

Changes in the Electrical Properties of CdTe Thin Films under the Influence of γ -Irradiation at Different Times

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Annotation

A CdTe coating with a thickness of 200 μm , formed on the surface of a substrate (Mo) by thermal evaporation under high vacuum conditions, was studied. The CdTe coating was annealed at 10600C for 30 minutes under high vacuum, then irradiated with γ -rays at different times using a Co60 radioactive source. As a result of γ -irradiation, it was found that the CdTe crystal size (D) decreased from 60 nm to 2 nm, and the number of dislocations (δ) increased from $2.7 \cdot 10^{10}$ to $1 \cdot 10^{15} \text{cm}^{-2}$. It was found that the I-U ratio of the CdTe crystal (U) decreases from (I) - $1 \cdot 10^{-7} \text{A}$ to $7.41 \cdot 10^{-10} \text{A}$ at -5 V. It has been determined that the crystal structure of CdTe changes significantly after γ -irradiation.

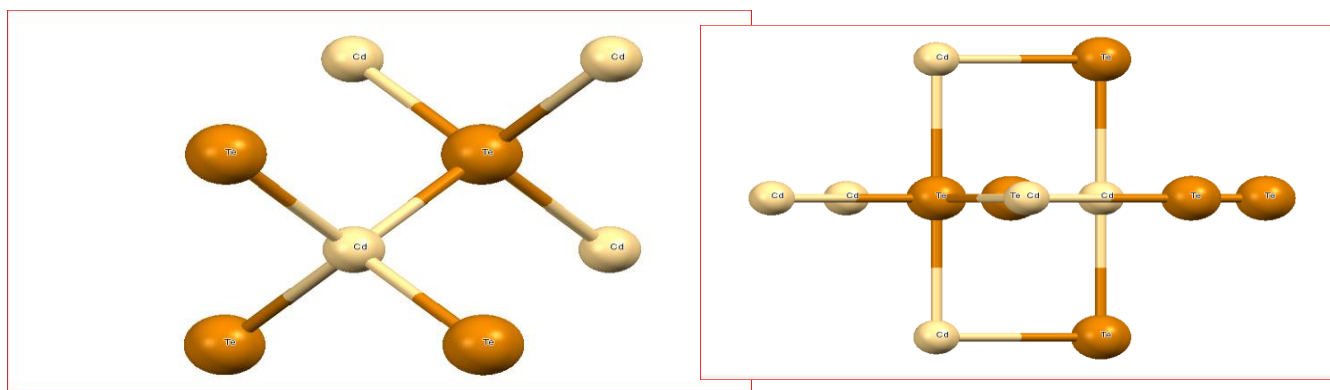
Keywords: Cadmium telluride, polycrystal, thin coating, γ -radiation, radioactivity, nanostructure, current, dislocation.



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1. INTRODUCTION

Currently, the demand for electricity is growing all over the world. To overcome these problems, we need to use more natural energies, such as solar energy. Nowadays, silicon (Si) is increasingly used for solar energy conversion, and a material that can compete with silicon in absorbing solar energy is polycrystalline CdTe. In the last decade, the production of CdTe thin films has been promoted by two methods: electrodeposition (ED) and spatial sublimation (CSS) [1]. After more than 40 years of research, the efficiency of CdTe thin film solar cells has been increased to 22% [2]. The arrangement of CdTe atoms is cubic, the lattice period is $a = 6.481 \text{ \AA}$ [3], as illustrated in Figure 1.



COD 9008840 Wyckoff, R.W.G., Crystal Structures (1963), 1, 85

COD 1010536 Zachariasen, W. H., Norsk Geologisk Tidsskrift (1926), 8, 302

F-4 3 m $a=b=c=6.480 \text{ \AA}$ $\alpha=\beta=\gamma=90^\circ$ cell size - 272.098 $\text{\AA}$

F m-3m $a=b=c=6.41 \text{ \AA}$ $\alpha=\beta=\gamma=90^\circ$ cell size - 263.375 $\text{\AA}$

