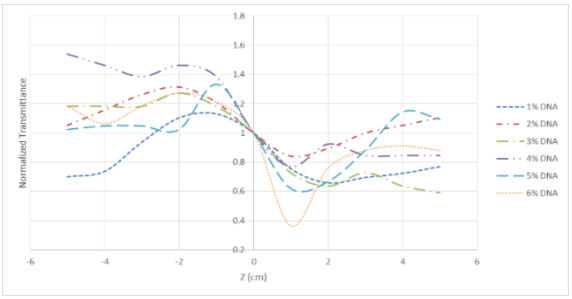


(b)

Figure (2): Z-scan curves for RhB doped PVA at different concentrations (a) open aperture (b) close aperture



(a)



(b)

Figure (3): Z-scan curves for RhB doped PVA with different weight concentrations of DAN (a) open aperture (b) close aperture

Table 1 Values n_2 and β for RhB/PVA films.

Concentrations (Ml)	β ($\times 10^{-3}$ cm/W)	n_2($\times 10^{-7}$ cm2/W)
1×10^{-6}	1.28	-1.97
5×10^{-6}	1.3	-1.98
1×10^{-5}	4.01	-3.93
5×10^{-5}	4.44	6.05
1×10^{-4}	4.77	7.64
5×10^{-4}	1.96	6.63

Table 2 Values of n_2 and β for RhB/PVA with DNA films

Weight (Wt. %)	β ($\times 10^{-3}$ cm/W)	n_2($\times 10^{-7}$ cm2/W)
1	-5.75	-8.66
2	-6.19	-8.69
3	-9.56	-11.7
4	-10.1	-12.7
5	-14.3	-13.1
6	-26.8	-16.7

Conclusions

As is clear, the PVA is a good matrix for Rhodamine B dye incorporated into the double helix of DNA molecule. Furthermore, the addition of DNA enhanced the nonlinear optical properties of prepared films and it plays good role in the nonlinear behavior of RhB/PVA films making them suitable for photonic devices. Z-scan experiments have revealed interesting features of the nonlinear absorption properties of DNA doped Rhodamine B/PVA films at 1064nm. RSA behavior was observed for RhB/PVA films. On doping DNA at 6 wt. % in RhB/PVA films, we have observed a switchover from RSA to SA behavior. And the prepared films of DNA/RhB/PVA showed a high self-defocusing negative nonlinear refractive index with a magnitude of 16.7×10^{-7} cm^2/W at a weight concentration 6% of DNA.

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