

Characteristics of pulse plated ZnTe films

K. R. Murali · P. Richards Rajkumar

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Abstract Stoichiometric films of ZnTe are electrodeposited on stainless steel and conducting glass substrates from an aqueous solution consisting of ZnSO₄ (50 mM), TeO₂ (17 μM) and H₂SO₄ to maintain a pH of 2.5. Structure, morphology, composition, and optical are studied using XRD, SEM, EDAX and optical transmittance spectroscopy. The films are composed of small crystallites (50 nm) with cubic crystal structure. The films were polycrystalline in nature with peaks corresponding to the cubic phase. Direct band gap of 2.30 eV was observed. XPS studies indicated the formation of ZnTe. EDAX measurements were made on the films and it was found that there was a slight excess of Te. AFM studies indicated a surface roughness of 15 nm and a crystallite size of 10–50 nm.

1. Introduction

Types II–VI compounds present a wide range of optical and electrical properties, making them an important class of material-competing candidates for silicon and other materials in photovoltaic conversion and optoelectronic applications. It is well-known that the structure and other properties of thin films depend strongly on deposition method and substrate temperature, and evaporation method and deposition rate. ZnTe, being a wide and direct band gap material, is attractive in optoelectronic devices in the visible region. It has been prepared by various methods, including thermal evaporation [1–4], sputtering [5–7], epitaxial growth [8], direct combination of Zn and Te in quartz ampoule [9] and

electrodeposition [10–12], and has been studied. The thermal evaporation is considered to be a standard and reproducible method for most of thin film materials. In this paper, we report the optical and structural properties of ZnTe films prepared by pulse electrodeposition technique. To our knowledge this is the first time report on pulse deposited ZnTe films.

2. Experimental methods

ZnTe films were deposited on conducting glass and stainless steel substrates using an aqueous solution of ZnSO₄ (50 mM), TeO₂ (17 μM) and H₂SO₄ to maintain a pH of 2.5. The duty cycle was changed in the range of 10–50 %. The deposition was carried out at room temperature and at a potential of −0.9V(SCE). The thickness of the films (estimated by the weighing method) after a deposition time of 60 min varied in the range of 1.0–2.0 μm. Structure of the films was studied by X-ray diffraction(XRD).using Cu-Kα radiation, the optical transmission, between 400 and 2200 nm, was recorded on UV–VIS–NIR spectrophotometer, while AFM was recorded using Molecular imaging system. XPS studies were made using a VG ESCALAB MKII spectrometer with MgKα radiation, EDAX measurements were recorded with the help of SEM attached with an EDAX microanalyser.

3. Results and discussion

Structural studies were made using x-ray diffraction studies. Fig. 1 shows the XRD patterns of the films deposited at different substrate temperatures. Peaks corresponding to (111), (220) and (311) orientations of the cubic phase are observed.

K. R. Murali · P. R. Rajkumar (✉)
Electrochemical Materials Science Division, Central
Electrochemical research Institute, Karaikudi–630 006

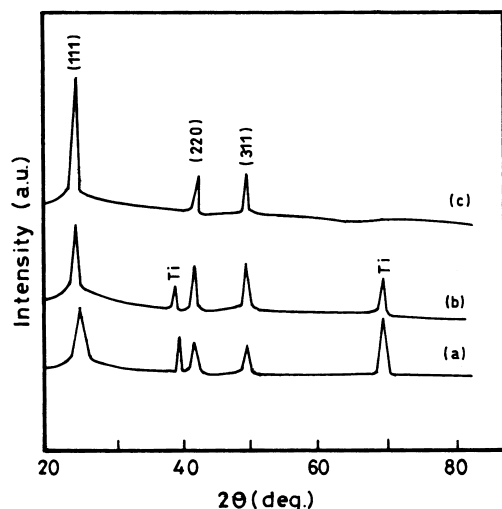


Fig. 1 X-ray diffractogram of ZnTe films deposited at different Duty cycles (a) 10% (b) 30% (c) 50%

As the substrate temperature increases, the (111) orientation peak increases in intensity and the width of the peaks also decrease as the temperature of the substrate temperature increases. The crystallite size was calculated using Scherrer's equation [13]. The crystallite size was found to increase from 40 nm–100 nm as the substrate temperature increases. The lattice constant was estimated to be 0.610 nm for the films deposited at a substrate temperature of 90°C. It is observed that the lattice constant is close to the value reported in the ASTM data [14].

