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## Review on metal telluride thin films

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### ABSTRACT

The main objective of this review paper is to study the preparation of metal telluride thin films using various deposition techniques. A series of experiments were carried out in order to obtain metal telluride thin films by using different precursors. Literature survey indicated that the obtained films were considered as the best candidate for use in electric and optoelectronic devices.

**Keywords:** telluride, thin films, chalcogenide, solar cells, electrodeposition.

### INTRODUCTION

Tellurium is rare element and located in the Group 6 of the Periodic table. Metal telluride is an important semiconductor material with the formula M-Te (M=metal such as Cu, Ni, Pb, Zn, Sn and etc). These compounds have many favorable properties such as direct band gap, high absorption coefficient and good transparency in the visible region. These properties are used in many applications such as radiation detectors, electro-optic modulators, solar cells, infrared detector, optical windows and lenses.

Overview:

Nanomaterials such as binary and ternary compounds are of great interest due to their electrical, mechanical and optical properties. These compounds have been grown by different techniques and were considered as a good candidate in the solar cells application. It is because of the band gap energy (Table 1) suitable to cope with the maximum of solar spectrum and has high absorption coefficient as well. On the other hand, the band gap falling in visible region helps in the development of light emitting diodes, photo detectors and blue green laser.

Table 1: Band gap energy of metal telluride thin films

Thin films	Band gap (eV)	Deposition method
CdTe [1]	1.45	Chemical bath deposition
Ag <sub>2</sub> Te [2]	1.34	Thermal evaporation
Cd-Se-Te [3]	1.4	Electro deposition
CdSe <sub>0.73</sub> Te <sub>0.27</sub> [4]	1.53	Electro deposition
CdZnTe [5]	1.54	Electro deposition
Hg <sub>x</sub> Cd <sub>1-x</sub> Te [6]	1.29	Thermal evaporation
In <sub>2</sub> Se <sub>2.5</sub> Te <sub>0.5</sub> [7]	1.45	Thermal evaporation

Closed space sublimation technique was used to deposit ZnTe films on glass substrate. Shah and Mahmood[8] have reported that the as-deposited films were doped with silver using low concentrated silver nitrate with different immersion times such as 5, 10, 20, 25 and 30 minutes. In the structure analysis, the crystallite size of as-deposited films was 23 nm, which increased to 48 nm after silver doping for 30 minutes. On the other hand, experiment results show that the silver doped thin films indicate low resistivity of the order of 1000 Ω-cm along

with a change in the carrier concentrations and mobility as well at room temperature. In photovoltaic cell applications, low resistive ZnTe is needed as a back contact for cadmium telluride films, which is important for the functionality of these cells. Alamri[9] studied the various X-ray diffraction (XRD) patterns of CdTe films under different substrate temperatures using closed space sublimation. Researcher concludes that the films grown at 335 °C were a highly preferred (111) orientation and the (111) texture coefficient reduced when the substrate temperature increased.

Silver telluride thin films were member of the I-VI group. They are classified as non-magnetic, self-doped and degenerate semiconductor. Ag<sub>2</sub>Te films were prepared using thermal evaporation by Pandiaraman and co-workers[2] on glass slides. These films have been polycrystalline with monoclinic structure. The high absorption coefficient of films of about 10<sup>4</sup>cm<sup>-1</sup> from the analysis of transmittance spectra confirms that silver telluride has direct band gap. On the other hand, the effects of annealing process on silver telluride films have been studied by Gnanadurai et al [10]. The annealed films undergo a structural phase transition at around 410K during heating and at around 380K during cooling. They summarize that the resistivity of silver telluride thin films decreases with decrease in film thickness in their research findings. Other thin films such as Ag<sub>2</sub>SeTe [11] and ZnTe[12] were prepared by using thermal evaporation method were reported by other workers.

