Influence of Cerium (Ce) Doping on the Structural Properties of Silver Telluride (Ag_2Te) Thin Films Deposited by Electrodeposition Method

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ABSTRACT

In this research, Silver Telluride (Ag_2Te) and Cerium doped Silver Telluride (Ce: Ag_2Te), thin films have been successfully deposited onto FTO glass substrate using electrodeposition method to investigate the influence of Ce doping on the structural properties of Ag_2Te thin films. Silver trioxonitrate (V) and tellurium (iv) oxide were the precursors used for silver and tellurium ions. Depositions of films made from cerium-doped silver telluride were conducted at room temperature. Variations of structural properties with concentration of cerium dopant, deposition time and with pH were considered in this research. The percentages concentration of cerium dopant used are 5% and10.0%. The Structural properties of Ag_2Te and Ce doped Ag_2Te thin films were investigated using X-ray diffractometry. The structural properties analysis of pure Ag_2Te and cerium-doped Ag_2Te thin films reveals significant changes in crystallographic properties (crystallite size, micro-strain and dislocation density) with increasing cerium concentration. The increase in crystallite size, coupled with the decrease in micro-strain and dislocation density, suggests that cerium doping improves the structural quality of Ag_2Te thin films, potentially enhancing their properties. The higher intensities of the doped samples' diffraction peaks imply better crystallinity and possibly lower defect densities, which are beneficial for applications requiring high-quality crystalline materials. Longer deposition times and optimizing pH enhance crystallinity , where lower values generally improve crystal quality by reducing lattice distortions. The findings highlight how controlled doping, deposition time, and pH conditions can fine-tune the structural properties of cerium doped silver telluride thin films, making it suitable for applications in optoelectronics and electronic devices.

Keywords: Silver-Telluride, Structural properties, Electrodeposition, X– ray diffractometer machine

INTRODUCTION

Silver telluride (Ag_2Te) is a chalcogenide semiconductor composed of silver (Ag) and tellurium (Te), belonging to group iv-vi compounds on the periodic table [1] which exhibit semiconductor properties. In bulk form, it crystallizes in a monoclinic $\beta -$ phase at room temperature and undergoes a phase transition to a cubic $\alpha -$ phase at elevated temperatures, approximately 423k [2], with associated changes in electrical behavior. Ag_2Te exhibits n-type conductivity and has been studied for magneto resistance and thermo electric applications [2]. Nanostructured forms of silver telluride, such as quantum dots or nanorods , show enhanced properties due to quantum confinement effects, including increased band gaps and strong photoluminescence within infrared range, which differs greatly from bulk materials [3]. These nanostructures are synthesized by different methods such as hydrothermal processes or chemical deposition, using precursors such as $AgNO_3$ and $TeCl_4$ [4]. Recently, Ag_2Te quantum dots have emerged as heavy metal-free alternatives to traditional chalcogenide nano materials, giving tunable optoelectronic properties for near-infrared (NR) and shortwave infrared (SWIR) photodetectors

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with competitive responsivity and detectivity [3]. Besides optoelectronics, the compound finds application in non linear optical devices, ion-selective electrodes, electrochemical storage cells, solar cells and biological sensors, stating its versatility in energy, environmental and sensing technologies [2]. Reports from literature [6, 7, 8, 9] showed no information on the influence of dopant concentration, deposition time and pH on the structural properties of cerium doped silver telluride films. The purpose of this research is to address the literature gap by investigating the influence of concentration of cerium doping, deposition time and pH on the structural properties of silver telluride films synthesized via electrodeposition.

Experimental

Reagents

Reagents used for electrodeposition of cerium doped silver telluride (Ce:AgTe) were; Silver nitrate : used as precursor for silver ion., Cerium (iv) sulfate tetrahydrate: used as precursor for cerium ion (dopant ion), Tellurium (IV) oxide: used as precursor for tellurium ion, ethylene diamine tetra acetic acid (EDTA): used as a complexing agent, distilled water was used as solvent.

Apparatus

The experimental arrangement shown in section 3.5, Figure 1 [5] illustrates the setup for electrodeposition, comprising the electrolyte, power supply unit, and electrodes. It adopts a three-electrode configuration for depositing thin films onto conducting substrates. The conducting substrate, specifically FTO, was used as the cathode or working electrode. A platinum electrode functioned as the anode or counter electrode, while a silver/silver chloride (Ag/AgCl) electrode served as the reference electrode. The energy supply for the electrodeposition setup is provided by a Dazheng digital DC-power supply unit, specifically the PS-1502A model. Two digital multimeters, the DT9201A CE and the highly sensitive Mastech: MY60 were employed for measuring voltage and current, respectively. The Mastech: MY60 multimeter is capable of measuring currents within the range of 10^{-6} A.

