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# Nuclear radiation effect on ZnO performance

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## Abstract

ZnO nanoparticle thin films were derived by sol – gel using spin coating technique. The thin films were prepared by deposited onto glass substrate at room temperature using sol gel composed from Zinc Acetate de-hydrate, Diethanol amine, isopropanol, and de-ionized water, the films were furnace at 600 degree for 60 min.

X-ray diffraction have been used to study crystallographic structures of ZnO thin films. The optical properties of the prepared films were studied using UV-VIS spectrophotometer with the range 320 - 1000 nm, and by using the fluorescence spectrometer. These thin films were exposed to nuclear radiation, alpha particles were the most effected one on the performance of the films than gamma rays.

## 1. Introduction

There is a lot of interest from our applied physics research group in working with alpha and gamma rays, in case of detection and application[1-4]. Now there is interest in studying the effect of these radiation in solar cell parameter, and the effect of these nuclear radiation on the efficiency of solar cell, in this work the performance of ZnO thin film should be checked first[5].

Zinc oxide (ZnO) is a prominent structure for a number of important and wide applications. The economic and ecological benefits of ZnO are low coast, available technology for films and Nano objects growth, nontoxicity and biocompatibility with human organism. ZnO attracted great interest as the material for ultraviolet and blue light emitting devices because of its wide band gap of 3.37eV.

The application of ZnO in photovoltaic is not limited to act as electron transport material (ETM) in dye sensitized solar cells (DSC) and hybrid solar cells (HSC)[6]. It can also applied as antireflection coating in inorganic solar cells [7,8],or as optical spacer in polymer solar cells[9-12]. The true consciousness about the potential impact of ZnO emerged once the simplicity

of its synthesis was revealed together with its availability and low coast , and opened up the opportunity for its application in a wide variety of devices, such as, solar cells, light emitting diodes, field effect transistors, electrochemical sensors, piezoelectric and thermoelectric devices, etc. ZnO can be regarded as the most promising materials in many fields[13-16]**.**

Thus, there is a great need to study and understand how different nuclear radiation affect ZnO performance at different exposure doses.

To our knowledge, there is no measurement to optical properties after nuclear irradiation for different doses on ZnO nanoparticles thin film, which carried out in this work.

## 2. Experimantal

Materials were used in this work, to create ZnO thin film were Zinc acetate ( 1.65 gm ) dehydrate (98% Merck), Isopropyl Alcohol( 35 ml )(99.5%, Fluka),and Diethanol amine( 2ml ).(99%BDH).

Glass substrates were cleaned with water and detergent. Then, they were cleaned with deionized water in an ultrasonic cleaner and washed with a mixture of acetone and alcohol. Spin coating was applied thereafter, by using the solution which prepared for that. All Spinning time was 30 sec, where the spinning rate was 600 rpm for the first 8 sec, and then increased 950 rpm for the last 22 sec.

A ZnO thin film was prepared by spin coating of sol-gel layer ZnO on top of the glass substrate .This process can be repeated many times to get film with desirable thickness. The ZnO sol-gel was prepared using the method previously reported[17,18]. By dissolving 1.65 gm of Zinc acetate dehydrate $[Zn(CH_3CO_2)_2.2H_2O]$(Merck 99.98%) in 35 ml of dehydrated isopropanol alcohol (Merck > 99.9%). The solution was stirred thoroughly on a magnetic stirrer for 30 min. A milky solution was obtained. Then 2 ml of dietrhanol Amin (Merck +99%) was added to the solution as stabilizer drop by drop until it became transparent, the solution was mixed by a magnetic stirrer at temperature of 60 C for about 120 min. The final solution was kept for 24 hr at room temperature before it used. The yield was a stable, clear, and homogenous sol. The sol was deposited by the spinning coating technique. Once the ZnO by sol-gel was applied by spin coating the substrate was annealed at 600 C for 1hr . The latter procedure allows for the ZnO thin film used as buffer layer which permits a better contact between glass and ZnO and to evaporate some others unwanted materials from the film.

To obtain the optical constants of ZnO thin films, the optical transmission measurements were carried out using a spectrophotometer spectro SC, LaboMed.inc, made in USA. in spectral range between 300 to 800 nm at normal incidence.

Fluorescence spectra for samples were measured by using Perkin Elmer LS-3 spectrofluorometer. The excitation wavelength was set at 340nm.

