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Morphology of CdTe thin films and CdTe/GaAs heterojunction

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Abstract

This paper is a study of films of CdTe pure and doped with both atomic percentages concentrations of Al and Sb (0.5% and 2.5%) of about 0.5μm thickness. These films of CdTe were prepared by a thermal evaporation technique deposited on glass substrate and both types of GaAs were deposited on wafers (p- and n-type). The substrate temperatures films were at room temperature (RT) and 423K. The energy dispersive X-ray analysis (EDX) technique was used to assess the role of the deposition parameters on the evolution of the films structure. Regarding the percentage comprised of prepared films, the outcomes data analysis for using this approach to scan the films prepared at various deposition conditions coincided with theoretical percentage values of Cd, Te, Al and Sb in pure and doped CdTe thin film. The heterojunction of CdTe/p- and n-GaAs was prepared and the surface morphology was investigated. The surface morphology of CdTe thin films was grown on glass and both types of GaAs were performed using nanoscanning electron microscope. In general, the results showed that the average grain size for doped film with Al and Sb is more than for pure films. All films are homogenous and the average grain size of film doped with Sb is higher than for pure films. For pure CdTe/p-GaAs heterojunctions, as the substrate temperature increases, the average grain size of CdTe thin films are enlarged and become more homogenous. The analysis of the findings of the present study suggests that these films can be used for fabrication of a variety of optoelectronic devices.

Keywords: Surface morphology, CdTe thin films, CdTe/GaAs heterojunction.
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1. Introduction

II-VI compound semiconductors and their alloys have been the subject of extensive research for several decades. The broad range of band gaps and high absorption are main reasons for making these semiconductors good candidates for fabrication of a wide range of optoelectronic devices.

Among the II-VI compound semiconductors is cadmium telluride. The semiconductor properties of this material are suitable for application in solar cells and many

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other devices such as detectors for the infrared and X-ray [1-4], because they have a direct band gap (approximately, 1.5 eV) with a high absorption coefficient (around 105 cm-1) [5,6]. Therefore, a thin film of CdTe is a viable candidate for low cost and high efficiency solar cell since these films possess suitable optical properties by having the right band gap, high absorption coefficient and easiness of film deposition [7, 8].

It is known that the quality of these optical devices is strongly influenced by the deposition techniques used for the preparation of component films. Accordingly, various methods have been used to prepare CdTe films [9–11].

Irrespective of the growth process, the grain size and surface morphology of CdTe films are two essential parameters that influence the performance of these films. It is known that the grain boundary barrier height in polycrystalline CdTe thin films can be changed by modifying either the grain size or by diffusing appropriate impurities along the grain boundaries [12-14]. Therefore, studying the microstructure and morphology evolution in polycrystalline CdTe films is important to assess the effect of these parameters on the performance of devices employing these layers.

The nanoscanning electron microscopy (NanoSEM) examination for CdTe films deposited by thermal evaporation method clearly reveals the strong dependence of their surface morphology and structure of the growth film on the type of the substrate.

In this work we investigate the surface morphology of CdTe thin films and CdTe/p-and n-GaAs heterojunctions which are deposited at substrate temperatures RT and 454K, each with a dopant percentage concentration of Al and Sb.

2. Experimental procedure

The films of CdTe are deposited using a thermal evaporation technique under 10^{-6} Torr vacuum pressure. Different deposition conditions were introduced to prepare the films such as substrate temperatures (T_s=RT and 423K) and dopant percentage concentrations of Al for n-type and Sb for p-type thin film. The films' thickness of about 0.5 μm were grown on corning glass 7059 and both types of (100) GaAs (n-and p-). The composition of the prepared films was determined using energy dispersive X-ray analysis (EDX) with the use of a Jeol JSM5600 equipment .The EDX scan results coincide with theoretical percentage values of Cd, Te, Al and Sb in undoped and doped CdTe thin film [15] .Surface morphology of prepared thin films and heterojunctions were studied using nanoscaning electron microscope (NanoSEM) A Nova 600.

3. Results and discussion

NanoSEM has been used to investigate the structural changes for the pure and doped CdTe thin films with 0.5% and 2.5% Al and Sb deposited at room temperature (RT).The surface morphology of pure and doped CdTe thin films deposited by employed thermal evaporation on (100) p-GaAs wafer at RT and 423 K were also studied using NanoSEM - A Nova 600.

A polycrystalline film with uniform and homogenous distribution of grain size was clearly observed for pure CdTe thin film deposited at RT on glass as shown in Fig. 1 (a), while the increase in the grain size is detected for doped CdTe thin film with 0.5% Al as shown in Fig.1 (b). This finding was represented by high growth, more grain necking which is scattered non-homogenously all over the film surface.