Material preparation

Molar solutions of the reagents prepared for the deposition include:

Silver nitrate

Silver nitrate is an inorganic compound with chemical formula $AgNO_3$. It is a versatile precursor to many other silver compounds. It is a colorless salt with molar mass of 169.87 g/mol. About 256 g of the salt is soluble in 100 ml at 25 °C. In this work, silver nitrate served as precursor for Ag ion and various concentrations (0.10 M and 0.01 M) of silver nitrate was prepared by dissolving particular amount of the compound in 100 ml of distilled water.

Cerium (iv) sulfate tetrahydrate

Cerium (IV) sulfate tetrahydrate, also called ceric sulfate, is an inorganic compound with chemical formula ($Ce(SO_4)_2 . 4H_2O$). The salt is a yellow solids that are moderately soluble in water and dilute acids. Solutions of ceric sulfate have a strong yellow color. It has a molar mass of 404.30 g/mol. In this work, 0.01 M of the salt was prepared by dissolving 0.40 g in 100 ml of distilled water

Tellurium (IV) oxide

Tellurium (IV) oxide, also known as tellurium dioxide (TeO_2) is a white crystalline solid with molecular weight of 159.60 g/mol and it is negligible soluble in water. Tellurium (IV) oxide served as precursor for tellurium ion. In this work, 0.20 mole solution of TeO_2 was prepared by dissolving 7.98 g in 250 ml of distilled water.

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Diluted sulfuric acid solution

H_2SO_4 has a molar mass of 98.079 g/mol. 1.0 M of H_2SO_4 was prepared by adding 55.60 ml of 96 % concentrated H_2SO_4 to 1000 ml of distilled water. The 55.60 ml of H_2SO_4 was obtained by using the percentage concentration of the H_2SO_4 (96%), molar mass of H_2SO_4 (98.079 g/mol) and specific density of (1.84 g/ml). The diluted H_2SO_4 served as pH adjuster

Substrate pre-treatment

Prior to electrodeposition of the films, the FTO substrates were subjected to distinct pre – treatment to ensure the presence of catalytic surface to improve the adhesion of the films to the substrates most especially when there is possibility of increase in film thickness as deposition proceeds. This pre – treatment of FTO glass substrates was achieved through the following six steps;

(i) We cleaned the FTO glass substrates with detergents.

(ii) We soaked the substrates in acetone for 10 minutes for degreasing.

(iii) We ultrasonicated the substrates for 20 minutes in an ultrasonic bath using ethanol as a solvent.

(iv) We ultrasonicated the substrates for 10 minutes in an ultrasonic bath using distilled as a solvent.

(v) We rinsed the substrates twice with distilled water.

(vi) We dried the substrates in an electronic oven for 10 minutes at a temperature of about 100℃.

Electrodeposition

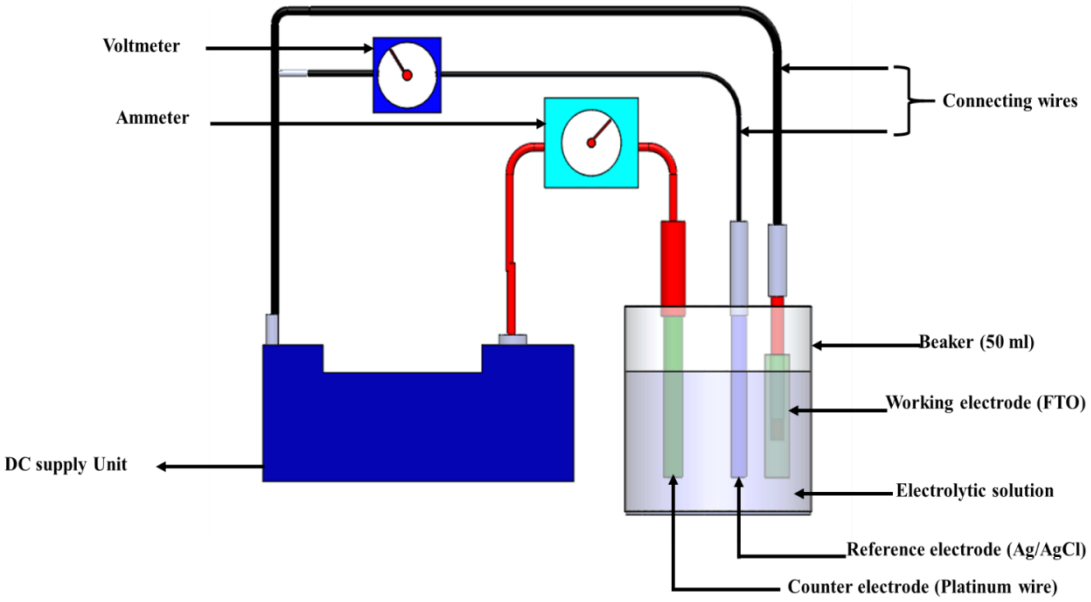

Figure 1: Schematic diagram of the electrodeposition experimental set – up [5]