To identifiy the thin films, X-ray spectrum were measured for the samples, by using X'Pert Pro MPD by PANalytical company, with CuK$\alpha$ radiation. Manufactured by Netherlands.

Manufactured samples were irradiated by using nuclear radiations such as gamma rays and alpha particles, and the irradiated spot has been marked, this spot has been used to pass UV through it, to see the effect of nuclear radiation for different doses on optical density passing the spot.

Gamma source used in this work was $CS^{137}$. This source presented in Education College, University of Basra. It was supplied by the Radiochemical LTd. J.L. Shepherd and Associates, California ) .Gamma photons from $CS^{137}$ source normally incident on samples.

In case of alpha particles, samples were irradiated inside a Canberra cylindrical

chamber, Spectro SC from Labomed, Inc. USA, with alpha source inside this chamber, distance between the source and the sample it was 2 mm, has been used as spectrophotometer to measure absorption spectrum for the samples under investigation .

## 3. Result And Ussion

### 3.1 X-Ray Diffraction

X-ray diffraction was used for crystal phase identification for ZnO thin films which prepared by sol-gel technique, Figure 1 shows the X-ray pattern of ZnO thin film prepared by using spin coating method.

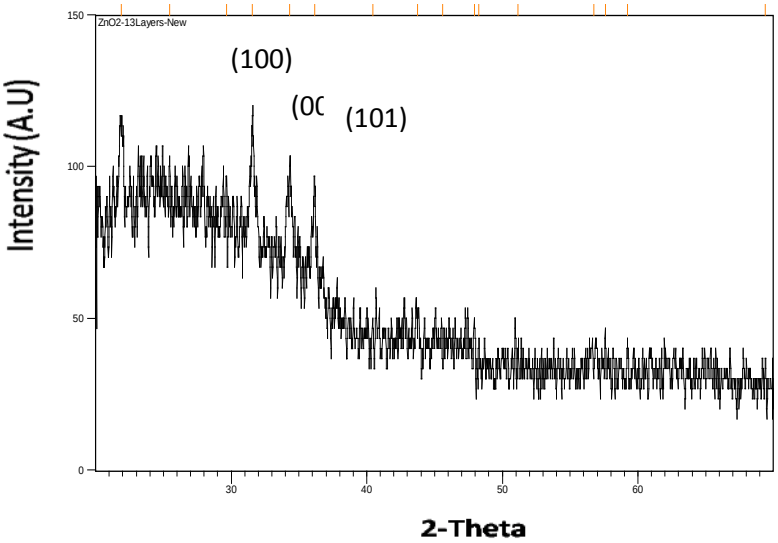


**Fig.1. X-ray diffraction of ZnO thin film prepared by spin coating.**

From figure 1 the film has amorphous structure with three noticeable ZnO diffraction peaks; (100), (002), and (101) appear at the "angle" of the diffraction $2\theta = 31.6^{o}, 34.3^{o}, and\ 36.2^{o}$ appear respectively, as listed in Table 1. These result are in agreement with the American Standard of Testing Materials (ASTM) and with Schmidt et. al. [19], as listed in Table 1.

**Table 1. The values of (hkl), 2Θ , and d for all peak of ZnO thin films**

| (hkl) | 2Θ degree | d ( $A^0$) (XRD) (ASTM) | d ( $A^0$) |
|---|---|---|---|
| (100) | 31.6 | 2.834 | 2.816 |
| (002) | 34.3 | 2.615 | 2.602 |
| (101) | 36.2 | 2.484 | 2.476 |

The lattice constant for ZnO thin films can be calculated by using the fallowing equation, as given by Ren et. al. [20] :-

$$\frac{1}{d^2} = \frac{4}{3}\left[\frac{h^2 + hk + k^2}{a_0^2}\right] + \frac{l^2}{c_0^2}$$

Where h ,k , l Miller Indices

$a_0$ , $c_0$ lattice constants

The ratio of the lattice constants c/a was calculated , and it was 1.61 which is nearly close to the ratio of an ideal hexagonal structure, which was recorded by Kim, et al. as 1.633[21].

### 3.2 Photoluminescence Spectrums

The photoluminescence (PL), carried out at this work , was at room temperature. This will provide information of different energy state available between valence and conduction bands responsible for irradiative recombination. Figure 2 - 4 represent the photoluminescence excitation spectrum of nuclear radiation - irradiated ZnO nanoparticles and non – irradiated ones. These films were excited at 340 nm.

