Influence of gamma radiation on the Optical Energy Gap and Some Optical properties of CuIn(Se$_x$Te$_{1-x}$)$_2$ films

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Abstract

We have studied the effect of the gamma irradiation on optical transmission, reflectance, absorption coefficient, Skin depth, optical energy gap , and the width of localized tails for CuIn(Se$_x$Te$_{1-x}$)$_2$ with (x=0.5) thin films which were prepared deposited on glass substrates by Vacuum thermal evaporation technique. From the analysis of the absorption and transmission spectra in the wavelength range (380-900nm) we have found that the optical transitions is a direct allowed transition, and the localized tail widths have been decreased from about (0. 86 eV) before irradiation to about (0.823 eV) after irradiation, while the optical energy gap has been increased from about (1. 84eV) before irradiation to about (1.96 eV) after irradiation.

Introduction:

CuIn(Se$_x$Te$_{1-x}$)$_2$ compound is one of the promising wide-band gap I-III-VI compound semiconductors, it is a crystalline compound as a chalcopyrite [1] .

CuIn(Se$_x$Te$_{1-x}$)$_2$ thin films can be used in several fields .It is employed as , for example: Hetero junction Photovoltaic cells due to its optical band gap [2], photo detectors, Light emitting diodes[3]. This material was prepared by several methods such as: Vacuum thermal evaporation, Magnetron Sputtering, flash evaporation[4].

The study of radiation-induced defects is not only important in observing the changes in the physical properties degradation or efficiency improvement in its applicability in a radiation environment, but it is also critical in getting basic information on vacancies, interstitials and their interaction with impurities.

In the present contribution we measure the transmission, reflectance of CuIn(Se$_x$Te$_{1-x}$)$_2$ films under the influence of gamma ray and determine the optical band gap (E$_g$) and the localized tail widths (E$_e$) and Absorption Coefficient(α) , and Skin depth .

Experimental details:

Thin films of CuIn(Se$_x$Te$_{1-x}$)$_2$ have been prepared by Vacuum thermal evaporation technique. using a CuIn(Se$_x$Te$_{1-x}$)$_2$ ingot as the source material. The elements for the ingot were mixed and Sealed in quartz tubes[5]. The tubes were heated at temperature (1373K), and then cooled to room temperature over 24 hours, The thickness of the films was measured by using the weight methods ,The accuracy of thickness measurements was (250 nm), with (x) takes the values (0.5).

A Cs^{137}gamma – rays used to irradiate the thin films under Investigation for ٢١ days.

Optical and transition spectra were recorded by double beam (UV/VIS) (Shimadzu Corporation Japan) in the wavelength range (300 -900) nm.

Results and discussion:

The absorption spectra in the lower region (IR) are useful in studying the molecular vibrations. The higher energy region (UV) can be useful to manifest the electronic states of the atoms and other important phenomena affected by irradiation [6].

Figure (1) shows the variation of Transmittance [%] with Wavelength for Unirradiated CuIn(Se$_x$Te$_{1-x}$)$_2$ & Irradiated one. The behaviors of the curves in this figure can discuss easier if it is divided to two parts, before (λ=620 nm) and after it. In the first region < λ=620 nm, Transmittance for Unirradiated CuIn(Se$_x$Te$_{1-x}$)$_2$ is higher than that for irradiated one, this might be attributed to the one or all of the following reasons:-

1- A decrease in light scattering losses [7].

2- The increased roughness of the irradiated thin films contributed to the drastic decrease of optical transmittance [8].

3- The increased scattering of photons by crystal defects, and the free carrier absorption of photons contributed to the reduction in optical transmittance[9].

