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# Influence of angle deposition on the properties of ZnTe thin films prepared by thermal evaporation

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ABSTRACT

Thin films of ZnTe were deposited at angles of 0°, 20°, 40°, 60° and 80° by thermal evaporation. The chemical, structural, morphological, optical, and photocurrent properties of ZnTe thin films were investigated. The elemental composition of the films was investigated by energy dispersive x-ray spectroscopy (EDX) and x-ray photoelectron spectroscopy (XPS). EDX and XPS analyses showed that at lower angles (0° and 20°), the deposited films were Te-rich, at 40°, the deposited film was nearly stoichiometric; and at higher angles (60° and 80°), the deposited films were Zn-rich. X-ray diffraction (XRD) analysis showed that all films were polycrystalline. X-ray diffraction patterns showed that lower-angles-deposited films had an extra peak at $2\theta = 36.47°$ that belongs to Te element. Atomic force microscopy analysis revealed that the surface roughness of films was increased by increasing the deposition angle from 0° to 80° because shadowing effect raised due to an oblique angle. It was observed that higher-angles-deposited films (ZnTe-60°, and ZnTe-80°) showed less transmittance and high reflectance compared to lower-angles-deposited films because of high metallic Zn content in these films. Current-voltage (I-V) measurements showed that nearly stoichiometric (ZnTe-40°) film showed better photocurrent response compared to non-stoichiometric films (ZnTe-0°, ZnTe-20°, ZnTe-60°, and ZnTe-80°).

## 1. Introduction

The II-VI compounds are direct bandgap semiconductors and find a wide range of applications in solid-state electronic devices like light emitting diodes, photodetectors and photovoltaic cells [1–3]. Zinc Telluride (ZnTe) belongs to II-VI compounds family with a band gap of 2.20–2.26 eV [3]. Thin films of ZnTe are used as a back contact in CdTe solar cells because the valence band offset between p-type CdTe and p-type ZnTe is less than 0.05 eV [4,5]. Moreover, ZnTe crystal has good sensitivity in the green spectral region (2.26 eV) that makes it an attractive host for the fabrication of optoelectronic devices. Specifically, it is used for light emitting diodes because its emission wavelength matches well with the maximum sensitivity of the human eye [2–5]. The control of elemental composition, defects, and impurities during films fabrication is very important to get better performance of devices.

A number of deposition techniques, including thermal evaporation, molecular beam epitaxy, hot wall epitaxy, RF and DC sputtering ionic layer adsorption reaction and closed space sublimation are used to prepare the ZnTe thin films [3,6,7]. Every deposition technique has its own merits and limitations. Thermal evaporation technique is the most commonly used for the preparation of ZnTe thin films due to its simplicity, scalability, and reproducibility to deposit onto large substrates [6,7].

In thermal evaporation, the growth of a thin film proceeds three processes: the sublimation of the source material into vapors, the transport of the vapors from the source material to the substrate surface, and the condensation of vapors to form a thin film [8–10]. The II-VI compounds dissociate into their components during thermal evaporation. The equation of dissociation of II-VI compounds is given as [9,10]:

$$A^{II}B^{IV}(S) \rightarrow A^{II}(g) + \frac{1}{2}B_2^{IV}(g) \quad (1)$$

The existence of molecular species $A^{II}B^{IV}$ (g) in the vapor state is not completely ruled out, but the evidence strongly favors the elemental species [8–10]. From mass spectroscopic investigations of the vapor species of II and VI elements over II-VI compounds, it appeared that the dominant vapor species of II and VI elements are in the monoatomic and diatomic molecules, respectively [9,11]. The total pressure ($P$) over the solid II-VI compound is equal to the sum of the partial pressures of dissociative elements [10].

$$P = P_{II} + P_{IV} = P_{II} + KP_{II}^{-2} \quad (2)$$

where $P_{II}$ and $P_{IV}$ are the partial pressures of II and VI elements, respectively, and $K\ (=P_{II}^2 . P_{IV})$ is the equilibrium constant. At any temperature, there will be a minimum pressure ($P_{min}$), which corresponds

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to the condition [12]:

$$P_{II} = 2P_{IV} = 2^{1/3}.\ K^{1/3} \quad (3)$$

Under this condition, the vapor has just the composition of solids, and as the result, stoichiometric sublimation occurs [10–12]. It is reported that thermally evaporated ZnTe films are always Te-rich [3,13,14]. During thermal evaporation, the molecules transport from the source material to substrate surfaces. This transportation is governed by the kinetic theory of gases [15,16]. The molecules collide during evaporation and change their direction [16]. The change in the composition of the fabricated ZnTe film from the source material may be due to collisions between the Zn atoms and $Te_2$ molecules in the vapor phase. The atomic and molecular masses of Zn and $Te_2$ differ from each other. Hence, they will deflect at different angles during a collision.

Here, we deposited the ZnTe films at different angles to study the effect of collisions between Zn atoms and $Te_2$ molecules, during transport on the elemental composition of the films, and also investigated the factors that affect the structural, morphological, optical, and photocurrent properties of the ZnTe films.