Figure 3 and 4 represent different thin films used for low and higher doses of gamma rays respectively.

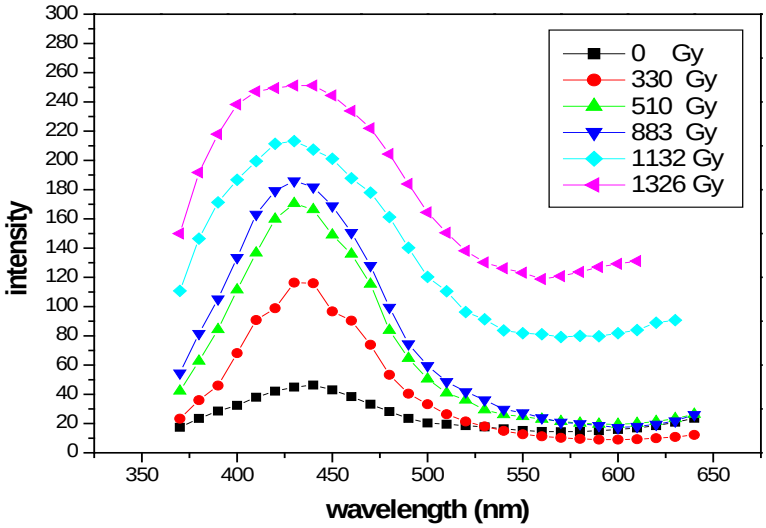


**Fig. 2. Represent the intensity for photoluminescence as a function of wavelength for ZnO nanoparticles thin film exposed for different doses of alpha particles.**

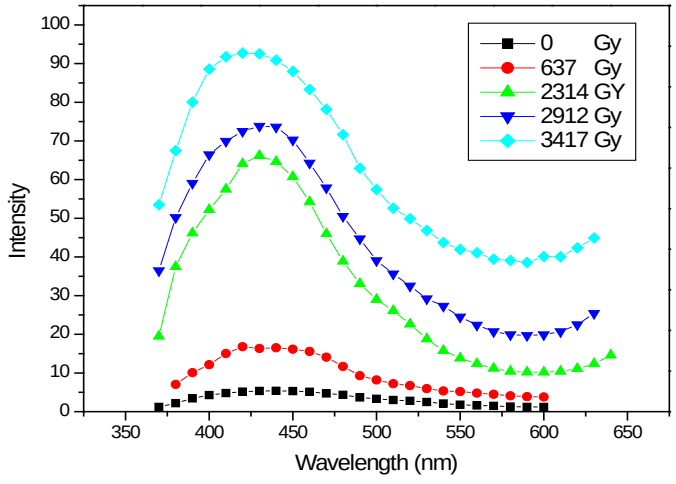


**Fig. 3. Represent the intensity for photoluminescence as a function of wavelength for ZnO nanoparticles thin film exposed for different doses of gamma rays.**

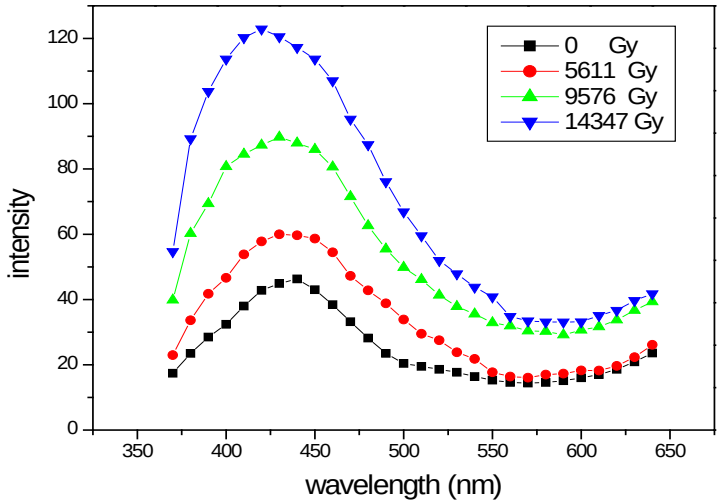


**Fig. 4. Represent the intensity for photoluminescence as a function of wavelength for ZnO nanoparticles thin film exposed for different doses of gamma rays.**

All these spectrums shows a single Peake at wave length range between 370 nm to 525 nm, and the fluorescence intensity of ZnO nanoparticles increased with nuclear radiation doses, this mean that the annealing due nuclear radiation causes this change in fluorescence intensity of the films, although peak wavelength was slightly shifted toward lower wavelength.