Depositions of thin films made from cerium-doped silver chalcogenide (Ce:Ag_2Te) were conducted at room temperature. Molar concentration bath parameter of the cerium precursor was adjusted to optimize their impact on the optical characteristics of these films.

Electrodeposition of silver telluride and cerium doped silver telluride$(Ce: Ag_2Te)$ thin films

For electrodeposition of silver telluride thin film on FTO substrate, aqueous electrolytic bath composed of 20 ml of 0.10 M of silver trioxonitrate (V) and 5 ml of 1.0 M of H_2SO_4 were poured into the electrolytic bath. The

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mixture was stirred for 5 minutes. This was followed by addition of 15 ml of 0.1 M of tellurium (IV) oxide solution to the mixture. This followed with another stirring for 5 minutes. After stirring, the three electrodes were immersed into the bath containing the electrolytic solution and 2 volts was allowed to pass through the setup for 15 seconds. After the allowed time, grey film of Ag_2Te was found to be deposited on the conductive surface of the FTO substrate. The deposited Ag_2Te thin film was heat-treated at 100 ℃ for 10 minute to remove water and improve the crystallinity of the deposited thin films. The mechanism of the formation of silver telluride and cerium doped silver telluride is shown in equation (1) and (2).

$$2Ag^{+} + Te^{4+} + 2e^{-} \longrightarrow Ag_2Te \qquad 1$$

Optimization of Ce ion concentration for Ce: Ag_2Te thin films

For the deposition of Ce doped Ag_2Te thin films, 0.05 M of cerium (IV) sulfate tetrahydrate was used as dopant source. Similar procedure used for deposition of silver telluride thin film was adopted but with addition of different volume concentrations of 0.05 M of cerium (IV) sulfate tetrahydrate as shown in Table 1. Four samples with different dopant volume concentrations of 1 ml, 2 ml, 3 ml and 4 ml were fabricated.

$$2Ag^{+} + Te^{4+} + Ce^{4+} + 2e^{-} \longrightarrow Ce{:}Ag_2Te \qquad 2$$

Table 1: Bath parameter for deposition of Ag_2Te and Ce doped Ag_2Te thin films

0.10 M of $AgNO_3$	**0.10 M of TeO_2**	**0.05 M of $CeSO_4{\cdot}4H_2O$**	**1.0 M of H_2SO_4**	**Applied Voltage**	**Time**
Vol. (ml)	Vol. (ml)	Vol. (ml)	Vol. (ml)	(volts)	(sec.)
20.00	15.00	-	5.00	2.00	15
20.00	15.00	1.00	5.00	2.00	15
20.00	15.00	2.00	5.00	2.00	15
20.00	15.00	3.00	5.00	2.00	15
20.00	15.00	4.00	5.00	2.00	15

Optimization of deposition time for $Ce{:}Ag_2Te$ thin films

For time optimization of Ce doped Ag_2Te thin films, similar procedure used for deposition of cerium doped silver telluride thin film was adopted. 0.10 M of silver nitrate, 1.0 M of H_2SO_4, 0.1 M of tellurium (IV) oxide and 0.05 M of cerium (IV) sulfate tetetrahydrate were used to deposit the desired thin film. Five films were deposited at time interval of 10 seconds, 20 seconds, 30 seconds, 40 seconds and 50 seconds. Table 3.8 shows the constituent of the electrolytic baths used for the deposition of Ce doped Ag_2Te at varying deposition time.