In the second region > λ=620 nm, Transmittance for Irradiated CuIn(Se$_x$Te$_{1-x}$)$_2$ is higher than that for Unirradiated one, and increased with increasing wavelength , in this region , the main radiation effect traps charges into the film which induce transmittance degradation [also called the Radiation- Induced- Attenuation (RIA)][10]. The irradiated thin film shows a much softer absorption edge, possibly indicating the presence of sub-band gap levels associated with defects.
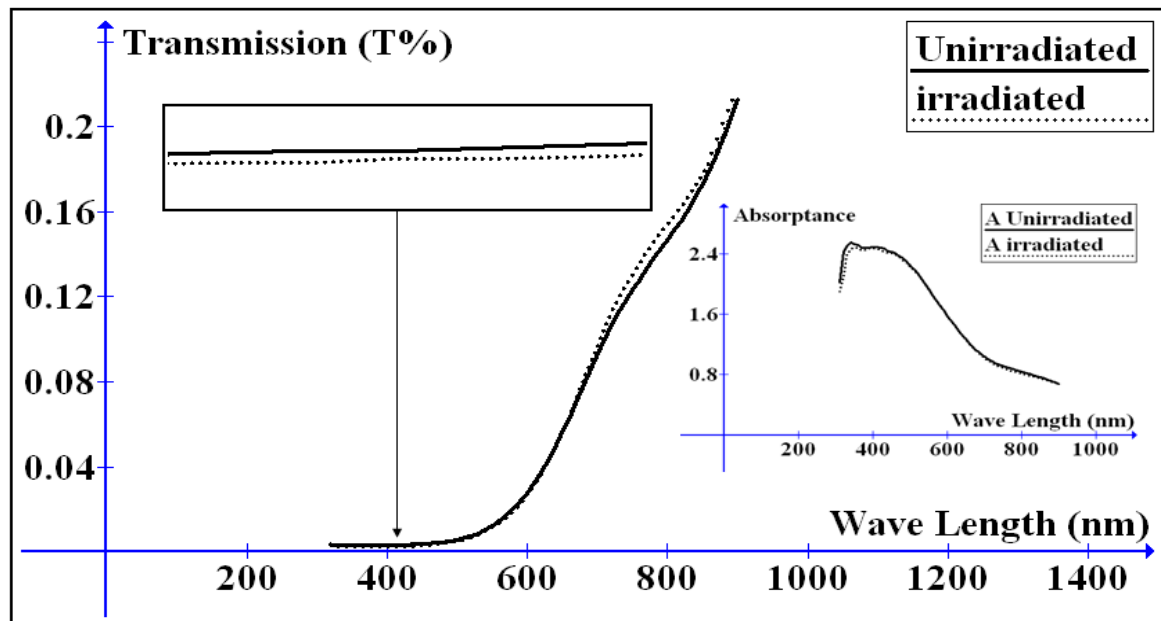
Figure (1) Optical transmittance as a function of wavelength. The inset shows Absorptance versus Wavelength.

Figure (2) shows the reflectance of unirradiated & irradiated CuIn(Se$_x$Te$_{1-x}$)$_2$ films versus photon energy from this figure R [irradiated CuIn(Se$_x$Te$_{1-x}$)$_2$] > R [unirradiated CuIn(Se$_x$Te$_{1-x}$)$_2$].

