Journal of Radiation Research and Applied Sciences xxx (2018) 1–5

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Journal of Radiation Research and Applied Sciences

journal homepage: http://www.elsevier.com/locate/jrras

Synthesis of polyvinyl alcohol and cuprous oxide (PVA/Cu_2O) films for radiation detection and personal dosimeter based on optical properties

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ARTICLE INFO

Article history:
Received 2 December 2017
Received in revised form
16 February 2018
Accepted 3 March 2018
Available online xxx

Keywords:
PVA
Films
Dosimeters
Cuprous
Radiation
Optical

ABSTRACT

The aim of the current study was to synthesize polyvinyl alcohol Cuprous Oxide composite films (PVA/Cu_2O) for radiation detection depending on optical changes. The method adapted from solving of 5% PVA in hot (80 °C) stirred water and after cooling to ambient temperature a 0.5 g of Cu_2O dissolved and stirred for 2 h. The films were made by casting in petri dishes contained 20 ml/each. The pealed films were enveloped after drying and receiving radiation doses of 1, 2, 4, 6 … 12 Gy. The analysis revealed a gradient change in color of films from light pink to dark brown with absorption peaks at 215 and 415 nm through entire doses which were increase as dose increment. The optical density of films increases linearly and significantly ($R^2 = 0.9$) as the dose increases from 0.06 (arb. unit) at 1 Gy to 0.4 (a u) at 12 Gy with sensitivity at 0.06 mGy. The energy band gap of the film decreased as the radiation dose increases from 3×10^{-12} to 2×10^{-12} e*V*. Conclusively; the feasibility of utilizing PVA/Cu_2O composite films as radiation detector and personal dosimeter would be applicable in rural sectors and low economic countries.

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1. Introduction

For the high secured accuracy of radiation therapy dose that should not exceed ±5% of the prescribed tumor dose (ICRU, 1976; Zhu, 2000), in addition to the optimum estimation of tissue damage in radiotherapy, radiation protection and researches many dosimetric methods and devices have been introduced such as Monte Carlo for radiation dose calculations (Ding et al., 2006; Rogers, 2006), Boltzmann Radiation Transport Solvers (Fogliata et al., 2011; Han et al., 2013; Vassiliev et al., 2010), the calculation of dose out the field by Day (Day, 1950), and Day & Aird, (Day & Aird, 1996), radiographic film, (Crosbie et al., 2008; Kron, Lehmann, & Greer, 2016), Thermoluminiscence Dosimeter (TLD) (Monti, Fourkas, & Nesbitt, 2004), polymer/Gel dosimeter which composed of normoxic hydroxyl-ethyl-acrylate/Gel (HEA/Gel) (Omer et al., 2011a) and polymer hybridized with nanocomposite metals. These entire endeavors have contributed successfully in radiation dosimetric field. Relative to this study; Abdullah et al. (Naim et al., 2017), prepared PVC and PVC/ZnO nanocomposite films by γ-rays irradiation at doses of 20 and 40 KGy that induce color change gradually following the dose increment as in (Fig. 1: shows the photographic pictures for pure and nanocomposite samples after 20 KGy and 40 KGy gamma rays irradiation). And Mohammed et al., (Ali Omer et al., 2013), have prepared and studied the response of PVA/$AgNO_3$ films to electron beam irradiation, in which they showed a gradient change of color from colorless to golden and dark golden; indicating different reduction state of silver ions in the composites as shown in (Fig. 2: Shows the PVA/Ag film (first raw was 0.03 Ag grams and second raw was 0.01 g) irradiated with electron beam and receiving doses of 0–10 Gy) which was proposed as radiation detector. Same studies carried out by Mohammed et al. (Omer et al., 2011b), related to

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Peer review under responsibility of The Egyptian Society of Radiation Sciences and Applications.

https://doi.org/10.1016/j.jrras.2018.03.001

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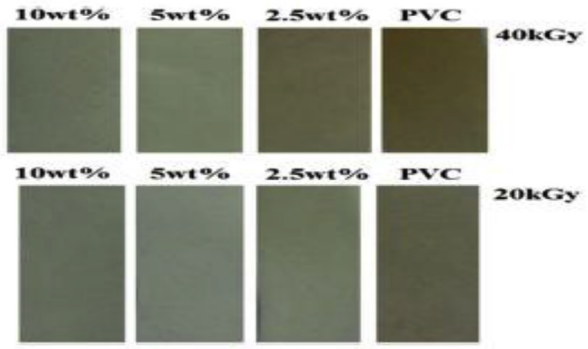

Fig. 1. Shows the photographic pictures for pure and nanocomposite samples after 20 KGy and 40 KGy gamma rays irradiation; Abdullah et al., (Naim et al., 2017).

polymer processing by irradiation to prepare conducting polyaniline hydrochloride hosted in polyvinyl alcohol in form of films in which upon γ-irradiation; aniline/PVA changed to polyaniline/PVA nanocomposite with green color as shown in photo (Fig. 3: The response of PVA/AniHCl composite to γ-irradiation, indicating the electrochromic and polymerization of aniline monomer).