Table 2: Bath parameter for time optimized Ce: Ag_2Te thin films

0.10 M of $AgNO_3$	**0.10 M of TeO_2**	**0.05 M of $CeSO_4{\cdot}4H_2O$**	**1.0 M of H_2SO_4**	**Applied Voltage**	**Time**
Vol. (ml)	Vol. (ml)	Vol. (ml)	Vol. (ml)	(volts)	(sec.)
20.00	15.00	2.00	5.00	2.00	10
20.00	15.00	2..00	5.00	2.00	20

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20.00	15.00	2.00	5.00	2.00	30
20.00	15.00	2..00	5.00	2.00	40
20.00	15.00	2.00	5.00	2.00	50

Optimization of deposition pH for Ce: Ag_2Te thin films

For pH optimization of Ce doped Ag_2Te thin films, similar procedures used for deposition of cerium doped silver telluride thin film were maintained. The 0.10 M of silver nitrate, 1.0 M of H_2SO_4, 0.10 M of tellurium (IV) oxide and 0.05 M of cerium (IV) sulfate tetrahydrate were used for the deposition of Ce doped Ag_2Te thin films at varying pH. Five films were deposited with different volume concentration of H_2SO_4. 1 ml. 2 ml, 3 ml, 4 ml and 5 ml of H_2SO_4 were used to achieve variation in pH of the medium. Table 3.9 shows the constituent of the electrolytic baths used for the deposition of Ce doped Ag_2Te at varying pH.

Table 3: Bath parameter for pH optimized Ce: Ag_2Te thin films

0.10 M of $AgNO_3$	**0.10 M of TeO_2**	**0.05 M of $CeSO_4 \cdot 4H_2O$**	**1.0 M of H_2SO_4**	**Applied Voltage**	**Time**
Vol. (ml)	Vol. (ml)	Vol. (ml)	Vol. (ml)	(volts)	(sec.)
20.00	15.00	2.00	1.00	2.00	15
20.00	15.00	2..00	2.00	2.00	15
20.00	15.00	2.00	3.00	2.00	15
20.00	15.00	2..00	4.00	2.00	15
20.00	15.00	2.00	5.00	2.00	15

Characterization of deposited thin films

The fabricated thin films were characterized to determine their optical properties using spectrophotometer, Thickness measurements of the films were carried out using gravimetric method

Film thickness measurement

The deposited film thicknesses (t) were evaluated using the gravimetric method given by [10]; [11]; [12].

$$t = \frac{\Delta m}{\rho A}, \qquad 3$$

In equation (3),Δm is the mass of the film. A is the surface area of the deposited film and ρ is the bulk density of the material film. The masses of the deposited films were obtained by finding the difference in mass between the mass of the glass substrate with the film after deposited and the mass of glass substrate before deposition. These differences in mass of the films were measured using analytical weighing balance with sensitivity of 0.0001 g.

Bulk density of Ag_2Te is 8.32 g/cm^3. Bulk density of cerium is 8.16 g/cm^3. Because of small amount of cerium impurity used and possibility of cerium ions to substitute silver in the crystal structure, density of Ce:Ag_2Te was approximated to bulk density of Ag_2Te

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Structural characterization

Crystal structural analyses of the deposited thin films were done using x – ray diffractometer machine. From the x – ray diffraction pattern obtained, other structural properties such as d – spacing, full width at half maximum (FWHM) were obtained. The crystallite sizes and microstrains of the films were evaluated using Scherrer's formula. Debye – Scherrer's formula for calculating crystallite sizes of a thin film material is given by [13; 14] as

$$D = \frac{0.9\,\lambda}{\beta cos\,\theta}. \qquad 4$$

The dislocation density (δ) of thin films can be estimated using expression as provided by [15; 16] in equation (5).

$$\delta = \frac{1}{D^2}. \qquad 5$$

Micro-strain (ε) of thin film sample can be estimated using the expression in equation (6) as given by [17 and 18].