Fluorescence spectrum shows increasing in peak broadening with exposed doses, that was due to cracking in the surface of the thin film, which acts like interface, and functioning like energy level between conduction and valance band. Peak shifting toward lower wave length was due to increase in colors centre contribute in this region, this color centre can be created by dislocation in atoms or electrons from the structure.

PL spectrum dose not show a clear separation between the peaks, this may be attributed to the high speed of spinning, which was needed to get homogeneous sample, and non newtonian sols behaviour utilized by highly condensation rate of Zn:Ac. Slight broadening of band to band transition peak might be related to the existence of micro crack on the surface of the films.

### 3.3 Optical Absorption Spectra

As can be observed in the absorption spectra Figure 5 – 7, the pristine ZnO nanoparticle system before irradiation and after irradiated with nuclear radiation.

These spectra shows a single broadening peak at 360 nm, with increasing in absorption with doses, mainly at visible region were due to micro cracking happening at thin film surface due to nuclear irradiation causing that increase, this can be noticed with Alpha irradiation, Figure 7, comparing to the effect of gamma rays, which required higher doses of gamma rays to produce effect in absorption and that effect still lower than the effect of alpha particles. The rise in the electronic temperature during irradiation, can be treated as a case of annealing which can lead to structural reorganization and hence, modification in the electronic states, which may caused also broadening in the peak.

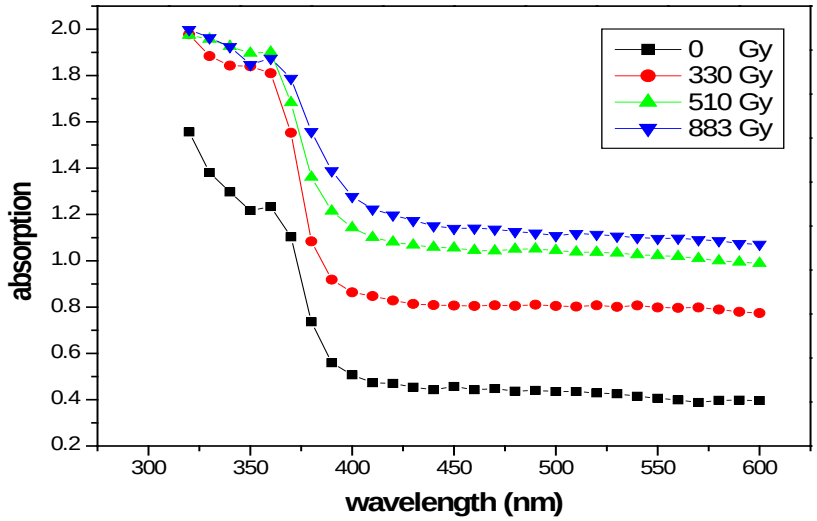


**Fig. 5. Absorption spectra of ZnO nanoparticles irradiated with Alpha particles.**
**Absorption increased due to doses used in this work were in the range between 82.203% to152.846 %.**

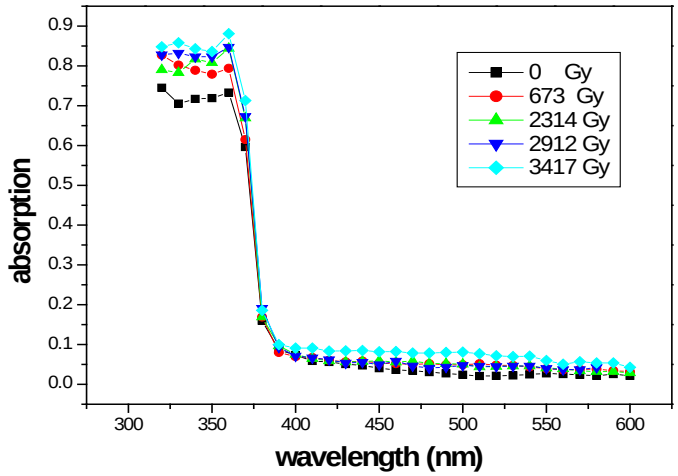


**Fig. 6. Absorption spectra of ZnO nanoparticles irradiated with gamma rays.**

There is no big change in absorption for the range of gamma doses shown in figure 8, but there is increased in the range of doses as shown in figure 7, between 15.622% to 92.287%.

