Influence of gamma radiation on structural and optical properties of Fe$_2$O$_3$ thin films prepared by chemical spray technique

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**Keywords:** gamma radiation, Fe2O3 thin films, energy gap, absorption coefficient, chemical spray prolisis technique

**ABSTRACT.** The purpose of this research is studying the effect of gamma radiation on the structural and optical properties of iron oxide Fe$_2$O$_3$ thin films. The technique used for prepared the thin films was thermal chemical spray. The effect of Co$^{60}$ irradiation on the structural and optical properties of the thin films was investigated. The crystal structure were studied by XRD pattern. The surface tested from crack and defect was looke by used microscope image. The absorption and transmission spectra by used UV/VIS for the as deposited and irradiated thin films. The energy gap and absorption coefficient were studied. It's found that the energy gap for the un-irradiated sample was 2.3 eV and than after exposed to gamma radiation at (25, 50, 75, 100 and 125) Gy the energy gap decreased and above 50 Gy was increasing. The absorption coefficient increased until (12x10$^4$) cm$^{-1}$ at 50 Gy and than was decreasing to (2x10$^4$) cm$^{-1}$ at 125 Gy. The effect of radiation on the structural and optical properties was positive at the levels of irradiation used.

1. INTRODUCTION

The researchers has been interest in metal oxides as suitable materials for solar cell, photoelectron and another applications in electrical advices field [1]. The study effect of radiation on the properties of thin film consider an important studies on the metal oxide. The radiation was used for this purpose such as X-ray, gamma ray and Beta particles [2]. The study optical properties of Fe$_2$O$_3$ thin films are important for characteristics to evaluation its optical and photo catalytic activity, which possible indicated to use the thin films in suitable application [3]. In the recent past the effect gamma radiation on the optical, electrical and micro structural of some metal oxide thin films has been done [2, 4, 5, 6, 7].

In this work Fe$_2$O$_3$ thin films had been prepared by used chemical spray paralysis, which is consider one of the important methods to prepared thin films [8,9]. And then study the optical and structural properties of Fe$_2$O$_3$ thin films before and after irradiation by gamma rays at high exposures level.

2. EXPERIMENTAL DETAIL

Ferric oxide Fe$_2$O$_3$ thin films were prepared by chemical spray paralysis techniques and deposited on glass substrates at dimensions (2.5x2.5x)cm$^2$. The main components set up of the system is showed in the schematic diagram of figure (1). The prepared chemical solutions is pumped through the metal nozzle at rate flow from (1 to 2) ml/minute, the gas pressure to carrier chemical solution was nitrogen gas. Table (1): summarizes the optimized chemical spray condition for preparation.
Table (1): Optimum condition of present method for the preparation of Fe$_2$O$_3$ thin films.

| Spray parameter                  | Value        |
|----------------------------------|--------------|
| Molecular weight                 | $w = (2.702)$ gm |
| FeCl$_3$, 5H$_2$O                 | 270.29 g/mol |
| Nozzle-substrate distance        | 29 cm        |
| Solution flow rate               | 10 cm$^3$/min|
| Gas pressure                     | $10^5$ N/m$^2$|
| Substrate temperature            | 400 °C       |

The substrate before deposited the thin film was cleaned by dipping in distilled water and then are ultrasonically cleaned in methanol for 10 min and then soaked in distilled water. Finally dried and polished with smooth paper. After preparation of samples and sure they without defects and cracks by used optical microscope and then samples had been exposed to source of gamma radiation type Co-60 at rate dose 8 Gy/min in the room temperature, wherein the average of doses was (25,50,75,100 and 125) Gy. The optical transmission spectra of Fe$_2$O$_3$ thin films were obtained in the ultraviolet and visible region by using (UV- 1650Pc) shimadzu software 1700-1650, UV-visible recording spectra photometer), (Philips), Japanese company in wavelength range (200-1100 nm).