$$\varepsilon = \frac{\beta}{4tan\,\theta} \qquad 6$$

RESULTS AND DISCUSSIONS

Structural properties of Ag_2Te and Ce doped Ag_2Te thin films

(a) Variation of structural properties with concentration of cerium dopant

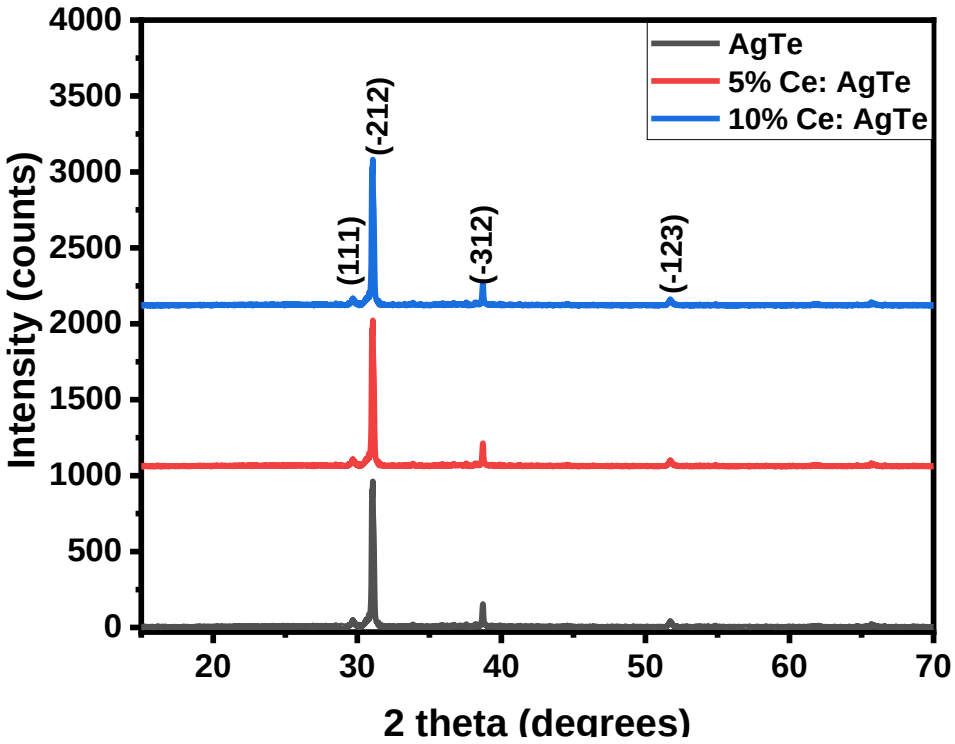

Figure 2: Diffractogram of Ag_2Te and cerium doped Ag_2Te deposited with different percentage concentration of dopant

Figure 2 shows the diffractogram of Ag_2Te and cerium doped Ag_2Te thin films deposited at different concentration of cerium ion. The diffractogram and accompanying table provide insight into the structural parameters of Ag_2Te and cerium-doped Ag_2Te thin films, with Ag_2Te corresponding to the JCPDS file number 01-081-1985 and known mineralogically as Hessite. The XRD patterns reveal distinct peaks corresponding to

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various crystallographic planes, indicating the monoclinic phase of Ag_2Te. The intensity of the diffraction peaks varies with the doping concentration, with undoped Ag_2Te showing lower peak intensities compared to the cerium-doped samples.

Table 4: Structural parameters of Ag_2Te and cerium doped Ag_2Te thin films

Doping Level	**2 Theta (°)**	**hkl**	**FWHM (°)**	**Crystallite Size (nm)**	**Dislocation Density × 10^{-3} $lines/nm^2$**	**Micro-strain (ε)× 10^{-3}**
Ag_2Te	33.827	111	0.305	28.142	1.263	5.019
	39.996	-212	0.187	46.041	0.472	2.936
	43.422	-312	0.113	78.151	0.164	1.398
	Average			**50.778**	**0.633**	**3.118**
5% Ce: Ag_2Te	29.706	111	0.277	31.014	1.040	4.554
	31.065	-212	0.187	46.031	0.472	2.937
	38.710	-312	0.113	77.992	0.164	1.401
	51.733	-123	0.274	33.596	0.886	2.470
	Average			**51.679**	**0.559**	**2.964**
10% Ce: Ag_2Te	30.731	111	0.216	39.764	0.632	3.436
	31.065	-212	0.161	53.586	0.348	2.523
	38.710	-312	0.113	77.518	0.166	1.409
	51.733	-123	0.221	41.736	0.574	1.988
	Average			**53.151**	**0.430**	**2.339**

Specifically, the intensity for the (111) plane increases significantly with 10% Ce doping, indicating enhanced crystallinity and possibly higher atomic density in these planes. Analysis shows that undoped Ag_2Te has crystallite sizes ranging from 28.142 nm to 78.151 nm, dislocation densities from 0.164 × 10^{-3} $lines/nm^2$to 1.263 × $10^{-3}lines/nm^2$, and micro-strain from 1.398 × 10^{-3} to 5.019 × 10^{-3}. With 5% Ce doping, the crystallite sizes range from 31.014 nm to 77.992 nm, dislocation densities from 0.164 × $10^{-3}lines/nm^2$ to 1.040 × $10^{-3}lines/nm^2$, and micro-strain from 1.401 × 10^{-3} to 4.554 × 10^{-3}. For 10% Ce doping, the crystallite sizes range from 39.764 nm to 77.518 nm, dislocation densities from 0.166 × 10^{-3} $lines/nm^2$ to 0.632 × $10^{-3}lines/nm^2$, and dislocation densities from 1.409 × 10^{-3} to 3.436 × 10^{-3} lines/nm². Analysis shows that undoped Ag_2Te has an average crystallite size of 50.778 nm, dislocation density of 0.633 × 10^{-3}lines/nm²and micro-strain of 3.118 × 10^{-3} lines/nm². With 5% Ce doping, these parameters improve to 51.679 nm, 0.559 × 10^{-3}lines/nm², and 2.964 × 10^{-3}, respectively. Further enhancement is observed with 10% Ce doping, resulting in an average crystallite size of 53.151 nm, dislocation density of 0.430 × 10^{-3} and micro-strain of 2.339 × 10^{-3}.The increase in crystallite size, coupled with the decrease in micro-strain and dislocation density, suggests that cerium doping improves the structural quality of Ag_2Te thin films, potentially enhancing their properties. The higher intensities of the doped samples' diffraction peaks imply better crystallinity and possibly lower defect densities, which are beneficial for applications requiring high-quality crystalline materials.