The preparation of Zn<sub>1-x</sub>Cd<sub>x</sub>Te thin films was reported by Becerril et al[13]. These films were grown on glass substrate at room temperature, in a radio frequency sputtering system. The results reveal that the band gap reduced from 2.27 to 2.22 eV as the cadmium was incorporated into the ZnTe lattice. The effect of radio frequency power and work pressure conditions of sputtered CdTe films were studied by Camacho-Espinosa et al [14]. They claim that the crystallinity was increased with the increase of radio frequency power, and to reduce with the increase of the work pressure. In Chen et al[15] works, they investigate the crystal quality of CdTe films prepared at various substrates such as glass, silicon and aluminum oxide. The obtained films which prepared on glass and silicon had a better crystal quality than the aluminium oxide in XRD patterns. On the other hand, field emission scanning electron microscopy (FESEM) analysis shows a continuous and dense morphology of films on glass and silicon substrates. Pawlewicz et al [16] prepared sputtered CdTe films in thickness of 2-10 μm using systematically selected deposition parameters. Crystal structure was varied from hexagonal to cubic as indicated in XRD analysis. They also reported that the deposition conditions greatly influence the grain size in the polycrystalline films.

The preparation of bismuth telluride films and (Bi<sub>x</sub>Sb<sub>1-x</sub>)<sub>2</sub>Te<sub>3</sub> films using electro deposition method was reported by Li et al., [17] and Frari et al., [18] respectively. This method has a relatively simple procedure and allows the deposition of thermoelectric films onto electrodes of variable geometry. The obtained films are commonly used for thermoelectric devices such as thermoelectric generators and coolers. For example, bismuth telluride films are applied in thermoelectric refrigeration at room temperature. On the other hand, relatively well-oriented of CdSe<sub>x</sub>Te<sub>1-x</sub> films were obtained at a potential of -1.12 V versus SCE (saturated calomel electrode) by Bouroushian et al [4]. These films consist of spherical grains larger than 1 μm in diameter based on the scanning electron microscopy (SEM) studies. Meanwhile, ternary thin films ZnCuTe films were prepared on fluorine doped tin oxide substrate by Pistone et al [19] using electro deposition method. The obtained results indicate that these films have a direct gap of 1.7eV with p-type transition materials.

CdTe films with thickness in the range 0.2-10 μm were deposited on glass substrates using hot wall epitaxy technique by Ribeiro et al [20]. The films are polycrystalline with a high preferential (111) orientation in XRD studies. Meanwhile, these films have pyramidal grain shapes with a size of 0.3 μm as shown in atomic force microscopy (AFM) and SEM studies. On the other hand, the molecular flow in the hot wall epitaxial system has been studied by Venkatachalam et al [21] using the Monte Carlo technique for the deposition of CdTe films. In their reports, they proposed to formulate the optimum conditions for enriched Cd and Te thin films, so that highly efficient CdTe solar cells can be fabricated at low cost. According to literature survey, this method has been used for the production of various metal telluride films by many researchers[22,23].

CdTe films were deposited on commercial glass substrates of 1 mm thickness by Suresh [24] using the chemical bath deposition. The films show polycrystalline with cubic structure as indicated in XRD patterns. Similar report also could be observed by other researchers (Sotelo-Lerma et al[25], Laxman et al[1]). The grains are more uniformly distributed over the substrate surface in SEM investigation. Deivanayaki et al [26] have reported the effect of annealing process on CdTe films under 350, 400 and 450 °C. In optical properties studies, the band gap for the as-deposited and annealed films was 1.5 and 1.4 eV, respectively. On the other hand, a significant increase in the XRD peak intensities for the annealed films could be seen.

Successive ionic layer adsorption and reaction (SILAR) have been used by many workers to deposited thin films onto various substrates such as glass, titanium dioxide (TiO<sub>2</sub>), fluorine doped tin oxide (FTO), zinc oxide (ZnO)

nanowires[27]. Studies on size dependent properties of CdTe films deposited using SILAR method was reported by Ubale and Kulkarni [28]. The obtained results show that decrease in band gap, electrical resistivity, activation energy have been observed as the films thickness was increased from 96 to 312 nm. On the other hand, Ubale et al [29] have prepared CdTe films have direct band gap of 1.41 eV using SILAR method. They also claimed that the resistivity is found to be of the order of 411000  $\Omega$ -cm at 523 K with activation energy of 0.2 eV.

