

Effect of Gamma Radiation on Structural, Optical and Electrical Properties of nanostructured CdHgTe Thin Films

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ABSTRACT: CdHgTe thin films were grown onto glass substrate via the Chemical bath deposition technique. XRD results indicate that a CdHgTe formed with a cubic polycrystalline structure. The crystallinity of CdHgTe thin films is gradually deteriorate with increasing the gamma irradiation. EDS spectrums confirms the presence of Cd, Hg and Te elements. DC electrical conductivity results depicted the conductivity of CdHgTe increase with increasing a gamma ray dosage.

Keywords: CdHgTe thin films, Cubic structure, Gamma ray, DC conductivity

1 Introduction

Nanomaterials have attracted extensive interest because of their novel properties in different fields in comparison with their bulk counterparts. Among them, composite materials have attracted much attention to a number of material science researchers and engineers, due to their new properties. These were caused by small size, large surface area and quantum dimension, which are able to improve their physical and chemical properties. Composite materials show good advantages over conventional materials in many applications. In particularly semiconductor thin films belonging to groups II-VI and III-V have been the subject of great interest due to their uses in various applications such as light emitting applications, photoelectric conversion in solar cells and other optical devices [1-4]. In these group Cd based materials such as, CdO, CdSe, CdTe and CdS. exhibit noticeable optical transparency in the visible region and high n-type electrical conductivity, which made it to be used as a transparent conductive oxide layer in solar cells [5, 6].

Ionizing radiation (γ -irradiation) is highly reactive with high reduction potential for particle size. Due to its ability to fine tune the radiation, it may offer better control over the size of particle and there distribution. Thin films irradiation by high energy radiation generates transient radicals through water radiolysis. These transient radicals have reducing and oxidizing species.

Thus the present work describes the preparation and characterization of the pure and gamma radiated CdHgTe thin films. Various characterization tools like X-ray diffraction (XRD), Energy dispersive X-ray spectroscopy (EDS) and DC electrical conductivity were used to analyze the obtained CdHgTe thin film.

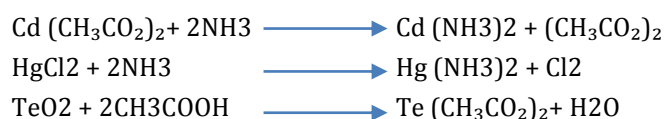
2. Experimental procedure

Chemical bath deposition technique was adopted for the preparation of cadmium mercury telluride thin films. The chemicals used for the preparation were analytical grade cadmium acetate (99%), tellurium oxide (99.5 %), and mercury chloride (97 %).

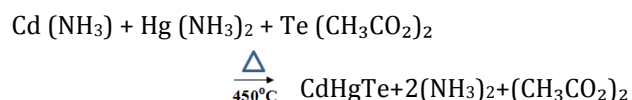
The deposition of CdHgTe thin films is based on the reaction of Cd, Hg and Te ions in deionized water solution. Chemical baths used for the deposition of CdHgTe thin films consist of cadmium acetate, Mercury chloride, Tellurium oxide and ammonia. The pH of the solution can be adjusted by adding ammonia. Thin film deposition is carried out at the temperature of 80°C. Three different molar proportions of cadmium acetate, Zinc acetate and Tellurium oxide namely 0.1:0.01 and 0.1 are used. For the deposition process pH value of the bath is maintained at ~9 to 11. The pH of the solution was measured by digital pH meter. The substrates are placed vertically in the bath for deposition time varying from 30 to 60 min.

The terminal thickness of the film has been obtained for a deposition time of 30 min. While varying the pH of the bath, it is found that the solution having pH value ~10–11 gives uniform and compact films. Thus deposition parameters such as temperature, concentration of ions in the bath and dipping time have been optimized.

The steps involved in the chemical deposition of CdHgTe thin film are as follows,



Overall reaction



At low deposition temperature (304 K), most of the ions are in a bound complex state and so slow release of ions takes place in the solution, which then condense on an ion-by-ion basis on the substrate mounted vertically in the solution. At intermediate temperature (353 K), the ions are released rather quickly and get sufficient time to condense on the substrate surface and therefore large amount of material gets deposited on the substrate giving maximum layer thickness. At relatively higher temperatures, more and more ions are released but all the ions do not get chance to adsorb on the substrate surface, they settle down at the bottom of the reaction container decreasing the film thickness.