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(b) Variation of structural properties with deposition time

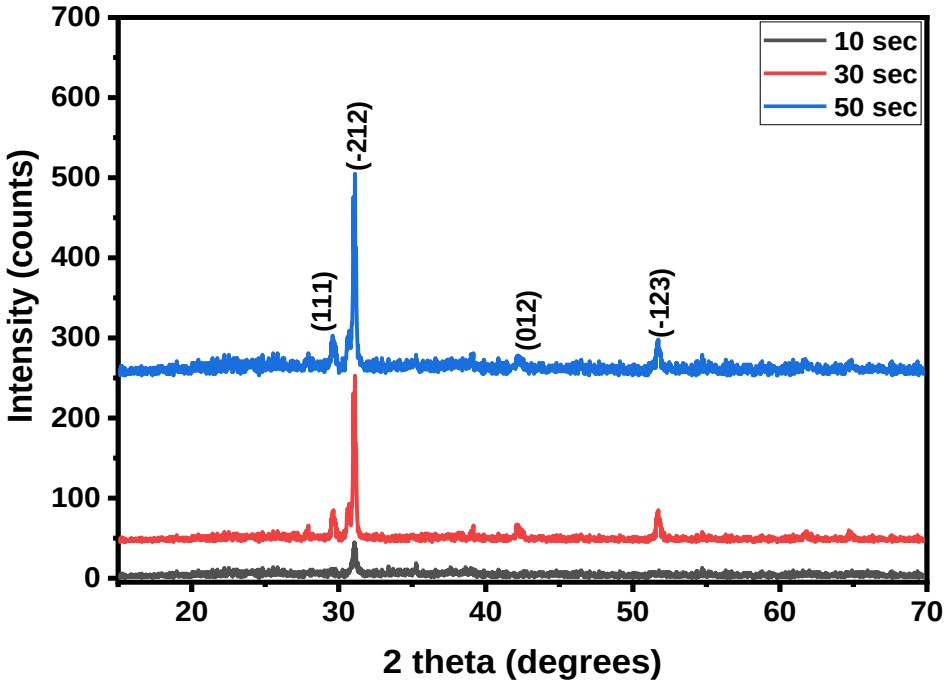

Figure 3: Diffractogram of cerium doped Ag_2Te deposited under different deposition time

Figure 3 shows the diffractogram of cerium doped silver telluride thin films deposited at different time of deposition. The diffractogram in figure 3 and table 5 provide detailed insights into the structural parameters of cerium-doped Ag_2Te thin films deposited under different deposition times. The deposited cerium doped Ag_2Te corresponding to the JCPDS file number 01-081-1985 and known mineralogically as Hessite. The XRD patterns reveal distinct peaks corresponding to various crystallographic planes, indicating the monoclinic phase of Ag_2Te. The intensity of the diffraction peaks varies with the deposition time, with longer deposition times resulting in higher peak intensities, suggesting improved crystallinity. Specifically, the (-212) plane shows a significant increase in intensity with increased deposition time, indicating enhanced atomic density in these planes.

Table 5: Structural parameters of cerium doped Ag_2Te thin films deposited at different time

Doping Level	**2 Theta (°)**	**hkl**	**FWHM (°)**	**Crystallite Size (nm)**	**Dislocation Density $\times 10^{-3}$ $lines/nm^2$**	**Micro-strain (ε)$\times 10^{-3}$**
10 seconds	31.065	-212	0.217	39.677	0.635	3.407
	Average			**39.677**	**0.635**	**3.407**
30 seconds	29.622	111	0.229	37.534	0.710	3.773
	31.068	-212	0.146	58.994	0.287	2.292
	42.225	-312	0.271	32.873	0.925	3.058
	51.722	-123	0.212	43.574	0.527	1.905
	Average			**43.244**	**0.612**	**2.757**
50 seconds	29.620	111	0.211	40.652	0.605	3.484

