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Identification of the nonlinear optical properties for a mixture of Sudan yellow 3G and poly methyl methacrylate for optical limiting applications

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ABSTRACT

A mixture of sudan yellow 3G dye and poly methyl methacrylate film is fabricated by casting. The optical constants are determined using measurements of absorbance, transmittance, and reflectance spectra. The indirect optical band gap is obtained from Tauc's formula, which is found to be 2 eV. By excitation of the sample with a continuous wave laser beam, the nonlinear optical and the optical limiting properties are studied. The change in refractive index, Δn, and nonlinear refractive index, n_2, for the sample is calculated from the diffraction ring patterns and is found to be 44.10×10^{-3} and 18.29×10^{-6} cm^2/W respectively. We employ Z-scan to determine nonlinear refractive index $n_2 = 0.6 \times 10^{-6}$ cm^2/W and nonlinear absorption coefficient $\beta = 8.79 \times 10^{-3}$ cm/W. The sample is proven to possess the properties of an optical limiter, as the threshold limiting value of the film is equal to 5.3 mW.

1. Introduction

The development during the last three decades in the field of nonlinear optics, through the discovery of several methods for determining nonlinear optical (NLO) parameters, opened wide prospects for the field of nonlinear optics to become a promising and vital field in photonics applications. Optical bi-stability [1], optical limiting (OLg) [2–5], optical modulation [6], optical phase conjugation [7], data storage [8–10], image processing [11] are photonic applications that depend on the nonlinear optical properties of the material. One of the best, most accurate, and easiest methods that were discovered in 1989–1990 by M. Sheik-Bahae is the Z-scan method [12,13]. This method provided the possibility of evaluating the nonlinear refractive index (NLRI) and the nonlinear absorption coefficient (NLAC). Also, this method does not require complex optical devices and compounds. This prompted many researchers to use this method to determine the NLRI and NLAC of many liquid materials, solid films, single crystals, etc., [14–23]. In addition to this method, another method that does not require complex optical devices is the diffraction ring patterns (DRP) [24], but through this method, only the NLRI can be calculated. Both methods are based on a change in the Gaussian distribution of the laser beam transmitted from the sample due to self-phase modification.

Linear optical properties are no less important than NLO properties in the field of photonics applications. The refractive index, absorption coefficient, optical conductivity, real and imaginary parts of dielectric constants, and optical energy gap of the material are important parameters that must be calculated in order to determine the appropriate photonic application of the material. The researchers tested several materials during the last period by studying their linear and NLO properties for the purpose of using them in photonic applications [25–37]. The most common materials are organic dyes, as they show high NLO properties, a high damage threshold, good solubility in different solvents, cheap, easy to prepare, and have the ability to form in optical devices. Among the currently available dyes, azo dyes have demonstrated their high efficiency in various photonic applications. Sudan dye is considered a member of the azo dye. Sudan IV dye has proven its possible usage as a medium in optical data storage [38], sudan III has shown efficient properties for the OLg [39], while sudan I, sudan orange G, and sudan red G have appeared with high NLO properties [40,41]. Because of the fascinating characteristics of the sudan dyes, we have chosen one type of these dyes, namely sudan yellow SY3G as a sample in the present study.

The objective of the current study is to improve the optical limiting properties of sudan yellow 3G for the purpose of having better optical limiting properties than conventional materials. Most of the previous studies in this field have proven that the process of mixing the polymer with the dye gives better optical limiting properties than using the dye alone. In addition to that, the polymer improves the adhesion of the dye

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