## 2. Experimental details

ZnTe thin films were deposited on unheated fused silica, tantalum, and single crystal silicon substrates at angles of 0°, 20°, 40°, 60° and 80° by thermal evaporation. The schematic diagram of angular deposition is shown in Fig. 1. ZnTe thin films deposited at 0°, 20°, 40°, and 60° and 80° angles were named as ZnTe-0°, ZnTe-20° ZnTe-40°, ZnTe-60°, and ZnTe-80°, respectively. The source material was ZnTe powder (Aldrich 99.99% purity) and was evaporated from a molybdenum boat. The thermal evaporation was carried out in a Leybold L560 unit at a base pressure of $9 \times 10^{-6}$ Pa. The distance between the substrate holder and the molybdenum boat was 35 cm. The thickness of the films was determined by a surface profilometer. ZnTe films deposited on tantalum substrates were used for XPS analysis. ZnTe films deposited on single crystal silicon were used for structural analysis. Similarly, ZnTe films deposited on fused silica used for EDX and AFM analyses and as well as for optical and photocurrent measurements. The chemical composition of the films was studied by x-ray energy dispersive spectroscopy (EDX) performed in a JEOL JSM-6610 scanning electron microscope (SEM) and by x-ray photoelectron spectroscopy (XPS) performed in a Thermo Scientific Escalab 250Xi spectrometer equipped with a monochromatic Al Kα (1486.6 eV) x-ray source. All samples were etched with 2 keV $Ar^+$ ion beam for 10-s prior to XPS analysis. The structural properties were studied by x-ray diffraction using a Bruker D2 Phaser diffractometer with Cu Kα radiation. The surface morphology of the films was examined using atomic force microscope (Veeco Innova diSPM) and the surface of the films was probed with antimony-doped silicon tip that had radius 10 nm and oscillated at its resonant frequency of 300 kHz. The electrical properties were measured using van der pauw geometry (Ecopia HMS 3000). The optical properties were measured by a Jasco V-570 spectrophotometer. The photocurrent of all the films was determined by its current-voltage (I-V) characteristics under dark and light illumination. A Keithley 238 source meter and a xenon lamp with a light illumination intensity of 150 $W/m^2$ were used as the electrical analysis system.

## 3. Results and discussions

### 3.1. Chemical analysis

Fig. 2 represents the EDX spectra of ZnTe films deposited at different

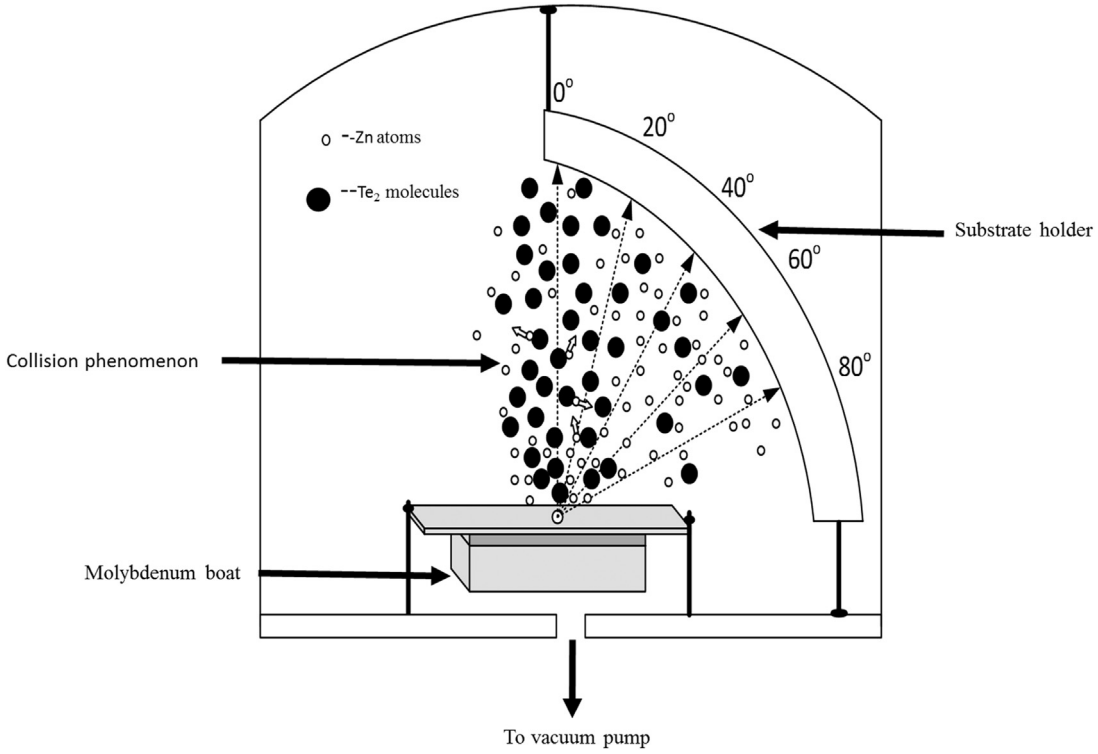


**Fig. 1.** Schematic diagram of angular deposition of ZnTe films.