Figure 1 - Arrangement of CdTe atoms

It has been experimentally established that CdTe can be easily grown from CdS and CdTe layers for n-, i- and p-type substrates of nano- and micro-sizes [4]. It is possible to obtain a chemically stable CdTe thin film with an open circuit voltage of 1 V and a short circuit current density of more than 30 mA/cm². [5]. The band gap (E_g) reaches 1.39–1.46 eV as a result of improved optoelectric properties by further processing of CdTe thin films. The electrical properties of r type concentration 10^{13} - 10^{16} cm^{-3} , resistivity 104 Ohm-cm, absorption coefficient ($\sim 105 \text{ cm}^{-1}$), significantly high mobility at room temperature ($1040 \text{ cm}^2/\text{V}\cdot\text{s}$) were determined. [6-7]. Therefore, high-quality CdTe thin films are widely used in electronics and optoelectronics, in devices such as solar cells, X-ray and radiation detectors, photodetectors, etc. [8-14]. This paper examines the changes in CdTe pole crystals before and after irradiating a CdTe sample with gamma rays at different times using an XRD-6100 instrument.

II. Research methodology

The CdTe coating was deposited on the surface of a molybdenum (Mo) substrate by thermal evaporation under high vacuum conditions. High vacuum was created using a mechanical fore-vacuum pump of the RVN-4 type and a steam-oil diffusion pump of the H-01 type. The starting vacuum was about 10^{-2} Pa . Crucibles made of aluminum oxide or beryllium were used as CdTe evaporators. The evaporation temperature of the crucibles was achieved by adjusting the current. The thickness of the CdTe coating was 200 μm . Subsequent annealing was carried out at a temperature of 1060°C for 30 minutes under high vacuum conditions. Changes in the crystallization of CdTe samples were observed using a X-ray diffractometer (XRD-6100 SHIMADZU). (Figure 2)

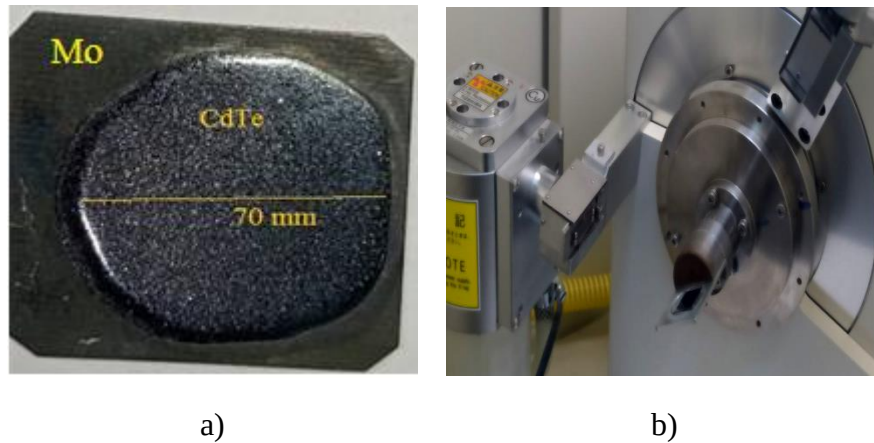


Figure 2. a) CdTe/Mo sample b) Process for obtaining XRD-6100 results

A polycrystalline CdTe sample was irradiated with γ -rays at different times using a cobalt-60 (Co_{60}) radioactive source. Then the effect of γ -rays on CdTe polycrystals was studied. The current-voltage characteristics of a CdTe polycrystal before and after γ -irradiation of the CdTe coating were determined using a SourceMeter-2400 device.

III. Main results and their discussion

The composition and morphology of the CdTe sample were studied using SEM microscopes of various sizes. Figure 3a shows the production of a CdTe hard coating with a high-quality smooth coating. Figure 3b shows the crystallization morphology of the CdTe coating. It was determined that the composition of the coating is CdTe Cd-47,51%, Te-52,49%.