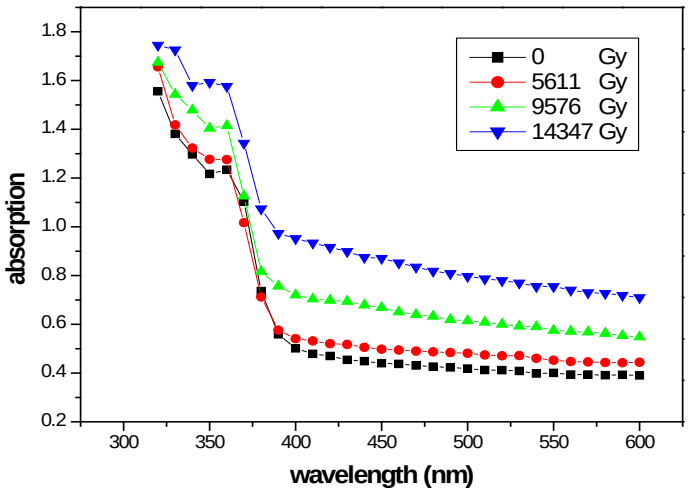


**Fig. 7. Absorption spectra of ZnO nanoparticles irradiated with higher doses of gamma rays.**

### 3.4 Optical Transmission Spectra

Transmission spectra for ZnO nanoparticles thin films irradiated with alpha particles, gamma doses and higher gamma doses, have been shown in figure 10 to figure 10 respectively. Irradiated samples shows less transmittance than non-irradiated one, this reduction in transmittance increased with doses. This change in transmittance very clear in visible region, high transmittances of the films throughout the VIS. regions make it a good material for photovoltaic applications.

Alpha particles shows more effect on transmittance than gamma rays, and to produce effect on ZnO Nano particles thin film by using gamma rays irradiation, high doses of gamma rays required as shown in figure 10.

This change in transmittance should be due to defects occur in the thin film, and most of the surface defects are due to single and double ionized oxygen vacancies, Zn dislocation, and change in electronic structure, because ionizing radiation , while traversing through the thin film loses its energy either by electronic energy loss due to inelastic collision of the incoming radiation with the electrons of the thin film, or with the nuclear energy loss due to the elastic collision with the atomic nuclei of the solid.

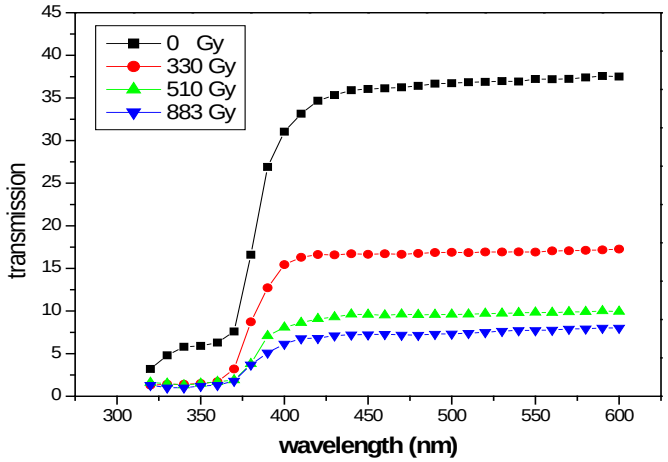


**Fig. 8. Optical transmittance vs. wavelength for ZnO Nano particles thin film irradiated with alpha particles.**

Alpha particles make reduction in transmittance specially in visible region for the doses shown in figure 8 , in range between 55% to 81%. As shown table 1. This will make a major effect on photovoltaic solar cell efficiency, due to reduction in transmittance. If it irradiated by alpha particles.