3. Characterization Techniques

To investigate the structural property of CdHgTe thin film, X-ray diffraction data (XRD) were recorded on a Bruker (AXS D8 Advance) diffractometer with Cu K α radiation ($\lambda = 1.5406 \text{ \AA}$) operating at 40 kV and 30 mA. The crystallites average size was determined by the Scherrer equation $d = \frac{K\lambda}{\beta \cos \theta}$ where d is the mean crystalline size, K is a grain shape dependent constant (0.9), λ is the wavelength of the incident beam, θ is a Bragg reflection angle, and β is the full width at half maximum (FWHM) of the main diffraction peak. The SEM analysis were performed using Philips Model XL 30. An energy dispersive X-ray (EDX) analysis was carried out with JEOL56000LV microscope at an accelerating voltage of 10 kV. Keithley 6517B digital electrometer with LabView program using to study the electrical conductivity. In gamma ray chamber ^{60}Co is used as a radioactive decay. The dose rate is to ~8.4 Gy and the dose is 120 Gy and it is increased likewise.

4. Results and discussion

4.1 X-Ray Diffraction analysis of CdHgTe thin films

The structural characterization is carried out on un-irradiated and gamma irradiated CdHgTe thin films. All the films were annealed in air at 450°C (Nil Dose) 15 minutes and then subjected to gamma ray (120 Gy to 840 Gy) and used for these analysis. The films were irradiated with γ -rays (Cobalt-60) in the dose range of 0–840 Gy at the dose-rate of ~6 Gy/min at room temperatures.

Figure.1 (a, b, c, d) Shows the XRD patterns for the un irradiated and gamma irradiated CdHgTe thin films at different dosages (120, 360, 480 Gy). This prepared sample peaks are observed at CdHgTe film depicts its polycrystalline structure. The XRD spectrum exhibits an intense (200) peak indicating preferential orientation in the <200> direction. A strong peak is observed around at $2\theta = 27.70^\circ$ can be attributed to the reflections from (200) plane. The weak peaks are obtained at $2\theta = 24.47^\circ, 37.49^\circ, 47.66^\circ, 50.8^\circ$ & 57.50° are due to with hkl values of (111), (220), (331), and (222) & (400) reflections respectively.

Moreover, it is the only main peak obtained with both films indicating that the presence of (200) planes at well crystalline nature and preferred textural growth.

orientation. This result revealed that the structure is such that the crystallographic a-axis is perpendicular to the substrate surface and the crystalline Orientation is favored. The XRD pattern showed that the prominent peaks are observed at $2\theta=27.70^\circ$ with hkl values (200) for various gamma ray dosages.

