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Original research article

Linear, nonlinear and optical limiting properties of carbon black in epoxy resin

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ABSTRACT

Films of an epoxy resin doped carbon black were prepared by casting method onto BK7 glass substrates. The surface morphology of these films were investigated together with the nonlinear optical properties under CW laser light irradiation of 532 nm wavelength using diffraction ring pattern and Z-scan techniques. The prepared samples exhibited strong self-defocusing effect and good optical limiting behavior.

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1. Introduction

During the last three decades organic materials gained increasing and continuous importance due to their unique properties such as high nonlinearities, short response time, ease of manufacturing, availability and cheapness. It was proved by many researches their efficient photonic and electronic applications such as optical switches, optical limiting, high density optical data storage, optical phase conjugation, etc. [1–4].

The study of some optical characteristics such as optical limiting required the study of nonlinear optical characteristics of these materials especially their nonlinear refractive index. There exist three techniques used to evaluate the nonlinear refractive index viz., thermal lens [5], diffraction ring pattern [6] and Z-scan [7] respectively.

Carbon black (CB) is virtually pure elemental carbon in the form of colloidal particles [8] prepared by partial combustion or thermal decomposition of gaseous or liquid hydrocarbons under controlled conditions. Its physical appearance is that of a black, finely divided pellet or powder. CB is used in a diverse group of materials in order to enhance their physical, electrical and optical properties. Its largest volume use is as a reinforcement and performance additive in rubber products. In rubber compounding, natural and synthetic elastomers are blended with CB. CB provides reinforcement and improves resilience, tear strength, conductivity and other physical properties. CB is the most used and cost-effective rubber reinforcing agent

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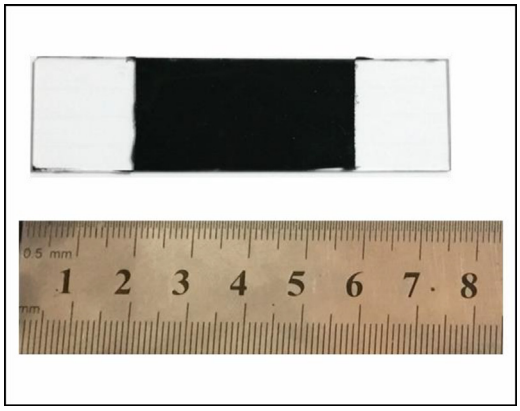

Fig. 1. Photograph of the epoxy resin doped CB on a rectangular glass substrate.

in tire components, in mechanical rubber goods, including industrial rubber goods, membrane roofing, automotive rubber parts.

Besides rubber reinforcement, CB is used as black pigment and as additive to enhance material perforcement including conductivity, viscosity, static charge control and UV protection. This type of CB is used in a variety of applications in the coatings, polymers and printing industries.

Epoxy resins are highly reticulated thermosetting polymers which are easy to process, with high-performance, containing at least two epoxy groups per molecules. The epoxy ring is formed by two carbon atoms bonded to oxygen atoms. Due to their high reactivity, epoxy rings may be used in several mechanical applications because of their adhesive properties, rigidity, specific resistance, dimensional stability, chemical resistance and high fluidity prior curing which allows for easy processing.

In the experiment carried out in this work epoxy resin [9] is used as a host for CB. The linear, nonlinear optical and optical limiting properties of epoxy resin doped CB films are studied under the effect of CB concentration. The surface morphology of these samples are reported too.

2. Experimental

2.1. Preparation of films

All chemical materials used in this study were purchased from Aldrich. A polymer was prepared by mixing epoxy with triethylene tetra amine as a hardener in a ratio of (2:1), yield was mixed with CB as a filler at different concentrations viz. (0.004, 0.005, 0.006) gram to 1 g of the prepared epoxy resin. Samples were prepared by the casting method. A rectangular glass (BK7) was used as substrates. The prepared solution was spread onto these substrates. Samples were left to dry in laboratory for one day. By this way three samples of epoxy resin CB doped of (0.4, 0.5, 0.6) wt% resulted. Fig. 1 is a photograph of one of the prepared samples.

2.2. UV–vis spectroscopic study

The UV–vis spectra of each epoxy resin doped CB film of different concentrations were obtained using a 6800 UV–vis spectrophotometer (Jenway-England) at room temperature. The optical absorbance spectra were analyzed to determine the absorption coefficient, α, of each sample.

2.3. Diffraction rings technique

Induced changes of refractive index due to optical field have effect on laser beam propagating in nonlinear medium can lead to spatial self phase modulation (SSPM). Owe to such effect, diffraction ring patterns appeared as a result of a laser beam traversing the nonlinear medium. Diffraction ring patterns were demonstrated in varieties of media such as nematic liquid crystals, solids and liquids [10,11]. Fig. 2 shows the experimental setup for producing diffraction rings in epoxy resin doped CB films. A laser beam is focused on each sample via the use of a 5 cm focal length positive glass lens and a semitransparent 30×30 cm screen located 145 cm from each sample. Solid state laser device working at the fundamental, TEM_{00}, mode and emitting continuous wave (CW) light of wavelength $\lambda = 532$ nm, having 1.5 mm spot size (at $1/e^2$ of the peak intensity) with variable power output (0–100) mW was used. The nonlinear refractive index, n_2, can be estimated by the diffraction ring technique.

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