Gamma rays irradiation effects in Na-Doped CZTS thin film prepared by sol-gel spin coating method

Jalil Bakhshi sara[1*], Tavakkol Tohidi[2], Jafar Poursamad[1], Mahdi Taghavi[2]

[1]Department of Laser and Optical Engineering, University of Bonab, Bonab
[2]Northwest Research Complex (Bonab), Radiation Applications Research School, Nuclear Science and Technology Research Institute, Tehran, Iran

[*] *Email: jalil2b@yahoo.com*

Abstract

Recently, Copper Zinc Tin sulfide (CZTS) based solar cells have been achieved more attention between thin-film solar cells due to their low cost production, good absorption coefficient, optimum band gap and environmental friendly properties. In this work, CZTS thin film which was prepared by sol-gel method was coated on microscope slides by a spin coating. After thermal treating the effect of gamma radiation on its optical and structural properties was investigated.

Keywords: Thin film, solar cell absorber layer, CZTS, gamma radiation

Introduction

The Cu_2ZnSnS_4 (CZTS) compound is a quaternary calcogenide semiconductor that has good physical and chemical properties for absorber layer of thin film solar cell devices. Between photovoltaic matrials, CZTS thin films have a higher absorption coefficient (i.e. above 10^4 cm^{-1}) and suitable band gap energy of about 1.5 eV [1].

Its demonstrated that properties of semiconductors affected by gamma irradiation[2]. In this work, we have synthesized sodium-doped CZTS thin films on soda lime glasses and irradiated them at different high gamma doses of 10, 20, 30 kGy. Structural, morphological and optical properties of produced thin films have been investigated before and after irradiation.

Experimental

The chemicals used as precursors were zinc acetate dehydrate ($(CH_3COO)_2$ $Zn.2H_2O$), copper chloride dehydrate ($CuCl_2.2H_2O$), thiourea (CH_4N_2S), stannic chloride dehydrate ($SnCl_2.2H_2O$). Also sodium acetate dehydrate ($C_2H_3NaO_2{\cdot}3H_2O$) was used as precursor for doping of sodium to CZTS absorber layer. The whole solution is stirred for four hour at 60 °C and then CZTS solution is deposited with a spin coater on clean glass substrates and immediately heat in a furnace.

Results and discussion

Structural analysis

Figure 1 shows the XRD spectrumof irradiated and non-irradiated Na-Doped Kesterite CZTS thin films, which it characterized using X-ray diffraction system (PHILIPS PW1730). XRD spectrum of the as-deposited CZTS thin layer exhibits four main peaks (112), (200), (220) and (312) corresponding to the CZTS kesterite crystal structure (JCPDS card No 00-026-0575) [3]. The sharp and the intense peak (112) indicates preferential orientation and good crystallinity of the films.

The grain size D has been estimateded using the Scherrer formula: $D = 0.9\lambda/\beta_{2\theta}\cos\theta$.

Where λ is the wavelength of incident X-ray radiation (1.5406 Å), β is the full width at half maximum (FWHM) and θ is the Bragg angle. The structural parameters of Na-Doped Kesterite CZTS thin films before and after gamma irradiation are presented in Table 1.

For the irradiated CZTS thin films, the crystal structure preserved same peaks and angles, but the full width at half maximum (FWHM) changed with the absorbed gamma doses at 10, 20 and 30 KGy, which indicates a change in the grain size of the layers after gamma irradiations. Also, the observed unusual increase in the grain size of the thin film irradiated with 20 KGy of gamma dose is related to the nature of gamma irradiations that ionizes the material and gives velocity to atoms which in turn generate successively multiple electrons and ions through atomic collisions [4]. Ionization impact directly on the crystalline structure of the CZTS layer and depends on the gamma energy, the elements composing the crystal lattice and the thickness of the films [4].

Table 1. Structural parameters of Na-Doped Kesterite CZTS thin films extracted from XRD before and after gamma irradiation at different doses.

Gamma radiation dose (kGy)	Pos. [°2Th.] (112)	FWHM Left [°2Th.] (112)	D (nm)
0	28.50	0.1476	57.91
10	28.09	0.1968	43.53
20	28.77	0.1476	58.01
30	28.42	0.3936	21.73

Surface morphology

Figure 2 shows the surface morphology of CZTS thin film before and after gamma irradiation at 20 kGy dose by scanning electron microscopy (FEI ESEM QUANTA 200)). It is also observed that the morphology of the surface is affected by gamma irradiations. Obviously the shape and size of the crystallites before and after gamma irradiation were changed.

Optical properties

Absorbanceof non-irradiated and irradiated Na-Doped CZTS thin films is presented in Fig. 3, which it recorded by an ultraviolet-visible (UV–Vis) spectrophotometer (Perkin Elmer, Lambda 45).