The irradiated thin film shows a much softer absorption edge, possibly indicating the presence of sub-band gap levels associated with defects.
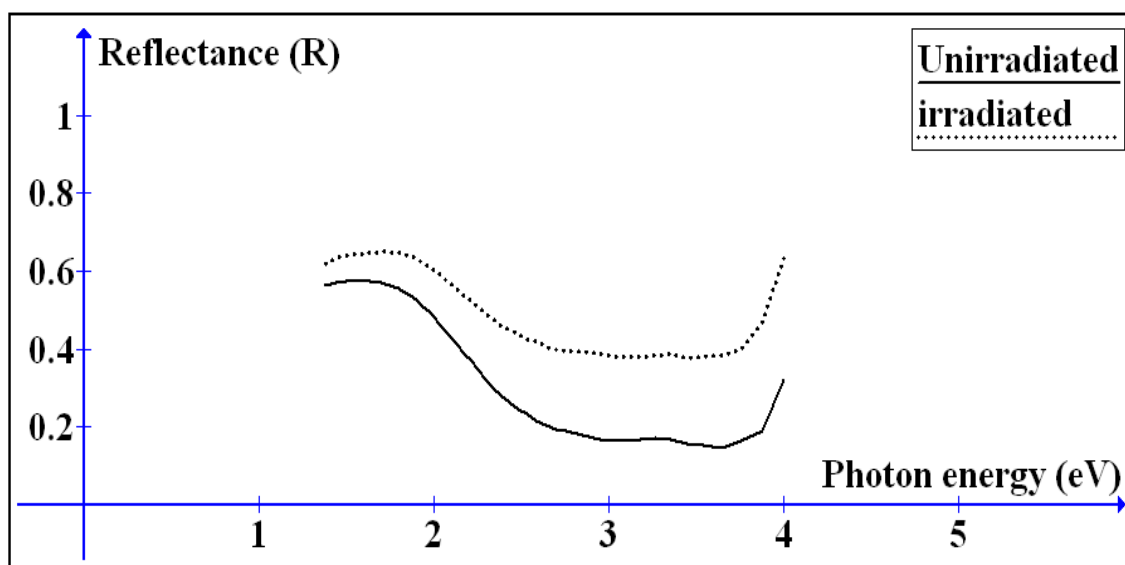

Figure (2) Reflectance as a function of Photon energy

Figure (3) shows the absorption coefficient (α) of unirradiated & irradiated CuIn(Se$_x$Te$_{1-x}$)$_2$ films versus photon energy.

from this figure α [irradiated CuIn(Se$_x$Te$_{1-x}$)$_2$] < α [unirradiated CuIn(Se$_x$Te$_{1-x}$)$_2$]
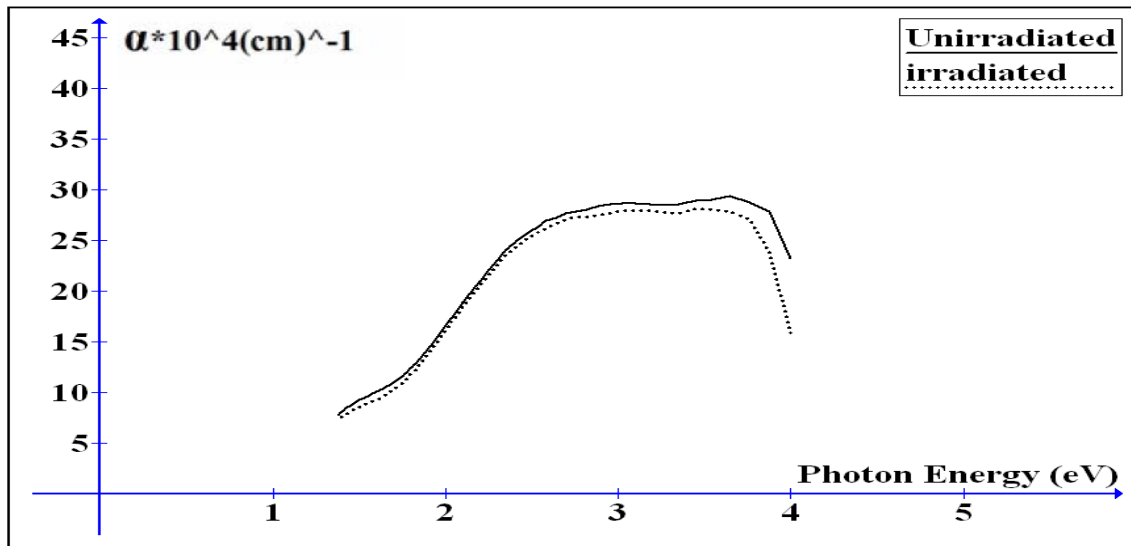

**Figure (3) Absorption coefficient as a function of Photon energy.**

this is attributed to decrease the defect states which leads to decrease absorption coefficient.