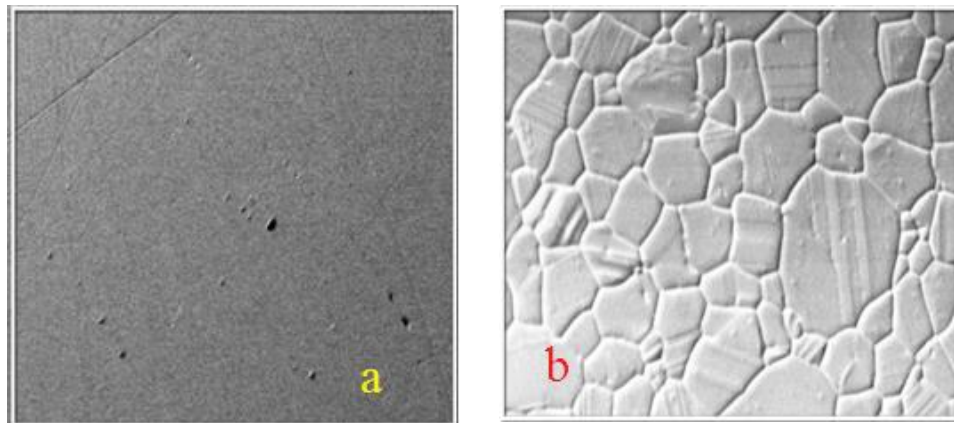


Figure 3. a) One-piece smooth CdTe coating. b) Morphology of CdTe crystallization.

Using X-ray energy dispersive spectroscopic analysis of a CdTe sample, it was found that the Cd element mainly corresponds to energy peaks from 0.1 keV to 3.1 keV, and the Te element from 3.2 keV to 5.1 keV. (Figure -4)

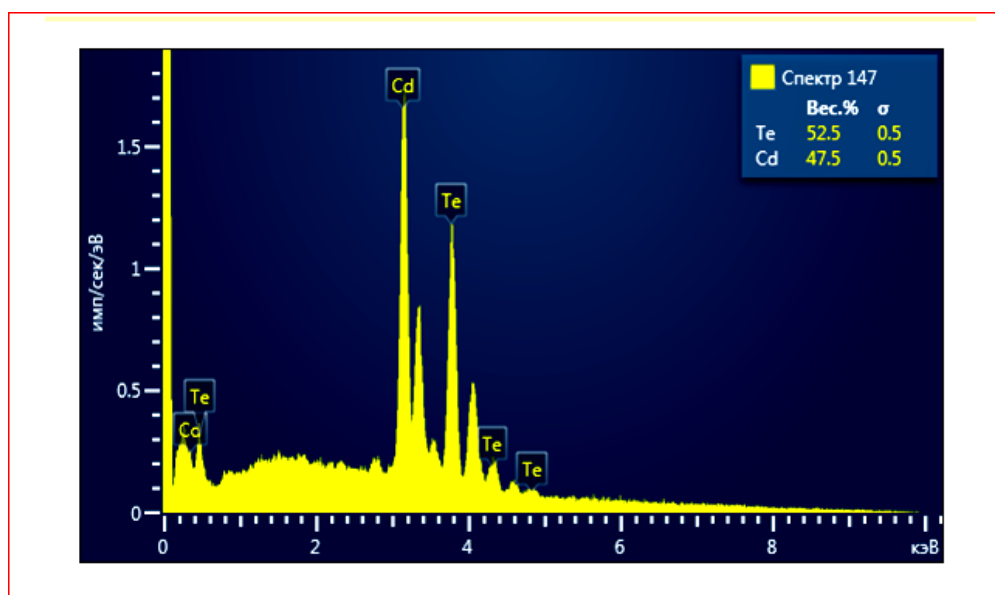


Figure 4 - X-ray energy dispersive spectroscopy analysis of a CdTe sample

Data obtained on CdTe samples (XRD-6100) were compared with data presented in the technical literature, and their agreement with the results obtained was established. High intensity peak 52230 at $2\theta = 23.25$ was detected before γ -irradiation of the CdTe sample. $2\theta = 38.8$; 45.95 ; 56.3 ; 61.9 ; Peaks of low intensity were detected in the corners. It can be seen that the CdTe sample has sufficient crystallinity (Figure 5)

2Theta (deg)	d (Å)	FWHM	Intensity (Counts)
23.2658	3.82017	0.21450	52230
38.8310	2.31728	0.13110	1370
45.9532	1.97333	0.14760	5734
56.3276	1.63201	0.13600	2474
61.9256	1.49724	0.13580	1004