A similar trend is also seen in Fig. 1 (c). These observations comply with a more uniform distribution of the grain size for film doped with 2.5% Al. In addition, they highlight the evidence of recrystallization as detected in the film structure shown in Fig. 1 (c) in comparison with the image of the film doped with 0.5% Al as illustrated in Fig. 1 (b). However it is less homogenous than pure film as seen in Fig. 1 (a).

The outcomes analysis of these data leads to a general conclusion for CdTe film doped with Al possesses higher average grain size in comparison with structure feature of pure CdTe film.

Fig. 1 (d) shows the morphology image of CdTe thin film doped with 0.5% Sb. The image is clearly a homogenous film with an increase in average grain size in comparison with pure films (Fig.(1a)). A noticeable change in CdTe film morphology was monitored upon the increase in dopant percentage of Sb to 2.5%. Accordingly, markedly change in structure of CdTe thin film doped with 2.5% Sb was revealed with high average grain size and homogenous distribution all over film surface as shown in Fig. 1 (e). In general, all films in Fig. 1 (a,d and e) are homogenous and the average grain size of film doped with Sb is higher than for pure film.

Fig. 2 (a and b) shows the NanoSEM images of the surface of pure CdTe/p-GaAs heterojunction deposited at RT and 423 K. Regarding CdTe/p-GaAs heterojunction deposited at RT as shown in Fig 2 (a), one notices no adsorbed colloidal particles as indicated by a presence of white boulders on the film surface. There was also a remarkable difference in grain sizes with their uniformity distributed all over the film surface. An elevation in substrate temperature caused an enlargement in average grain size of CdTe thin film and the film becomes more homogenous as depicted in Fig. 2 (b).

Fig. 3 (a-d) markedly reveals a change in the structure of doped CdTe thin film (0.5 and 2.5% Al) deposited on p-GaAs at RT and 423 K. For 0.5% Al doped CdTe/p-GaAs heterojunction deposited at RT Fig. 3 (a), there was a uniform growth at the film surface and there was a clear presence of microstructure throughout the film surfaces. As the substrate temperature increased, the heterojunctiom as displayed in Fig. 3 (b) had higher grain size, more necking, and is less porous in comparison with heterojunction deposited at RT Fig. 3(a). Figure 3 (b) also demonstrates that the grain took a geometrical uniform shape with sharp edges. The morphology of the doped (2.5% Al) CdTe/p-GaAs heterojunction deposited at RT is shown in Fig. 3 (c). This figure presents more homogenous and larger average grain size than that displayed in Fig. 3 (a). On the other hand for heterojunction deposited at 423 K as depicted in Fig. 3 (d), the grain took a clear geometrical uniform shape and is less porous than that for CdTe doped 0.5% Al CdTe/p-GaAs heterojunction at 423 K as seen in Fig. 3 (b) and undoped CdTe/p-GaAs heterojunction deposited at 423 K as shown in Fig. 2 (b).