Approximately, the absorption rate of used doses were same in all samples. These results clearly indicate the well-known physical properties of Na-Doped CZTS thin films when irradiated with high gamma radiations.

The relation between energy of photon and absorption coefficient can be expressed by Tauc's relation. Fig. 4 shows $(\alpha h\nu)^2$ versus $(h\nu)$ for CZTS thin films. The extrapolation of straight line portions to zero (absorption coefficient $\alpha = 0$) gives the direct band gap energy E_g. By this estimation method, the E_g valuse for CZTS films befor and after irradiation are 1.5017eV and 1.4601 eV, respectively.

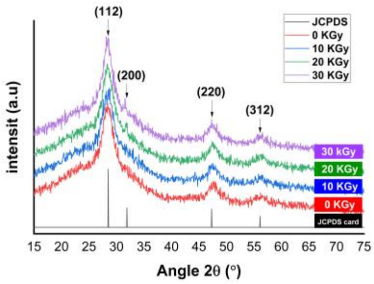

Figure 1. XRD spectra of Na-Doped Kesterite CZTS thin films before and after gamma irradiation at different doses (10, 20 and 30 kGy).

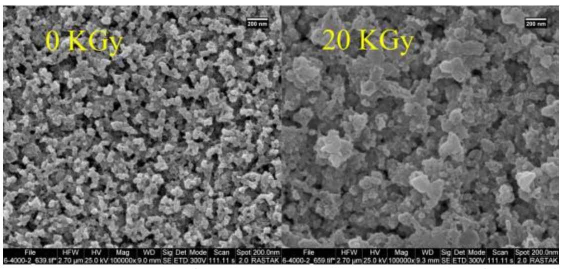

Figure 2. SEM images of Na-Doped Kesterite CZTS thin films before and after gamma irradiation at moderate dose (20 KGy).

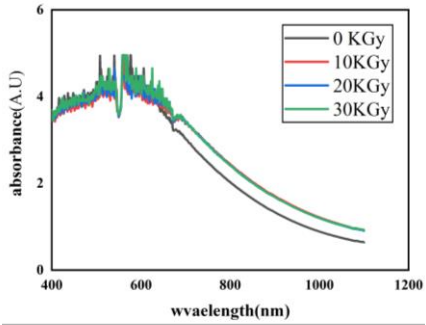

Figure 3. Absorbance versus wavelength of Na-Doped Kesterite CZTS thin films before and after gamma irradiation at different doses (10, 20 and 30 kGy).

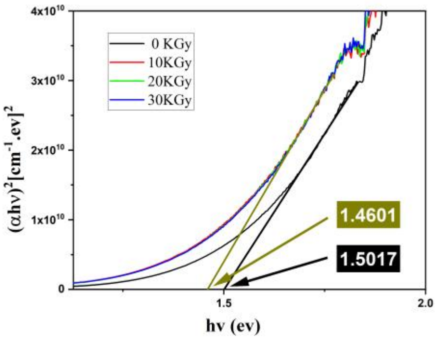

Figure 4. Tauc-plot of Na-Doped Kesterite CZTS thin films before and after gamma irradiation at different doses (10, 20 and 30 kGy).

Conclusions

The impact of ionizing gamma rays on structural, morphological and optical of sodium doped CZTS (Cu_2ZnSnS_4) properties were investigated. A slight improvement in crystalline structure has been found by an increase of grain size from 57.91 to 58.01 nm for 20 kGy. Preferred orientation and diffractions angles have been maintained in different doses which demonstrate the radiation hardness of our thin film material. Band gap energy evolution under gamma irradiation has shown good variations and has been kept around 1.4 eV for all doses which is an outstanding result because the absorber character of CZTS thin films for photovoltaic applications has not been lost despite the absorption of an enormous amount of radiations. Absorption coefficient has not been widely affected after irradiation and remained almost constant in the visible light range.

This results are Appropriate for many applications such optoelectronic devices placed near high gamma radiations environments besides photovoltaic cells and apparatus placed in outer space.

References

[1] Li, Wei, et al. "Fabrication of Cu2ZnSnS4 thin film solar cells by annealing of reactively sputtered precursors." Journal of Alloys and Compounds 701 (2017): 55-62.

[2] Nefzi, Chayma, et al. "Enhancement by high gamma radiations of optical and electrical properties of indium oxide thin films for solar devices." Journal of Materials Science 52.1 (2017): 336-345.

[3] Laghfour, Z., et al. "Sodium doping mechanism on sol-gel processed kesterite Cu2ZnSnS4 thin films." Superlattices and Microstructures 120 (2018): 747-752.

[4] Souli, M., Nefzi, C., Seboui, Z., Mejri, A., Vidu, R., & Kamoun-Turki, N. (2018). Improved structural properties, morphological and optical behaviors of sprayed Cu2ZnSnS4 thin films induced by high gamma radiations for solar cells. Materials Science in Semiconductor Processing, 83, 50-57.