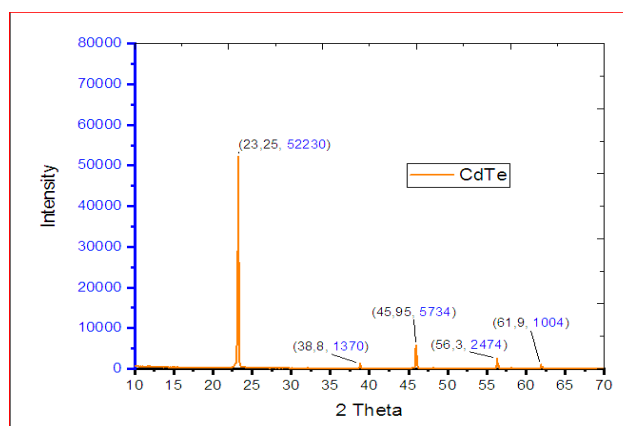


Figure 5 - X-ray diffraction analysis of CdTe before γ -irradiation

The CdTe coating was treated for 1 hour with γ -rays with an irradiation dose of 100 Gray, a radiation power of 90 r/s, using a cobalt-60 (Co60) radioactive source. Changes in the structure of CdTe were detected due to the absorption of gamma ray energy by the crystal lattice of a thin layer of CdTe. In CdTe samples, the intensity of the peaks decreases from 52230 to 48506 at $2\theta = 23.25$, $2\theta = 45.92$; 56.26 ; thin peaks were detected. (Figure 6)

2Theta (deg)	d (Å)	FWHM	Intensity (Counts)
23.2527	3.82229	0.17410	48506
45.9282	1.97435	0.14090	7826
56.2678	1.63361	0.13390	2038

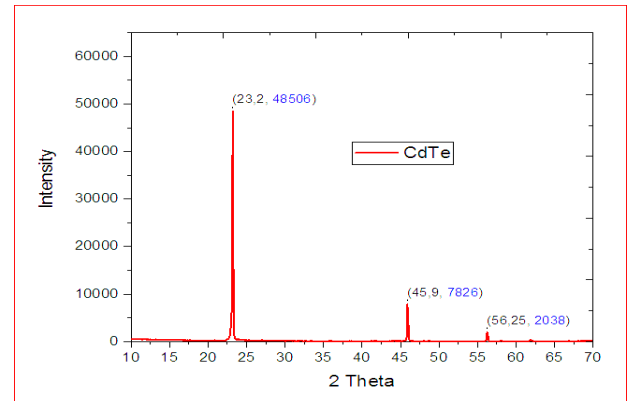


Figure 6 - X-ray diffraction analysis of CdTe after 1-hour γ -irradiation

After 2 hours of γ -irradiation, a significant effect of gamma rays on the crystal lattice of a thin CdTe layer was observed. The change in the structure of CdTe consists in a decrease in the intensity of the peaks to 1412 at $2\theta = 24.1015$, $2\theta = 39.7011$; 46.7298; Peaks with significantly lower intensity were detected. From X-ray diffraction analysis, we can tell that CdTe changes from crystalline state to amorphous state due to significant impact on the crystal lattice (Figure 7).

2Theta (deg)	d (Å)	FWHM	Intensity (Counts)
24.1015	3.68956	3.14410	1412
39.7011	2.23501	4.35000	888
46.7298	1.94233	4.33340	644

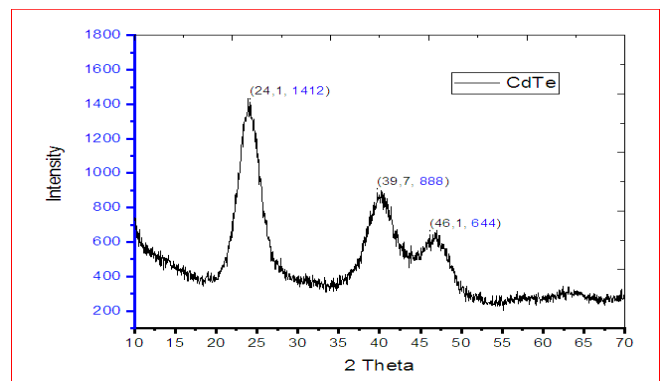


Figure 7 - X-ray diffraction analysis of CdTe after 2-hour γ -irradiation

Using the Debye-Scherrer formulas for the crystal structure of CdTe, the average crystal size was determined by the following formula:

$$D = K\lambda \cos(\theta)$$

Here D is the average crystal size, K is the dimensionless particle shape coefficient (Scherrer constant); λ is the wavelength of X-ray radiation; β -peak width at half maximum (in radians and 2θ units); θ -diffraction angle (Bragg angle). The K coefficient can take different values depending on the shape of the particles. For example, for spherical particles K is usually taken equal to 0.9 [15-18]. The Scherrer constant is presented as a function of the distance (d) between CdTe atoms. The crystall size of the CdTe crystal before γ -irradiation ranged from 23 to 54 nm (Figure 8).