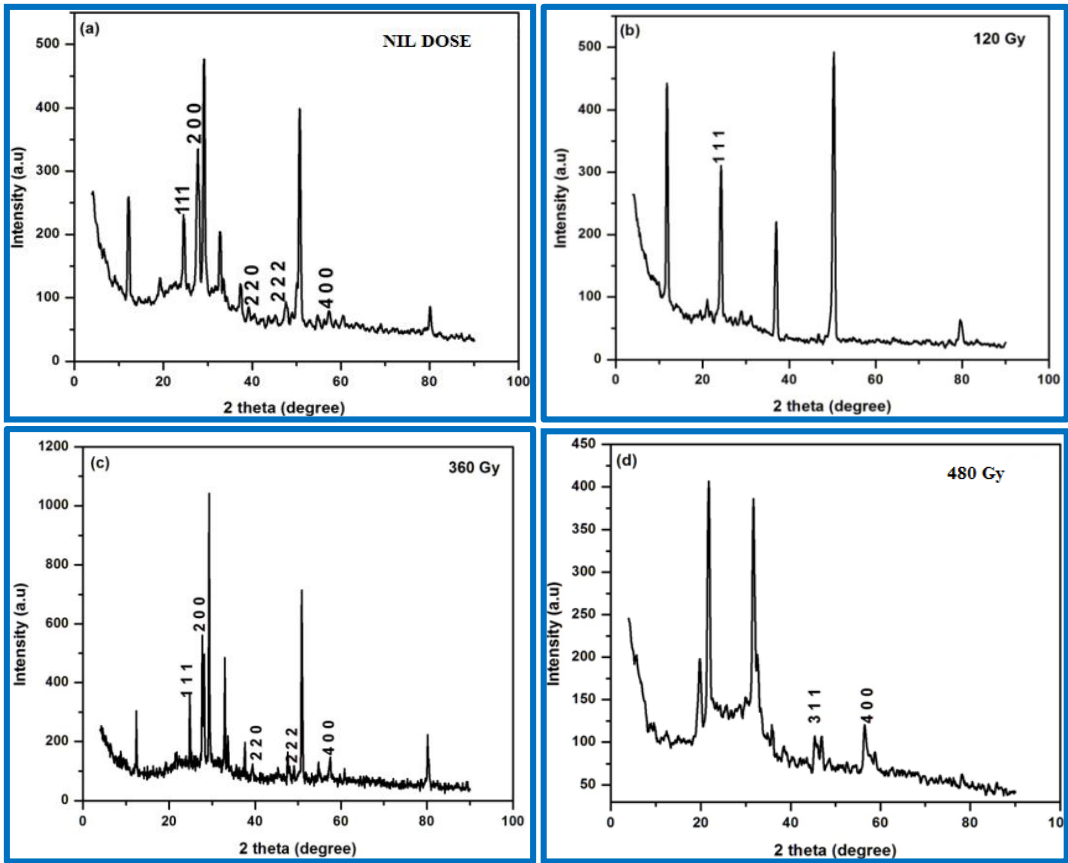


Figure 1. XRD spectrum of (a) un radiated and (b-d) gamma radiated (120, 360, 480 Gy) CdHgTe thin films at different dosages.

Table 1. Comparison of observed and standard values of lattice constant, d-spacing, strain, crystallite size of un-radiated and gamma radiated CdHgTe thin films

Gamma Dosage	Lattice constant (JCPDS)	Lattice constant (calculated)	Crystallite size (D)	strain(ϵ) X (10^{-3})	Dislocation Density (ρ) lines/min ²	d-spacing (JCPDS)	d-spacing Calculate d
NIL DOSE	a= 6.469	6.6901	17.33	2.000	3.3290x10 ¹⁵	3.8627	3.7418
120Gy	a= 6.469	6.4341	25.21	1.375	1.5730x10 ¹⁵	3.2170	3.1864
360 Gy	a= 6.469	6.4816	29.59	1.171	1.1421x10 ¹⁵	3.2408	3.2178
480 Gy	a= 6.469	6.5100	19.58	1.771	2.6070x10 ¹⁵	1.6291	1.6352

When the dosage increase the peak intensity also increases which is shown in Figure 1(c, d), as Increase of peak intensity at 360 Gy may be attributed to the increase in the degree of crystalline. As shown from the previous Moreover, the produced data for all films prepared at different temperature of CBD solution showed a good agreement with the data of CdHgTe PDF file (JCPDS data card number 65-6126) which corresponding to the cubic crystalline structure. The JCPDS spectrum is indicated by vertical lines. The height of this line is proportional to the relative intensity of the peaks for film samples.

The relative intensities of the matching lines correspond to the observed intensities of the coatings. The diffraction of the (200) planes are clearly observed on the diffraction pattern of CdHgTe. In addition, average CdHgTe crystalline size is estimated from the full width at half maximum (FWHM) of the diffraction peaks at 27.70° , using scherrer equation. For evaluation of crystal lattice parameters we have used the cubic relation

$$a = d\sqrt{h^2 + k^2 + l}$$

So a, b and c are the cubic lattice ($a=b=c$) parameters. In this relation (h, k, l) are miller indices of reflector plans appearing on the diffraction spectra and dhkl their inter-reticular distances. The obtained values of lattice parameters are equal, $a=6.469$ nm. Therefore it has been concluded that the un-irradiated and gamma irradiated films are polycrystalline in nature with Hexagonal structure.

The observed and standard values of grain size (D), dislocation density (δ), micro strain (δ) and d-spacing were estimated and presented in table1. The XRD data shows that the gamma irradiated film having high intensity rather than non-irradiated film and also the increase in peak intensity up to 360 Gy is due to the improvement in the crystallinity and decreasing the internal micro strain of the film.