The energy band gaps of these films were calculated with the help of the absorption spectra. To determinate of the energy band gap, we plotted (αhf)^2 versus (photon energy) using the relation [11].

$$\alpha hf = const.(hf - E_g)^n$$

where E$_g$ is the band-gap energy. E$_g$ could be obtained from the intercept of (αhf)^2

versus (hf) for direct allowed transitions, as shown in figure (4).
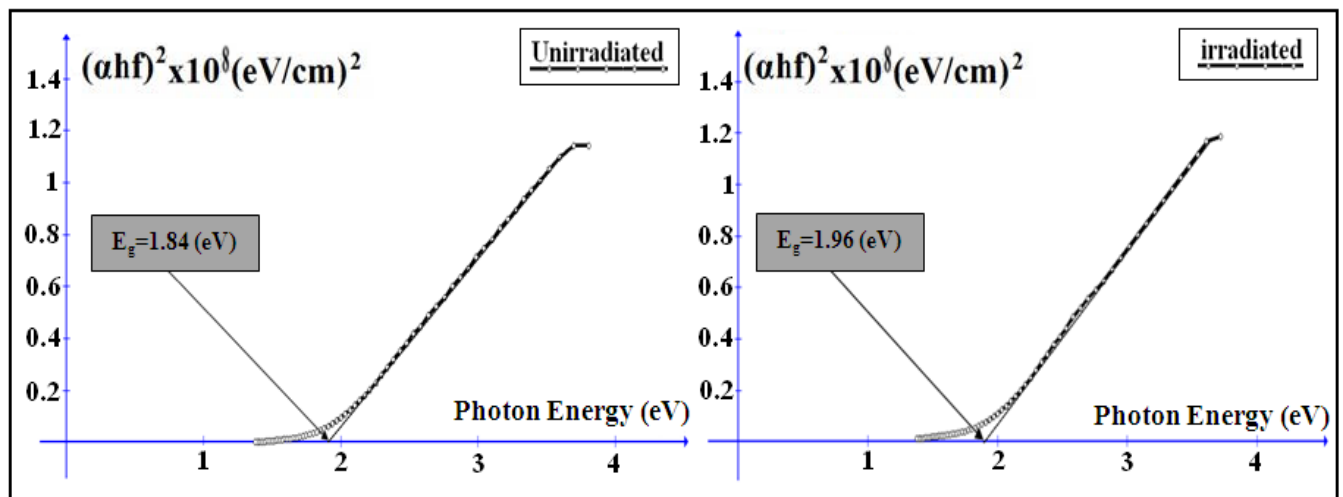
Figure(4) Band gap E$_g$ estimation for Unirradiated & irradiated CuIn(Se$_x$Te$_{1-x}$)$_2$ films.

The optical band gap was shifted from (1.84 eV) to (1.96 eV) due to irradiation .

For absorption-coefficient values in the range defined by (10 cm-^{1} ≤ α ≤ 10^4 cm-^{1}), the absorption is due to electronic transitions between valence-band-tail and conduction-band states and depends exponentially on photon energy according to the Urbach relation as follows [12]:

$$\alpha = \alpha_0^{(h\upsilon/E_e)}$$

Where(E$_e$) is the Urbach energy, hυ is photon energy. Fig. (4) shows the relationship between ln(α) and photon energy. The value of (E$_e$)for CuIn(Se$_x$Te$_{1-x}$)$_2$ film of unirradiated is (0.86 eV) and irradiated is (0. 823 eV).