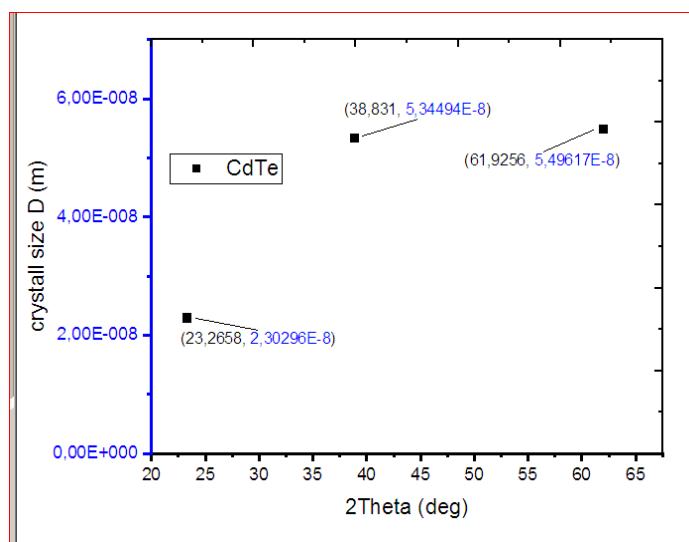


Figure 8 - CdTe crystal size before γ -irradiation

After γ -irradiation of CdTe crystals for 1 hour, the crystal size (D) for CdTe decreases from 27 nm to 24 nm. The effect of γ -irradiation on the crystal size was discovered (Figure 9).

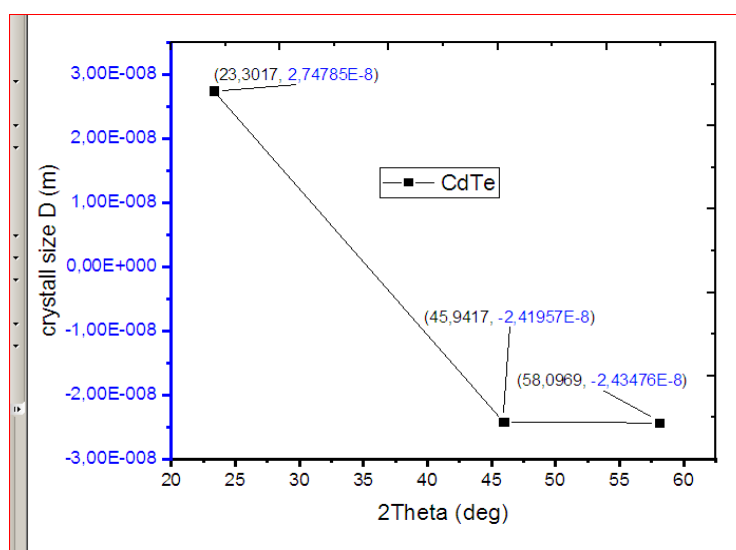


Figure 9 - CdTe crystal size after γ -irradiation for 1 hours

The crystal size (D) for CdTe varies from 2.29 nm to 0.37 nm with a γ -irradiation time of 2 hours. It was found that the size of the CdTe crystal differs up to 17 times before and after γ -irradiation (Figure 10).

