Optik 127 (2016) 7459–7468

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

A detailed investigation of the gamma-ray radiation effects on the optical properties of polyvinyl butyral film

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ARTICLE INFO

Article history:
Received 25 March 2016
Accepted 23 May 2016

Keywords:
Polyvinyl butyral
Optical properties
Gamma irradiation
Optical parameters

ABSTRACT

Polyvinyl butyral (PVB) films were irradiated with various doses up to 250 kGy by gamma radiation. The PVB was synthesized using solution method and in order to uniform exposure, film form of it was provided. Formation of PVB was confirmed using the Fourier transform infrared spectroscopy (FT-IR). The effects of gamma irradiation on the various optical properties of films such as absorption coefficient, penetration depth, Urbach energy, optical band gap energy, threshold wavelength, extinction coefficient, refractive index, optical dispersion parameters, dielectric constant and dissipation factor were studied by UV–vis spectroscopy. The results showed some changes in the optical properties of PVB films due to cross-linking formation between polymer chains. At doses higher than 70 kGy, however the polymer began to decompose due to chain scission and trend of the optical properties changing became inverse.

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1. Introduction

Polyvinyl butyral (PVB) extendedly employed for optical systems, solar cells in the aerospace and military industries, and optical windows in equipment due to its excellent properties such as high radiation resistance and high adhesion to surface [1–5]. Moreover, PVB was used as dosimeter in nuclear industry [6]. More than 90% of produced Polyvinyl butyral has industrial application in the form of film and it commonly used for applications that requiring a strong connection, optical clarity, adhesion to surfaces, hardness and flexibility.

There are significant amounts of gamma radiation outside the earth's atmosphere due to the phenomenon of bursts radiation. Gamma ray bursts (GRBs) within a few seconds dispersed total energy equal to the sun's energy in the space. For this, absorbed radiation dose and its effect on the performance of optical systems which used in the aerospace's equipment were widely studied by researchers. So far, many literatures were published about the effects of gamma irradiation on the optical properties of various polymers such as CR-39, polystyrene (PS) films, and aromatic polymers [7–12].

The present work aims to study the effect of high dose gamma ray on the optical properties of PVB films. First, PVB films were synthesized by solution method. Then, a detailed study about the effects of various doses of gamma radiation on the different optical properties of prepared film such as absorption coefficient, penetration depth, Urbach energy, optical band gap energy, threshold wavelength, extinction coefficient, refractive index, optical dispersion parameters, dielectric constant

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http://dx.doi.org/10.1016/j.ijleo.2016.05.076
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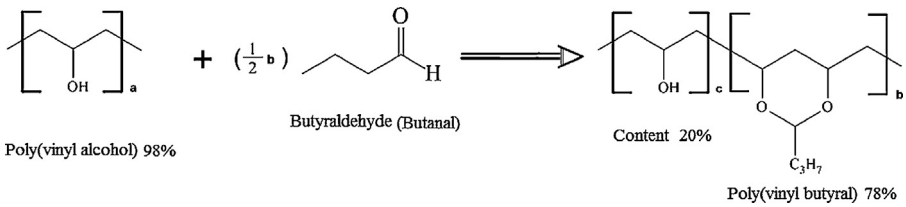

Scheme 1. Synthesize of PVB from reaction PVA with butyraldehyde (butanal).

and dissipation factor was done. However, to the best of our knowledge, such a detailed study of the optical properties of PVB films has not been reported in any previous work. Such detailed studies may have profound consequences for practical application of the optical devices which use PVB in their structure.

2. Experimental

2.1. Materials and method

The materials that used for synthesis of PVB include; Polyvinyl alcohol (PVA) with molecular weight of 72000 g/mol and hydrolysis percentage of 98% from AppliChem Co., Butyraldehyde (Butanal) with MW = 72.11 g/mol from Merck Co. and sodium dodesylsulfate (SDS) from Merck Co.

2.2. Polymer synthesis

Required PVB was synthesized by solution method (acetic acid and water mixture (50:50)), using PVA and butyraldehyde according to Scheme 1 [13,14]. In this reaction, PVA is the primary polymer and butyraldehyde is the modifier of primary polymer.

Preparation of PVB by the solution method is as follows; 7 gr of PVA was dispersed in water, acetic acid, sulfuric acid (a few drops), SDS (0.1 gr) and then stirred 30 min. With adding 4.05 gr of butyraldehyde at temperature of 10 °C stirring was continued for 120 min. Then temperature was raised to 70 °C for 30 min and mixing was continued. Finally, PVB with addition of distilled water was precipitated, then filtered and dried in oven.

2.3. Film preparation

In order to uniform exposure and because the most of industrial applications of PVB are in the form of film, PVB film was provided for irradiation. First, 5% PVB solution was prepared from PVB powder in the methanol solvent and stirred at room temperature for two days. Then it was kept overnight for air bleeder and remove air from solution. The solution was poured into a mold and was kept in foothold for evaporating the solvent about 48 h. At last for complete removal of solvent, it was put in an oven at 50 °C. The prepared film was cut into six strips with dimensions of $2.5 \times 15\ cm^2$.

2.4. Gamma irradiator system

Gamma cell GC-220 irradiator system was used for irradiation of samples. The gamma source of this gamma irradiator consisted of ^{60}Co rods, dose rate was determined about 3.65 ± 0.006 kGy/s. Irradiated samples include five strips with different dose of 20, 50, 70, 100, 250 kGy at ambient conditions, and one strip was used as blank.

2.5. FT-IR spectroscopy

FTIR spectra were obtained by using a spectrophotometer of JASCO (FTIR-6300) and reflection technique (ART).

2.6. UV–vis spectroscopy

The absorbance spectra of solved films (in methanol) were done with PERKINELMER (Lambda 45) UV/Vis spectrophotometer in the wavelength range of 220–500 nm. The reflectance spectra of PVB films were done with JASCO (V-670) spectrophotometer by ART technique in the wavelength range 200–700 nm.

3. Results and discussion

Formation of butyral ring (C-O-C)in PVB structural was confirmed by FT-IR spectrum of the prepared PVB film in the range of 4000–450 cm^{-1} (Fig. 1). the significant peaks (cm^{-1}) that exist in the FTIR spectrum include; 3380: OH stretching related

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