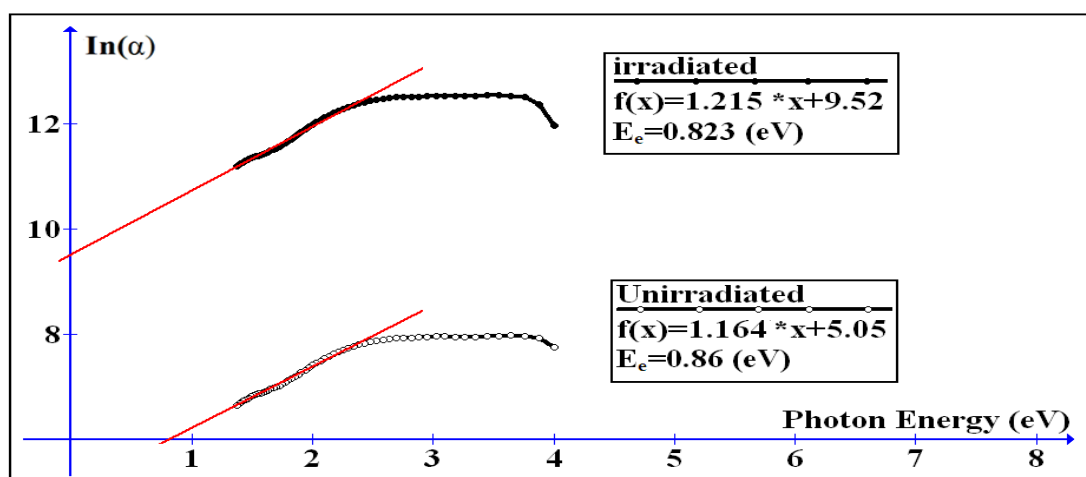**Figure (5) Relation between lnα and photon energy for Unirradiated & irradiated CuIn(Se$_x$Te$_{1-x}$)$_2$ films.**

It is useful to define a characteristic ''skin'' thickness that is subject to an appreciable density of optical energy. A convenient form used widely is simply the inverse of α, i.e. 1 / α. This skin depth is usually denoted by χ:

$$\chi = 1 / \alpha$$

In other words ,the electromagnetic wave will have amplitude reduced by a factor 'e' after traversing a thickness (called the skin depth) [13]. In long wavelength greater than absorption edge, skin depth increases with irradiation as shown in figure (6), this might be due to decrease the probability of absorption with irradiation and the amplitude of the incident photons will be reduced by a factor 'e' through the short distance within the film thickness .
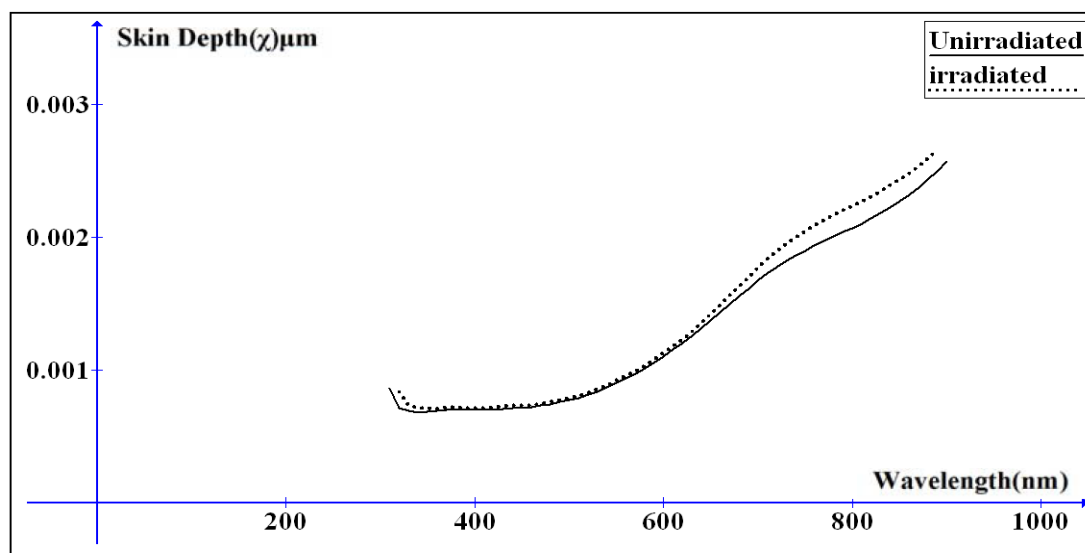

Figure (6) Skin depth as a function to Wavelength.