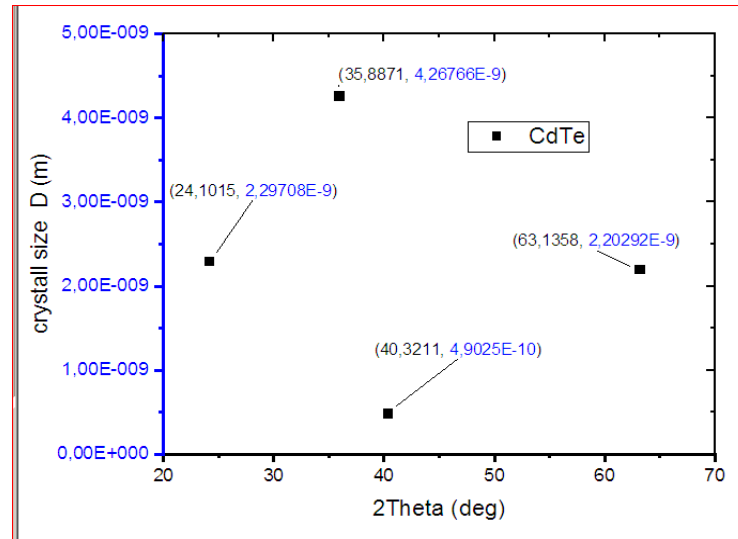


Figure 10 - CdTe crystal size after γ -irradiation for 2 hours

Based on the size values of CdTe crystals, the value of the dislocation density of CdTe nanoparticles can be determined using the Scherrer equation. The dislocation density can be calculated using the appropriate equation. The value of the dislocation density indicates a change in the degree of crystallinity of the nanoparticle [19-20].

$$\delta = 1/D^2 \quad (2)$$

It has been established that the dislocation (δ) of a CdTe crystal before gamma irradiation varies from 2.7×10^{10} to $1.8 \times 10^{11} \text{ cm}^{-2}$ (Figure 11).

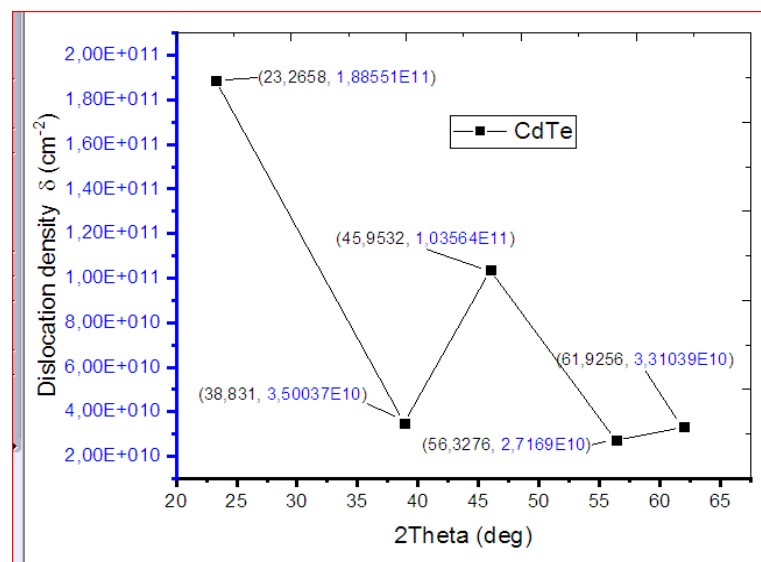


Figure 11 - (δ)-dislocation of a CdTe crystal before γ -irradiation

When a CdTe crystal was irradiated with γ -rays for 1 hour, it was found that the number of dislocations in CdTe polycrystals changed from 1.32×10^{11} to $1.7 \times 10^{11} \text{ cm}^{-2}$ (Figure 12).

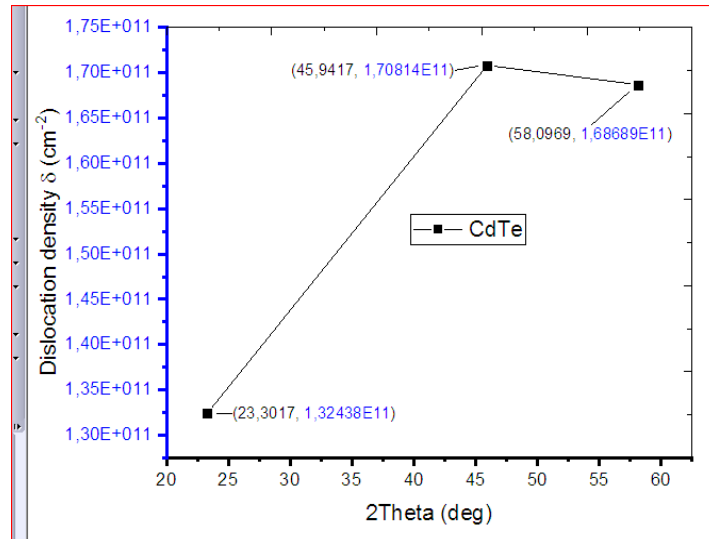


Figure 12 - Dislocation (δ) of a CdTe crystal after 1 hour of γ -irradiation

It was found that when CdTe polycrystals were irradiated with γ -rays for 2 hours, the number of dislocations between CdTe polycrystals changed significantly from 5.4×10^{12} to 1×10^{15} cm⁻². (Figure 13)