Spray pyrolysis was used to prepare CdTe thin films by many scientists [30,31]. The results of Hall's effect indicated that the prepared films were p-type [32,33] indicating they can be used for fabrication of hetero-junction solar cell [34,35]. In XRD patterns, the obtained films have polycrystalline structure with hexagonal structure.

#### Disadvantages of tellurium

In terms of power conversion efficacy, metal telluride thin films such as cadmium telluride has lower efficiency levels (Table 2) if compared to silicon based solar cells. Furthermore, the high toxicity level of these films is another problem. Recently, concerns that the risks of cadmium telluride films have been raised due to the environmental issue of cadmium. Nowadays, scientists are work hard in order to find out new materials that could be replaced toxicity materials such as cadmium. Lastly, as researchers know that tellurium is considered as the rarest material found in earth crust. As results, it causes the limitation of the use of tellurium to prepare metal telluride thin films. In future, researchers should emphasize on the metal sulfide (Table 3) and metal selenide (Table 4) thin films. Somereasons aresulfur and seleniumavailable anywhere in the world, and more cheaper if compared to tellurium.

**Table 2: Power conversion efficacy for metal telluride thin films**

Thin films	Conversion efficacy (%)	Deposition Method
CdSe <sub>0.6</sub> Te <sub>0.4</sub> [36]	0.43	Chemical bath deposition
CdSe <sub>0.6</sub> Te <sub>0.4</sub> [37]	0.64	Electrodeposition
CdTe [38]	0.136	Chemical bath deposition
CdS <sub>0.5</sub> Te <sub>0.5</sub> [38]	0.023	Chemical bath deposition
CdTe [30]	3.4	Spray pyrolysis

**Table 3: Metal sulphide thin films**

Thin films	Deposition Method
FeS <sub>2</sub> [39]	Chemical bath deposition
Bi <sub>2</sub> S <sub>3</sub> [40]	Chemical bath deposition
MnS <sub>2</sub> [41]	Chemical bath deposition
SnS <sub>2</sub> [42]	Successive ionic layer adsorption and reaction
MnS [43]	Chemical bath deposition
NiS [44]	Successive ionic layer adsorption and reaction
CuS [45]	Chemical bath deposition
CoS[46]	Chemical bath deposition
Ni <sub>4</sub> S <sub>3</sub> [47]	Chemical bath deposition
PbS [48]	Successive ionic layer adsorption and reaction
FeS [49]	Chemical bath deposition
CdS [50]	spray pyrolysis
Cu <sub>2</sub> S[51]	Chemical bath deposition
ZnS [52]	Chemical bath deposition
SnS [53]	Chemical bath deposition

**Table 4: Metal selenide thin films**

Thin films	Deposition Method
SnSe [54]	Chemical bath deposition
CuSe [55]	Thermal evaporation
PbSe [56]	Chemical bath deposition
InSe[57]	Electrodeposition
ZnSe [58]	Chemical bath deposition
NiSe[59]	Chemical bath deposition
CdZnSe [60]	Photoelectrochemical deposition
CuInSe <sub>2</sub> [61]	thermal evaporation
(CdS) <sub>0.8</sub> Se <sub>0.2</sub> [62]	thermal evaporation
CdIn <sub>2</sub> Se <sub>4</sub> [63]	potentiostatic deposition
CuIn(S,Se) <sub>2</sub> [64]	Spin coating
CuZnSnSe [65]	vacuum evaporation

## CONCLUSION

Several telluride of metal have been described by many scientists in this review paper. The important of CdTe films have grown significantly because of they were used in the field of solar cell application.

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