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	31.067	-212	0.156	55.272	0.327	2.446
	42.244	-312	0.240	37.044	0.729	2.712
	51.724	-123	0.203	45.486	0.483	1.825
	Average			**44.613**	**0.536**	**2.617**

For the 10-second deposition time, the average crystallite size is 39.677 nm, dislocation density is 0.635×10^{-3} lines/nm², and micro-strain is 3.407×10^{-3}. For the 30-second deposition time, the crystallite sizes range from 32.873 nm to 58.994 nm, dislocation densities from 0.287×10^{-3} to 0.925×10^{-3} lines/nm², and micro-strain values from 1.905×10^{-3} to 3.773×10^{-3}, with an average crystallite size of 43.244 nm, dislocation density of 0.612×10^{-3} lines/nm², and micro-strain of 2.757×10^{-3}. For the 50-second deposition time, the crystallite sizes range from 37.044 nm to 55.272 nm, dislocation densities from 0.327×10^{-3} to 0.729×10^{-3} lines/nm², and micro-strain values from 1.825×10^{-3} to 3.484×10^{-3}, with an average crystallite size of 44.613 nm, dislocation density of 0.536×10^{-3} lines/nm², and micro-strain of 2.617×10^{-3}.

The table indicates that increased deposition time enhances the structural quality of cerium-doped Ag_2Te thin films by increasing crystallite size, reducing dislocation density, and lowering micro-strain. The higher intensities of the diffraction peaks with longer deposition times imply better crystallinity and potentially lower defect densities, which are beneficial for applications requiring high-quality crystalline materials.

(c) Variation of structural properties with pH

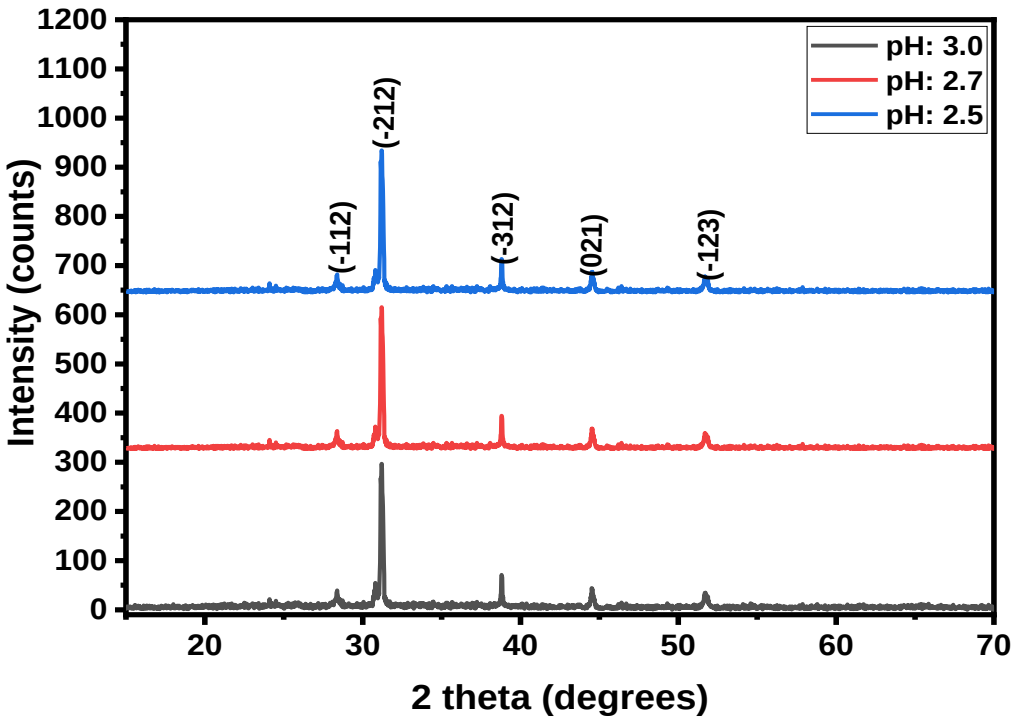

Figure 4: Diffractogram of cerium doped Ag_2Te deposited under different pH value

The diffractogram as shown in Figure 4 and the structural parameters in table 6 provide detailed insights into the structural quality of cerium-doped Ag_2Te thin films deposited under different pH conditions. Ag_2Te corresponds to the JCPDS file number 01-081-1985 and is known mineralogically as Hessite. The XRD patterns reveal distinct peaks corresponding to various crystallographic planes, indicating the monoclinic phase of Ag_2Te. The intensity of the diffraction peaks varies with the pH value of the deposition solution, higher pH values results in lower peak intensities, suggests improved crystallinity. Specifically, the intensity of the (-212) plane shows a significant increase with higher pH, indicating enhanced atomic density in these planes.