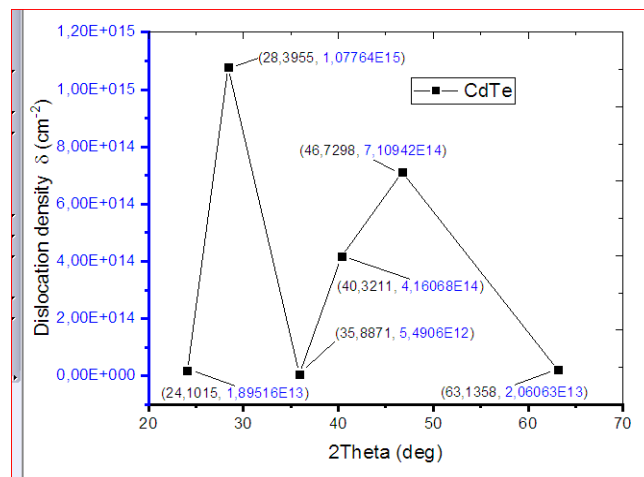


Figure 13 - Dislocation (δ) of a CdTe crystal after 2 hours of γ -irradiation

Using a SourceMeter-2400 developed by KEITHLEY Tektronix, the (I-U) ratio was determined for polycrystalline γ -irradiation conditions of CdTe before and after irradiation. The γ -dependence of a CdTe polycrystal before irradiation (I-U) was determined at a voltage of 0.5 V, a current change of 1.7×10^{-9} A, a current change of 1×10^{-7} A at a voltage of 5 V (Figure-14)

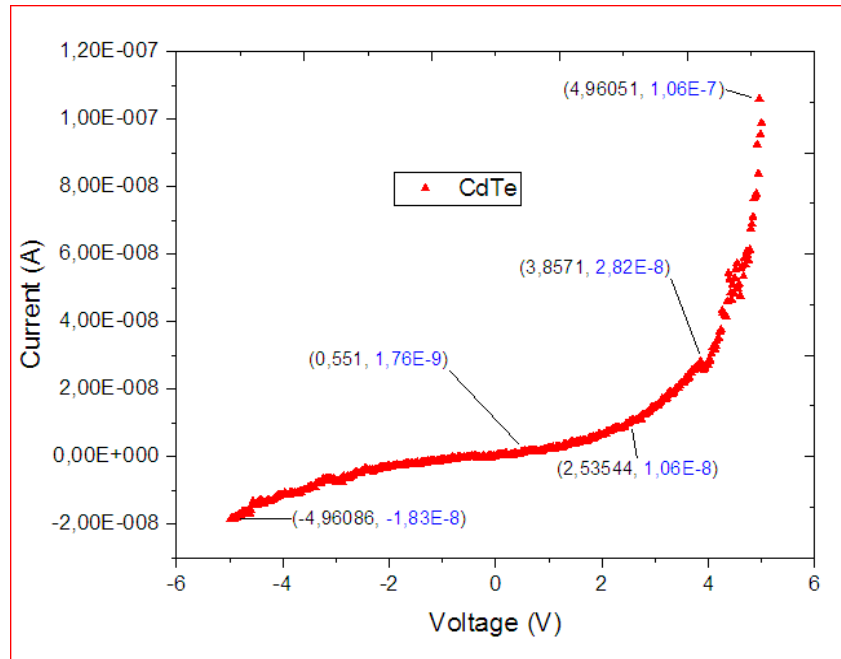


Figure 14 - I-U graph before γ -irradiation of CdTe

CdTe polycrystal after 1 hour of γ -irradiation (I-U) dependence, the current was 2.48×10^{-10} A at a voltage of 0.5V, and the current was 1.52×10^{-9} A at a voltage of 5V (Figure 15).