Optical absorption spectrum of the films deposited on conducting glass substrates were recorded in the wave-

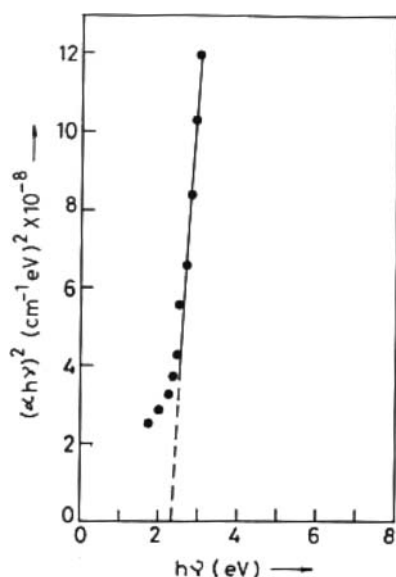


Fig. 2 $(\alpha h\nu)^2$ vs $h\nu$ plot of ZnTe film deposited at a duty cycle of 50%

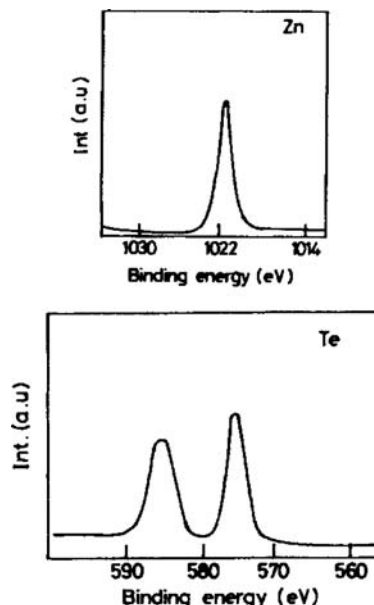


Fig. 3 XPS spectrum of ZnTe films deposited at a duty cycle of 50%

length ranges 400–800 nm. Fig. 2 shows the $(\alpha h\nu)^2$ vs $h\nu$ plot for the films deposited at a substrate temperature of 90°C. The plot is linear indicating the direct band nature of the films. Extrapolation of the linear region to the energy axis indicated a band gap of 2.30 eV. This value is similar to the value obtained on single crystals [15].

X-ray photoelectron spectroscopic indicated the formation of ZnTe. Fig. 3 shows the XPS spectrum of ZnTe films deposited at 90°C. XPS studies indicated the Zn 3p and Te 3d peaks, which are in close agreement with the reported values for Zn and Te in ZnTe. Depth profiling was carried out at a sputter rate of 10 nm/min, this indicates a uniform distribution of Zn and Te throughout the thickness. EDAX measurements yielded a composition of 49.5% Zn and 51.5% Te (Fig. 5).

Atomic force microscopic studies indicated that the crystallite size increases as the duty cycle increases. Fig. 6 shows the AFM pictures of the films deposited at different duty cycles. At lower duty cycles, the flux of ions are low, since the time for which the potential is applied (ON time) is low and the time for which the potential is not applied (OFF time) is higher. Due to the higher OFF time compared to ON time, sufficient time is available for the nuclei to form and the crystallites to relax before the next pulse and larger grains for lower duty cycle compared to higher duty cycle, where the ON time is higher than the OFF time. The crystallite size is found to vary from 10–50 nm as the duty cycle decreases from 50–10%.

The surface roughness of the films also decrease with increase of duty cycle. The RMS roughness values of the

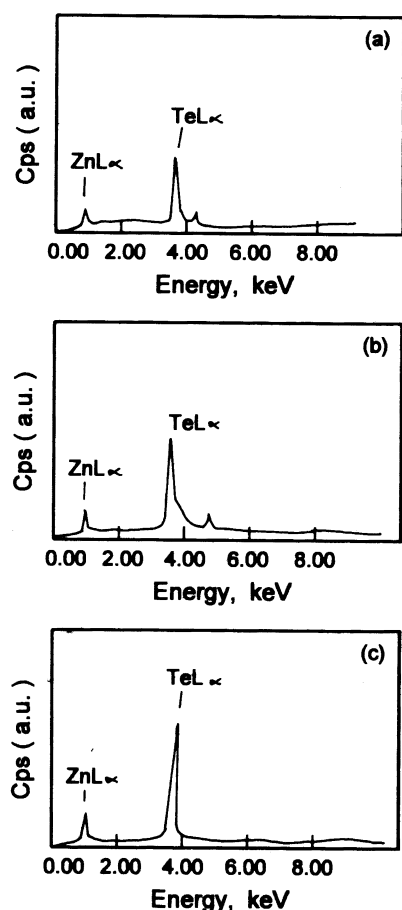


Fig. 4 EDAX spectrum of ZnTe films deposited at different duty cycles (a) 10% (b) 30% (c) 50%

surfaces were found to decrease due to the evenly distributed ZnTe deposits on the surface. The average peak to valley distance decreased as more of the substrate surface is covered as a consequence of the lateral growth of the composite particles during the initial stages of deposition. The increase in the RMS roughness values of the films after 30 min to approximately 15 nm can be attributed to growth of the particles. As particles grew in height, they also spread laterally so that the RMS roughness remained approximately constant as the average thickness of the films increased for deposition times longer than 30 min, with the final RMS roughness values of 15 nm for the films deposited at a duty cycle of 50%.