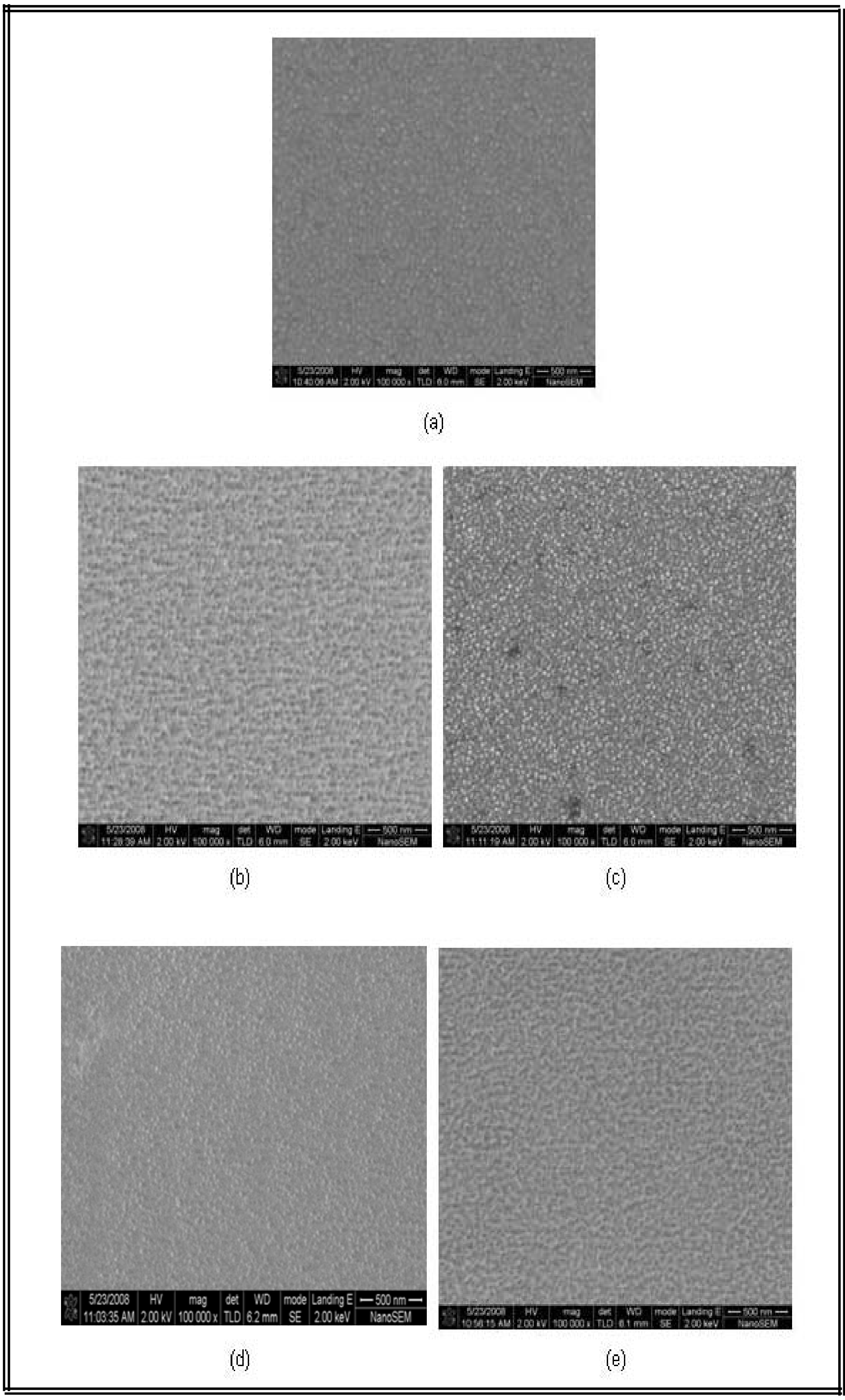
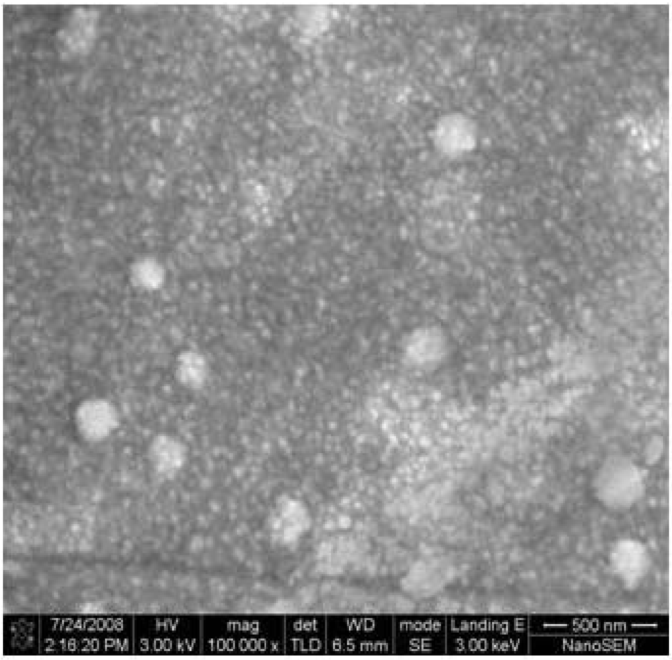
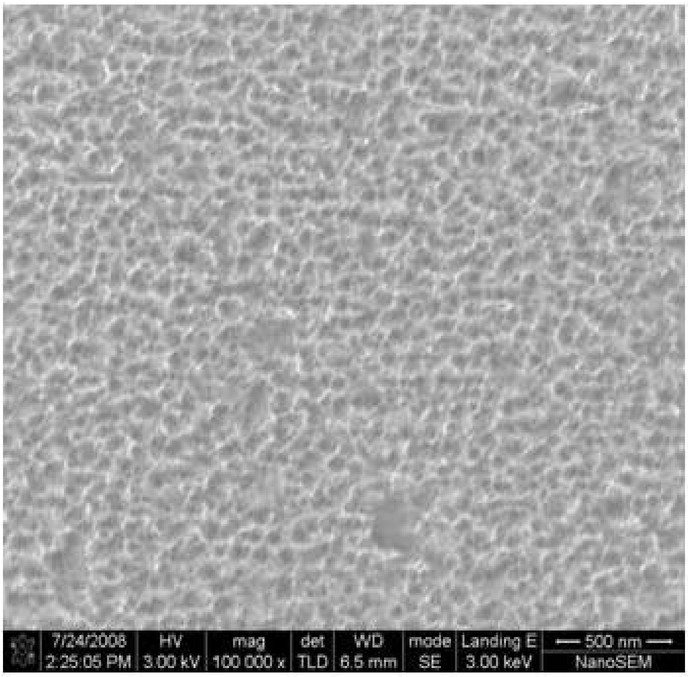


Fig. 1 (a-e): Nanoscanning electron microscopy images of (a) pure CdTe thin film, and doped with (b) 0.5% Al (c) 2.5% Al (d) 0.5% Sb (e) 2.5% Sb deposited on glass at RT.