Conclusions:

the CuIn(Se$_x$Te$_{1-x}$)$_2$ thin films have been prepared successfully by Vacuum thermal evaporation technique . The actions of irradiation by gamma ray on CuIn(Se$_x$Te$_{1-x}$)$_2$thin film are: increasing the reflectance ,skin depth, and decreasing the absorption coefficient , The optical band gap increasing from (1.84 eV) to (1.96 eV), and the Urbach energy decreasing from (0.86 eV) to (0. 823 eV).

References :

[1] Leno M.Preparation and some semiconducting properties of CuIn(Se$_x$Te$_{1-x}$)$_2$
Thin films grown by triode sputtering. Eigth E. C. photovoltaic solar energy conference.
Proceedings of the international conference, helt at florence, Italy 1988;2(9-13 May):1077.

[2] Diaz R. Preparation and some semiconducting properties of CuIn(Se$_x$Te$_{1-x}$)$_2$ Thin films
grown by thermal evaporation. Eigth E.C. photovoltaic solar energy conference .Proceedings of the international conference,helt at florence, Italy 1988;2(9-13 May):1075.

[3] Ruada F. Composition effects in flash evaporated of CuIn(Se$_x$Te$_{1-x}$)$_2$ Thin films.J.Vac.Sci.Technol.1994;A12(6),Nov/Des:3082.

[4] P. K. Ghosh, S. Jana, S. Nandy, K. K. Chattopadhyay, Materials Research Bulletin, Vol. 42, pp. 505, (2007).

[5] Thesis, Sabah A. S. AL-Mustansiriay University,(1998).

[6] A. Abu El-Fadl, Cryst. Res. Technol. 39, No. 2, 143 – 150 (2004).

[7] S.H. Jeong*, J.W. Lee, S.B. Lee, J.H. Boo .Thin Solid Films 435 (2003) 78–82.

[8] N. Tigau, V. Ciupina, G. Prodan, G. I. Rusu, C. Gheorghies, E. Vasile, J. Optoelectron. Adv. Mater., 5, (2003),907.

[9] Ali Jasim AL-Jabiry , thesis , University of Technology,Baghdad,2007.

[10] R.Chen et al, Solution of a kinetic equations governing trap filling. Consequences concerning dose dependence and dose-rate effects, Physical review B, Vol : 24, No. 9, November 1981.

[11] T. Minami, H. Nanto, and S. Takata, Thin Solid Films 124, 43 (1985).

[12] J. Tauc, A. Menth, J. Non-Cryst. Solids, 8-10 (1972) 569-585.

[13] J. F. Eloy , " Power Lasers " , National School of Physics, Grenoble , France , John Wiley & Sons , 1984 , 59.

تأثير أشعة كاما على فجوة الطاقة البصرية وبعض الخصائص البصرية لأغشية CuIn(Se$_x$Te$_{1-x}$)$_2$

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الخلاصة

تم دراسة تأثير أشعة كاما على معامل الامتصاص ،النفاذية البصرية، الانعكاسية ،عمق الاختراق ، فجوة الطاقة البصرية، وعرض الذيول الموضعية لأغشية CuIn(Se$_x$Te$_{1-x}$)$_2$ وبنسبة (X=0.5) المرسبة على قواعد زجاجية باستخدام طريقة التبخير الحراري في ومن تحليل طيف الامتصاصية والنفاذية في مدى الأطوال الموجية nm(٣٠٠–٩٠٠) وجدنا أن نوع الانتقالات البصرية هو من النوع المباشر المسموح. وقد لوحظ أن عرض الذيول الموضعية قد قلت من حوالي (0.823 eV) إلى (0.86 eV) بعد التشعيع ،أما قيمة فجوة الطاقة فقد أزداد من حوالي (1.96 eV) إلى (1. 84 eV) بعد التشعيع.