3. RESULTS AND DISCUSSIONS

Surface image of the all samples were shown in figure (2). For all samples the image is shown that surface was free defect crack and homogeneous. Figure (3) shown the X-ray diffraction of all samples irradiated, it's clear that the results of the all films of Fe$_2$O$_3$ irradiated have polycrystalline structure, also its found that the irradiation with gamma radiation led to high diffraction peaks and increased in the intensity, which is indicated the Fe$_2$O$_3$ thin films become more polycrystalline, and that due to the effect of radiation on the lattice crystal, which is led to increase grained regularity and decrease the grain size. That is mean the gamma radiation work as well as annealing treatment, which is causing broken the bond of the irregular arrangements and turning the thin films to more arrange systematic[2]. This is increasing with increased of radiation dose.
The optical absorption and transmission spectra for all samples with and without irradiation shown in figure (4, 5) respectively. Clearly the exposure to gamma radiation causes change in the shape of optical absorption consequently led to change in optical transmission and reflections spectra. The values of the absorption coefficient in figure (6) shown as exponential and dependence on the photon energy which is indicated to change in absorption coefficient with the exposure to the gamma radiation, wherein the absorption coefficient is increasing until 50 Gy and then decreased with increasing the radiation exposure. This is changed in the optical absorption, transmission and absorption coefficient is due to increase the energy width of band tails of the localized states, which can be attributed to the induced effects of gamma-ray[2].
The optical band gap for the preparation thin films had been found for as deposited about 2.3 eV and the variation doses shown in table (2). Clearly the optical band gap is decreasing from 2.3 eV to 1.7 eV for the radiation dose 50 Gy. This decrease in optical band gap belong the increase in the energy width of the band tails of localized state. During irradiation the defect are created within the thin films and at the same time the defect also annihilated, this creation and annihilated at low dose radiation the annihilated is more from creation of defects, therefore the optical bandgap was decreasing but above 50 Gy the creation of defects become more than annihilated[2], so the optical bandgap is increasing with high rate dose. 

Table (2) Represent the value of optical band gap of all samples.

| samples | Dose of gamma Gy | Optical band gap Eg (eV) |
|---------|------------------|-------------------------|
| S1      | As deposition    | 2.2                     |
| S2      | 25               | 2.14                    |
| S3      | 50               | 2.3                     |
| S4      | 75               | 2.02                    |
| S5      | 100              | 2.08                    |
| S6      | 125              | 2.11                    |
Fig(7): The optical band gap with of all samples.
Fig (8): Represented the value of optical band gap of all samples with dose of gamma radiation.

4. CONCLUSION

The optical and structural propert were studied for Fe$_2$O$_3$ thin films which prepared by chemical spray technique as deposited and exposure to various dose from gamma radiation. The results shown that the optical band gap was decreasing with increase the dose rate until appointee level of gamma radiation and then increasing with increasing the dose rate, the structure of Fe$_2$O$_3$ enhanced with increase of gamma dose, this indicate that the high dose of radiation negative effect on the optical proportions of the Fe$_2$O$_3$ thin films.

Reference

[1] S. S. shinde, R.A. Bansode, C. H. Bhosale and K. Y. Rajpure, "physical properties of hematite α- Fe$_2$O$_3$ thin films: application to photoelectrochemias, solar cells" Journal of semicondmetors, V. 32, No 1, Junuray 2011.

[2] T. K. Muity Sand S. L. Shurma, "Effect of gamma radia
tion on optical and electrical properties of tellurium dioxide thin films", Bull Master Sci. Vol. 31, No. 6, November (2008) 841-846,.

[3] R. Cornell, U. Sh wentmunn, "The iron oxids: structure, properties, reation occurrence and uses." Darmstadt: wiley- VcH Gmb H and Co. KGaA, (2003).

[4] C.D Cress, C. M. Schauerman, B. J Landi' "Radiation effects in the single- walled carbon nanotube papers" J. Appl phys, 107, 014316, (2010).

[5] A. B. Kaiser, V. skakulova "Modelling conduction in carbon nano tube net works with different thickness chemical treatment and irradiation". Phys, E, 40,(2008) 2311-2318.

[6] K. M. Abhirami, R. sathyamurthy, K. A sokan, "structural, optical and electriad properties of gamma irradiation SnO thin film Journal: Radiation physics and chemistry ISSN: 0969806x, Vol. 91,(2013) 35-39.

[7] A. M. Al-Baradi, M. M. El-Nahass, M. M. El-Raheem. "Effect of gamma irradiation on structure and optical properties of Cd$_2$SnO$_4$ thin films deposited by Dc sputtering technique" Journal: Radiation physics and chemistry ISSN. 0969806x, Vol. 103, (2014) 227-233.
[8] T. Sall, B. Mollar, "chemical spray pyrolysis of b-In253 thin films deposited of different temperatures" Journal: Journal of physics and chemistry of solid, ISSN: 00223697, Vol. 76,(2015) 100-104.

[9] H. K. pulker, "characterization of optical thin film" Appl. Opt, Vol. 18, no 12, (1979).

[10] J. Tauce, "Amorphous and liquid semicond ucfors plennmpres", London and NewYork (1974).

[11] Aytune ATES, BeKir GURBULK, Muhammet YILDIRIM, "Urbach's Rule and optical properties of TiGas2 "Turk J physic. 26 (2002), 127- 131.