4.2 SEM and EDX analysis

Figures 2 (a-b) illustrates the SEM micrographs of the surfaces of the as prepared and gamma radiated CdHgTe thin films. These illustrations reveal that increase in the gamma ray affects the surface morphology of the CdHgTe films markedly. A close observation on these

pictures revealed a fact that increases in gamma ray greatly increases the size of the agglomerates in the thin film. Further, the morphology of the grains is observed to be near spherical in nature and is more uniform throughout the analyzed area in the specimen.

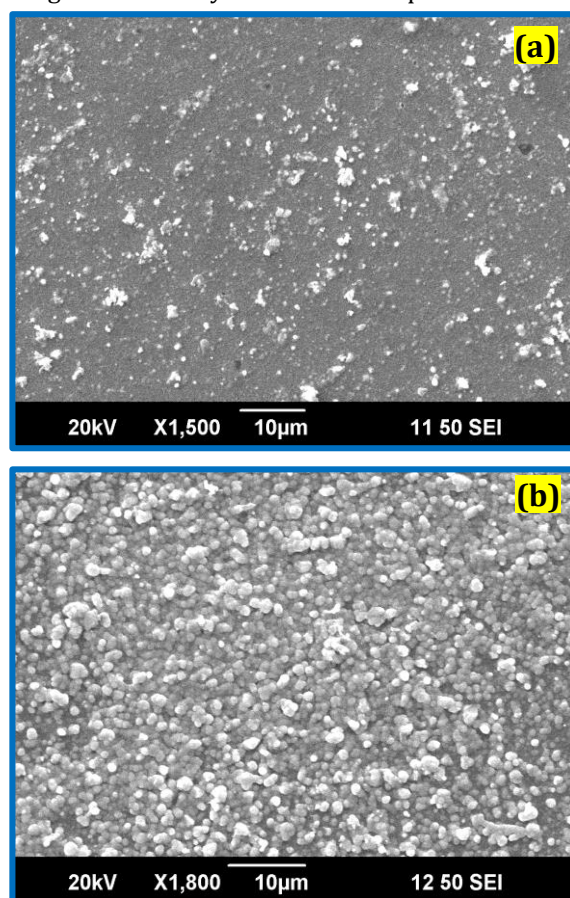


Figure 2. (a) Un radiated and **(b)** gamma radiated CdHgTe thin films (360 Gy).

The composition of the films was investigated using an energy dispersive analysis By X-ray analysis (EDAX) set up attached with scanning electron microscope. Figure 3 Shows the EDAX analysis for the chemical bath deposited CdHgTe thin films.

The elemental analysis was carried out only for Cd, Hg and Te, the average atomic percentage of Cd:Hg:Te was 34.2(Cd):65.8(Te): showing that the sample was slightly cadmium rich. The atomic and mass percentage is given in Table 2.

Table 2 The atomic and mass percentage of CdHgTe thin films				
Element	(keV)	Mass %	Atom %	K
Hg	8.63	7.91	13.42	9.2289
Cd	3.132	55.16	54.46	58.0985
Te	3.768	36.94	32.12	30.073
Total		100	100	

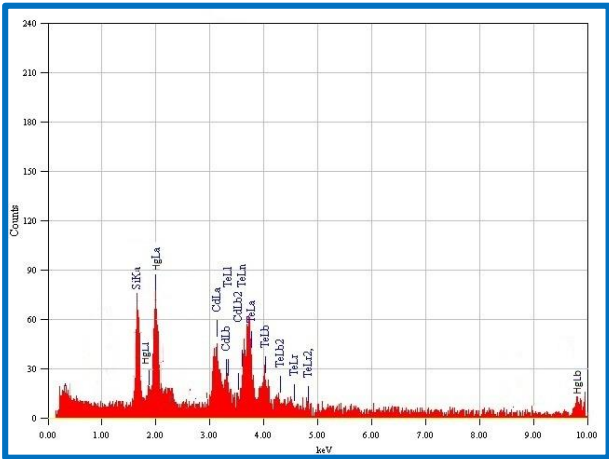


Figure 3. EDAX spectrum of CdHgTe thin film.