**Table 1. shows how transmittance decreased with alpha doses.**

| Doses Gy | Transmittance % decreased |
|---|---|
| 330 | 55 |
| 510 | 75 |
| 883 | 81 |

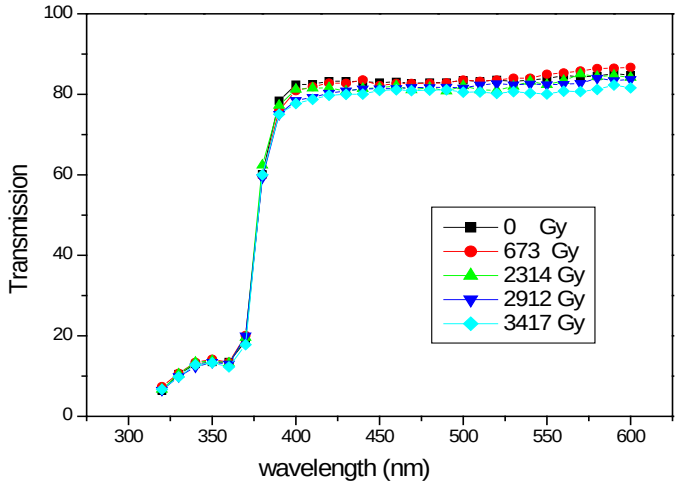


**Fig.9. Optical transmittance vs. wavelength for ZnO Nano particles thin film irradiated with different doses of gamma rays.**

Gamma rays shows no big change in transmittance for the doses shown in figure 9, but there is a reduction in transmittance for the doses shown in figure 10 , in the range between 12% to 56% at 500 nm . As shown table 2. This will make a major effect on photovoltaic solar cell efficiency, due to reduction in transmittance. If it exposed to gamma doses as shown in table 2 .

**Table 2. shows the percentage reduction due to effect of gamma rays.**

| Doses Gy | Transmittance % decreased |
|---|---|
| 5611 | 12 |
| 9576 | 31 |
| 14347 | 56 |

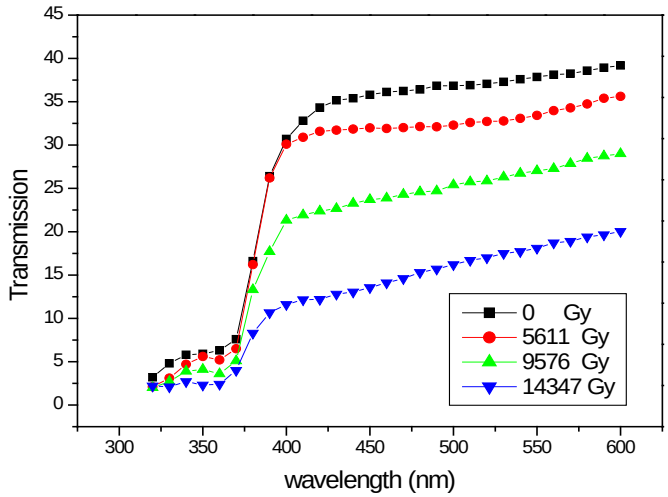


**Fig.10. Optical transmittance vs. wavelength for ZnO Nano particles thin film irradiated with higher different doses of gamma rays.**

## 4. Concolusion

In conclusion, Optical modification of solid state derived ZnO nanoparticles are studied with alpha particles and gamma rays irradiation. After irradiation, the fluorescence spectra shows broadening and increasing in intensity with doses. The absorption pattern was found to be altered owing to the defect and modification of electronic states, transmittance pattern decrease with doses, and alpha particles shows more effect than gamma rays.

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## تأثير الإشعاع النووي على الأغشية الرقيقة لمركب الزنك اوكساید

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**الخلاصة**

الأغشية الرقيقة لمركب الزنك اوكساید التي حضرت من السائل الهلامي باستخدام تقنية البرم , تم إعداد الأغشية الرقيقة من الزجاج في درجة حرارة الغرفة باستخدام هلام يتكون من (زنك اسيتيت دي–هيدرات ,داي ايثانول امين وايزوبروبانول ) ووضعت الأفلام في فرن بدرجة حرارة 600 لمدة 60 دقيقة .

وقد استخدمت الأشعة السينية لدراسة حيود التركيب البلوري لأفلام الزنك اوكساید , وتمت دراسة الخصائص البصرية للأفلام المعدة باستخدام مطياف الضوء فوق البنفسجي – المرئي في المدى 1000– 320 نانومتر ,وباستخدام طيف الفلورة .

هذه الأفلام عرضت إلى الأشعة النووية ,جسيمات ألفا كانت أكثر تأثيرا على الأفلام مقارنة بأشعة كاما .