Such effects could be detected and quantified by using different instruments such as: optical densitometer, Ultra-violet-visible spectroscope, IR-spectroscope (optical properties), Raman spectroscope, Infrared spectroscope (chemical effects) in addition to morphological changes by scanning electron microscope (SEM) and transmission electron microscope (TEM). Therefore these effects could be correlated to the reference exposure dose which in turn could be scheduled and applied as a measuring method for radiation detection or personal exposure dosimeter as highlighted by Slobodan, (Devic, 2011). The aim of this study will be recon on quantifying the optical density and the absorption coefficient of irradiated films and plotted in graphs versus relevant radiation doses to applicable in rural areas and small towns where the facilities of TLD reader in not available and the economic status is not supporting.

2. Materials & method

2.1. Materials

- PVA (polyvinyl alcohol) $(CH_2CHOH)_n$, SIGMA (Mw = 72,000 g/mol, 99–100% hydrolyzed) & Cu_2O (Sigma - USA): polymer binder/plasticizer and available in the form of powders, fibers and films.
- Optical densitometer & UV–visible spectrophotometer model Camspec M530 - USA
- Syringe 20 ml & Magnetic stirrer/with control temp (60–80 C^o) (Herenz - German)
- Petri dish & Sealed black envelopes (Herenz - German)

2.2. Method

PVA as 5% has been dissolved in distill water under control temp of 80 °C, with continuous stirring using magnetic stirrer for 3 h, after obtaining homogenous solution and cooled to ambient temperature; a cuprous oxide Cu_2O with an amount of 0.5 g were added to the solution (500 ml of PVA) and stirred for 2 h. The solution has been poured in petri dishes; each contains 20 ml using Syringe. The petri dish with solution left under ambient temperature and controlled area free of dust, and light for 3 days for water vaporization (dryness). Then casted films have been peeled off from petri dishes, cut into small pieces 2 × 2 cm, packaged in small fastened envelopes, sandwiched between 0.5 cm buildup polystyrene for electronic range accumulation at films then irradiated with γ-ray from ^{60}Co teletherapy machine receiving doses (0, 1, 2, 4, 6. 12 Gy). The ^{60}Co-teletherapy machine calibrated based on IAEA report standard series No. 16/2000 & Andreo et al., (Andreo et al., 2004; IAEA, 2000). Then the films characterized by using optical densitometer and UV spectroscope to show the induced optical effects. The collected data analyzed in forms of spectrum and correlation using EXCELL software 2010.

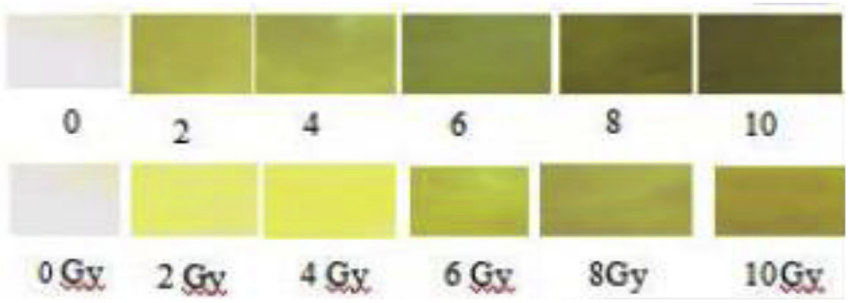

Fig. 2. Shows the PVA/Ag film (first raw was 0.03 A g grams and second raw was 0.01 g) irradiated with electron beam and receiving doses of 0–10 Gy; Mohammed et al., (Ali Omer et al., 2013).

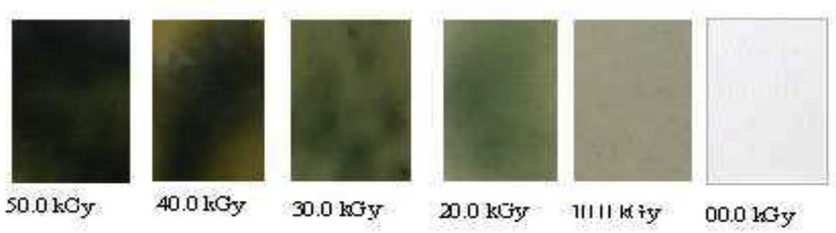

Fig. 3. The response of PVA/AniHCl composite to γ-irradiation, indicating the electrochromic and polymerization of aniline monomer; Mohammed et al., (Omer et al., 2011b).

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