4.3 Electrical Measurements

During exposure to nuclear radiation dose-rate plays an important role in creating excess charge carrier in the device as long as the radiation is on. The excess carrier generated in the substrate recombines within a short period of time after the radiation is switched off. For that reason, the samples were kept at room temperature for 15 min before making any measurements, so that the charge carriers can settle down. DC electrical characteristics of CdHgTe films were performed on two probe setup connected to Keithley High Resistance Meter/ Electrometer 6517B (computerized).

These measurements were taken at room temperature. This electrometer (6517B) has an in-built capability of output independent voltage source of ±1000V. So, the same equipment (6517B) was used to apply the voltage across the sample and to measure the current through the sample, to ensure good ohmic contact. I-V measurements for Un-radiated and gamma radiated CdHgTe thin films were shown in Figure 4a.

From the figure 4a it is observed that the value of measured current is considerably increased with the

increase in radiation dose upto360Gy. The electrical conductivity of the film were calculated using given formula

$$\sigma = \left(\frac{d}{RA} \right)$$

Where, R is the measured resistance, d is the thickness of the sample, and A is the area of the sample. The electrical conductivity was shown in Figure 4b. It is clear from the figure that the change in both current and electrical conductivity varies linearly with the cumulative dose of 480 Gy.

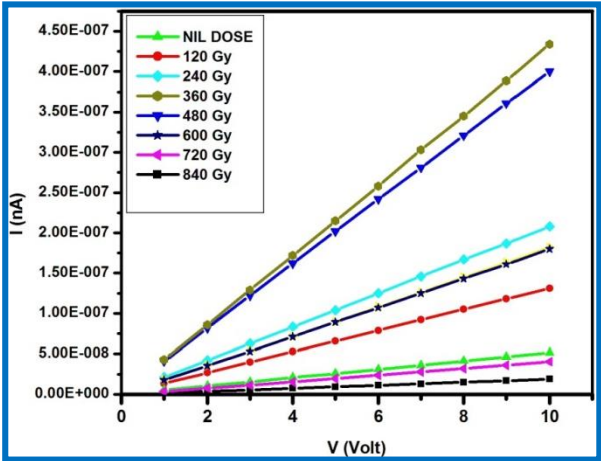


Figure 4a. The applied Voltage Vs Current (nA) for CdHgTe thin films.

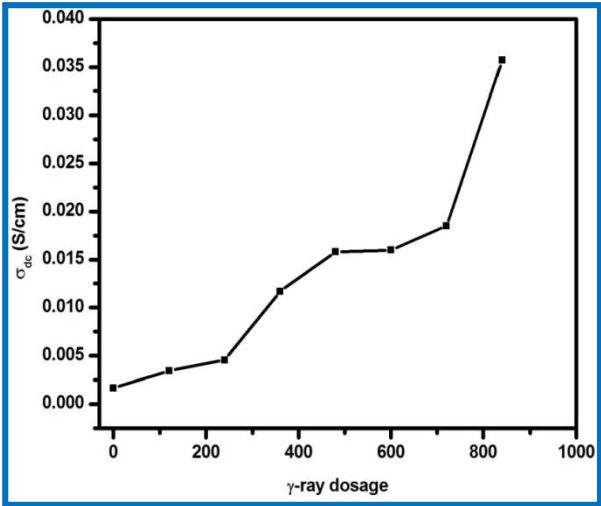


Figure 4b. The gamma ray dosages Vs conductivity (σ S/cm) for CdHgTe thin films

5. Conclusions

The X - ray diffraction study shows that variation in the peak intensity also the strain was found to decrease

with irradiated film. The increase in peak intensity and decreasing the internal micro strain of the film is due to the improvement in the crystallinity. The plane (200) from crystallographic a-axis is perpendicular to the substrate surface and the crystalline Orientation is favored. Morphology of the grains is observed to be near spherical in nature for the gamma radiated CdHgTe thin films. On the other hand, the current-voltage characteristics show that the current increases near linearly with the gamma radiation dose up to a certain critical dose (a quantity dependent upon the thickness of the film) and that the current decreases for the gamma radiation doses above this value. The near linear variation of the current with the radiation dose clearly indicates that the CdHgTe thin films have high potential for their use in the real time gamma dosimetry and also for solar cell applications.

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Competing Interests:

The authors declare that they have no competing interests.

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