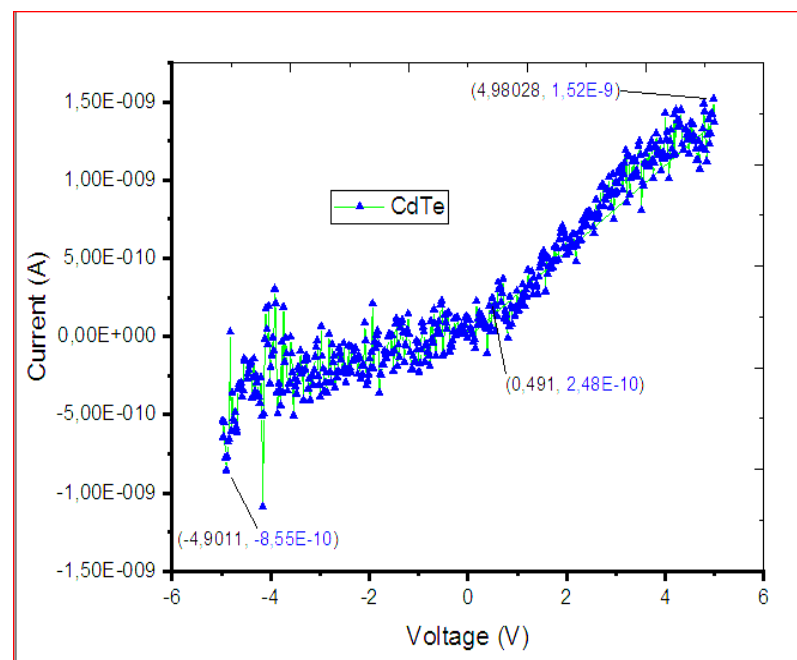


Figure 15 - I-U plot for CdTe after 1 hour of γ -irradiation

After γ -irradiation of CdTe for 2 hours (Figures 8 and 11), it was found that the Scherrer constant decreases in size, the number of dislocations increases, and the change in the dependent state (I-U) is 7.41×10^{-10} A at a voltage of 5 V. (Figure 16)

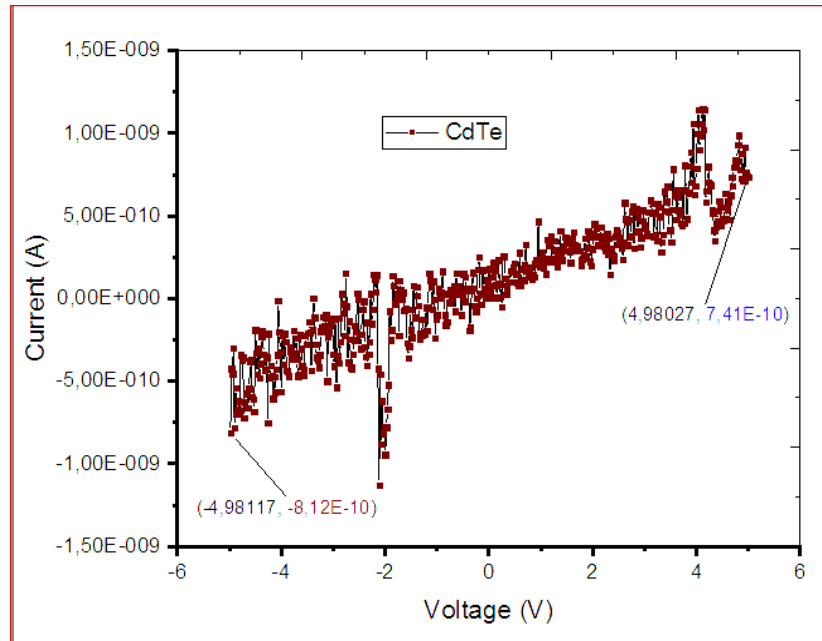


Figure 16 - IU plot of CdTe after 2 hours of γ -irradiation

As a result of research, it was found that long-term γ -irradiation of a thin CdTe coating, which competes with silicon in converting solar energy into electricity, has a negative effect on CdTe crystals.

III. CONCLUSION

A study of a CdTe coating formed on the surface of molybdenum by thermal evaporation under high vacuum conditions after annealing at a temperature of 1060°C for 30 minutes showed that a polycrystalline CdTe sample changes significantly when irradiated with γ -rays using a cobalt-60 (Co_{60}) source. The influence of γ -quanta on CdTe polycrystals, determined using an X-ray diffractometer (XRD-6100 SHIMADZU), indicates a change in the CdTe crystal size (D) from 60 nm to 2 nm and an increase in the number of dislocations (δ) from 2.7×10^{10} to $1 \times 10^{15}\text{cm}^{-2}$. Using SourceMeter-2400, it was found that the I-U ratio of the CdTe crystal (U) decreases from (I)- $1 \times 10^{-7}\text{A}$ to $7.41 \times 10^{-10}\text{A}$ at -5V.

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