4. Conclusion

The results of this investigation indicate that films with crystallite size of 10–50 nm can be grown with a surface roughness around 15 nm.

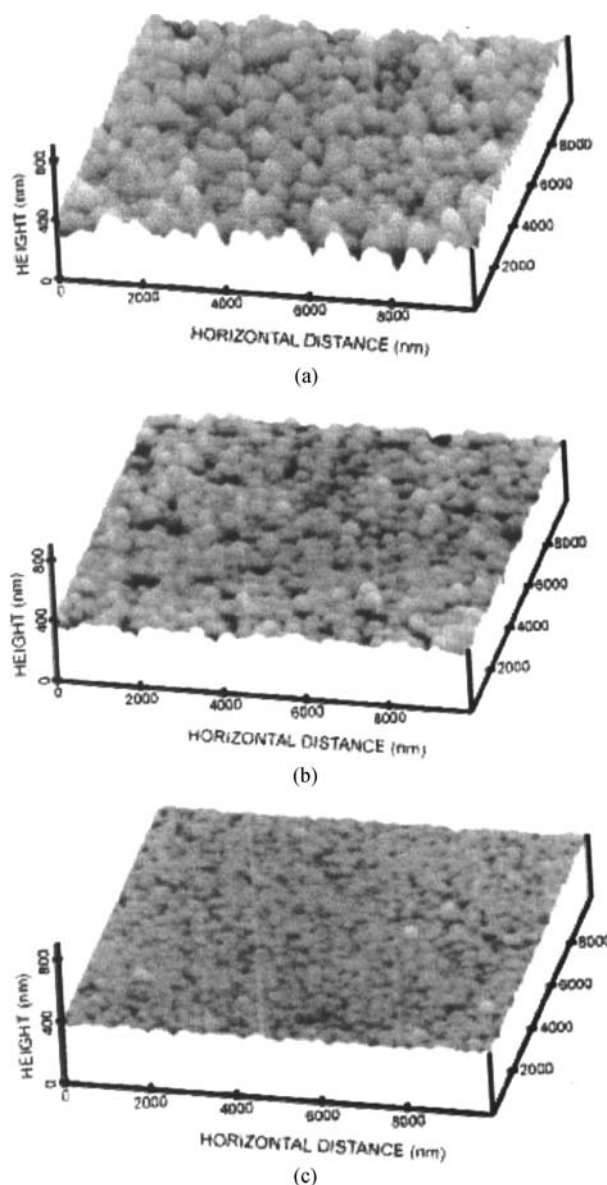


Fig. 5 AFM image of ZnTe films deposited at different duty cycles (a) 10% (b) 30% (c) 50%

References

1. Brown, H.M., Brown, D.E., Can. J. Phys. **50**, 2512 (1972)
2. Chu, T.L., Chu, S.S., Firtz, F., J. Appl. Phys. **59**, 1259 (1986)
3. Mondal, A., Chaudhuri, S., Pal, A.K., Appl. Phys. A **34**, 81 (1987)
4. Kisiel, A., Pukowska, B., Tomkowicz, W., Thin Solid Films **34**, 399 (1976)
5. Bllakhder, H., Debbagh, F., Outzourhit, A., et al., Sol. Energy Mater. Sol. Cells **45**, 361 (1997)
6. Gulino, D.A., J. Vac. Sci. Technol., A **43**, 509 (1986)
7. Gessert, T.A., Sheidom, P., Li, X., Dulavy, D., Niles, D., Proceeding of 26th IEEE Photovoltaics Specialists Conference, 923 (1997)

8. Matsumoto, T., Ishida, T., J. Cryst. Growth **67**, 35 (1984)
9. Pal, U., Saha, S., Chaudhuri, A.K., Rao, V.V., Banerjee, H.D., J. Phys. D: Appl. Phys. **22**, 65 (1989)
10. Basol, B.M., Kapur, V.K., Thin solid films, **165**, 237 (1988)
11. Michael Neumann Spallart and C.Königstein, Thin solid films, **265**, 33 (1995)
12. Mahalingam, T., John, V.S., Rajendran, S., Ravi, G., Sebastian, P.J., Surface Coatings Technol, **155**, 245 (2002)
13. Guiner, A., Theorie et Technique de la Radiocristallographie, Editions Dunod, Paris, 1969
14. ASTM x-ray powder data 15-746, 19-1482, 4-554
15. Sato, K., Adachi, S., J. Appl. Phys, **73**, 926 (1993)