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Table 6: Structural parameters of cerium doped Ag_2Te thin films deposited at different pH

pH	**2 Theta (°)**	**hkl**	**FWHM (°)**	**Crystallite Size (nm)**	**Dislocation Density $\times 10^{-3}$ $lines/nm^2$**	**Micro-strain (ε)$\times 10^{-3}$**
3.0	28.383	-112	0.386	22.163	2.036	6.663
	31.208	-212	0.197	43.746	0.523	3.077
	38.809	-312	0.111	79.324	0.159	1.374
	44.548	021	0.220	40.740	0.603	2.345
	51.741	-123	0.283	32.623	0.940	2.543
	Average			**48.411**	**0.906**	**3.705**
2.7	28.376	-112	0.309	27.740	1.300	5.325
	31.208	-212	0.196	43.935	0.518	3.063
	38.809	-312	0.113	77.548	0.166	1.405
	44.550	021	0.226	39.601	0.638	2.412
	51.743	-123	0.295	31.248	1.024	2.655
	Average			**49.741**	**0.661**	**3.264**
2.5	28.376	-112	0.209	41.040	0.594	3.599
	31.208	-212	0.196	43.935	0.518	3.063
	38.809	-312	0.113	77.548	0.166	1.405
	44.550	021	0.226	39.601	0.638	2.412
	51.743	-123	0.295	31.248	1.024	2.655
Average				**50.531**	**0.479**	**2.620**

For the pH 3.0 deposition, the crystallite sizes range from 22.163 nm to 79.324 nm, dislocation densities from 0.159×10^{-3} to 2.036×10^{-3} lines/nm², and micro-strain values from 1.374×10^{-3} to 6.663×10^{-3}, with an average crystallite size of 48.411 nm, dislocation density of 0.906×10^{-3} lines/nm², and micro-strain of 3.705×10^{-3}. For the pH 2.7 deposition, the crystallite sizes range from 27.740 nm to 77.548 nm, dislocation densities from 0.166×10^{-3} to 1.300×10^{-3} lines/nm², and micro-strain values from 1.405×10^{-3} to 5.325×10^{-3}, with an average crystallite size of 49.741 nm, dislocation density of 0.661×10^{-3} lines/nm², and micro-strain of 3.264×10^{-3}. For the pH 2.5 deposition, the crystallite sizes range from 31.248 nm to 77.548 nm, dislocation densities from 0.166×10^{-3} to 1.024×10^{-3} lines/nm², and micro-strain values from 1.405×10^{-3} to 3.599×10^{-3}, with an average crystallite size of 50.531 nm, dislocation density of 0.479×10^{-3} lines/nm², and micro-strain of 2.620×10^{-3}. The results as shown in table 4.9 indicate that higher pH values reduces the structural quality of cerium-doped Ag_2Te thin films by decreasing crystallite size, reducing dislocation density, and lowering micro-strain. The lower intensities of the diffraction peaks with lower pH values imply better crystallinity and potentially lower defect densities, which are beneficial for applications requiring high-quality crystalline materials.

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CONCLUSION

Thin films of silver telluride (Ag_2Te), and cerium-doped silver telluride (Ce: Ag_2Te) were successfully deposited on fluorine-doped tin oxide (FTO) glass substrates using the electrodeposition technique. The precursors used for the deposition included aqueous solutions of silver trioxonitrate (V), cerium tetraoxosulphate (VI) tetrahydrate, and tellurium (IV) oxide, which served as sources of Ag, Ce, and Te, respectively. Ethylene diamine tetra acetic acid (EDTA) was employed as a complexing agent, while tetraoxosulphate (VI) acid was used to adjust the pH of the electrolyte bath. Cerium ions were incorporated as dopants into Ag_2Te matrices. Deposition parameter such as dopant concentration (5% and 10%), pH and time were systematically optimized to study their effects on the film structural properties.

Structural properties obtained from X-ray diffraction (XRD) revealed that Ag_2Te crystallized in the monoclinic phase. Cerium doping led to enhanced peak intensities and reduced peak broadening, indicating improved crystallinity. Crystallite sizes increased with doping and optimized deposition parameters: from 39.68 to 53.15 nm. Dislocation densities correspondingly decreased from 0.91×10^{-3} to 0.43×10^{-3} while micro-strain values also reduced, confirming enhanced crystal quality.

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