(a)



(b)

Fig. 2 (a & b): NanoSEM images of pure CdTe/p-GaAs heterojunction deposited at (a) RT (b) 423 K.

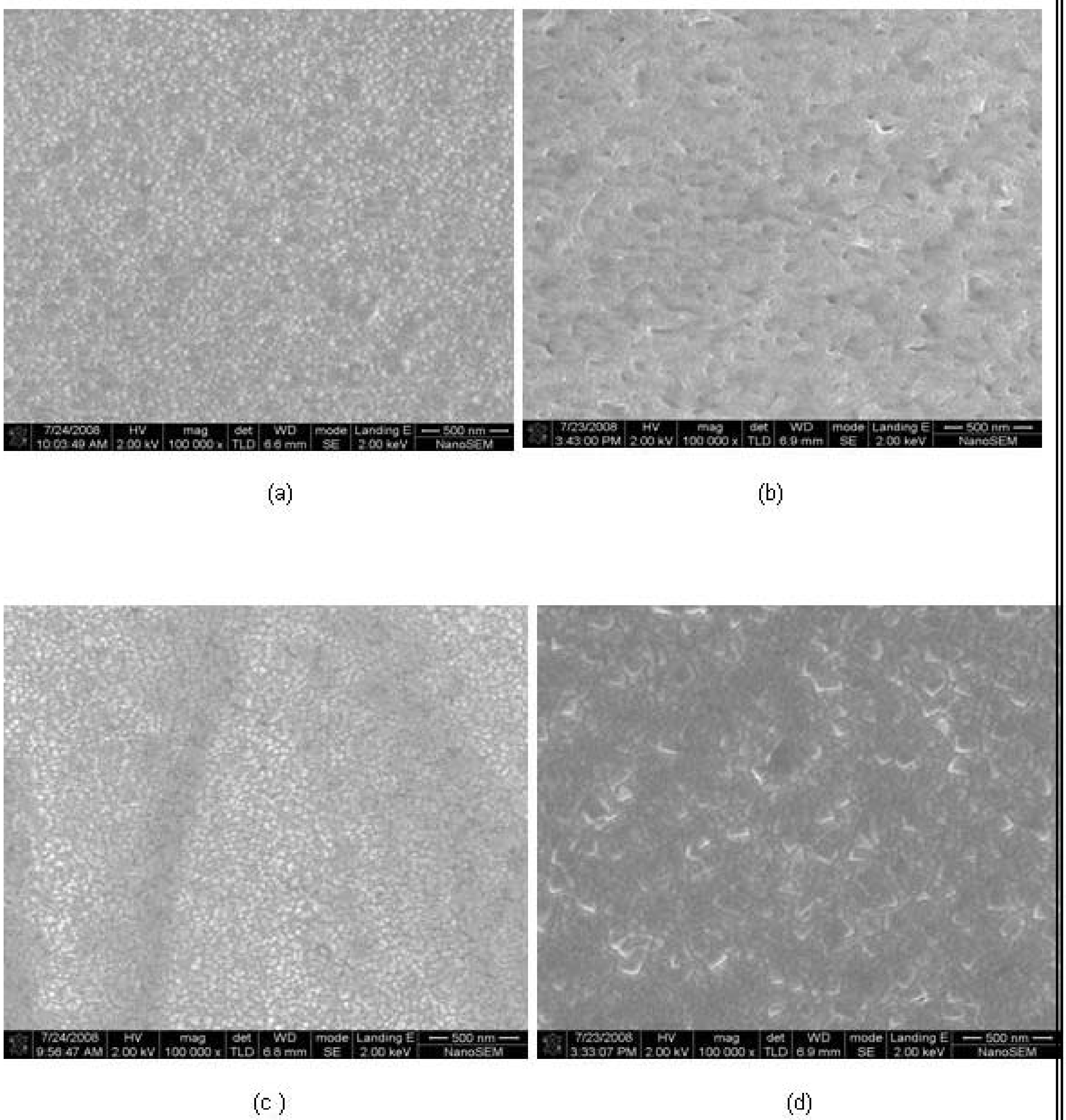


Fig. 3 (a-d): NanoSEM images of CdTe/p-GaAs heterojunction doped with 0.5% Al deposited at (a) RT (b) 423 K. and with 2.5% Al deposited at (c) RT (d) 423 K.

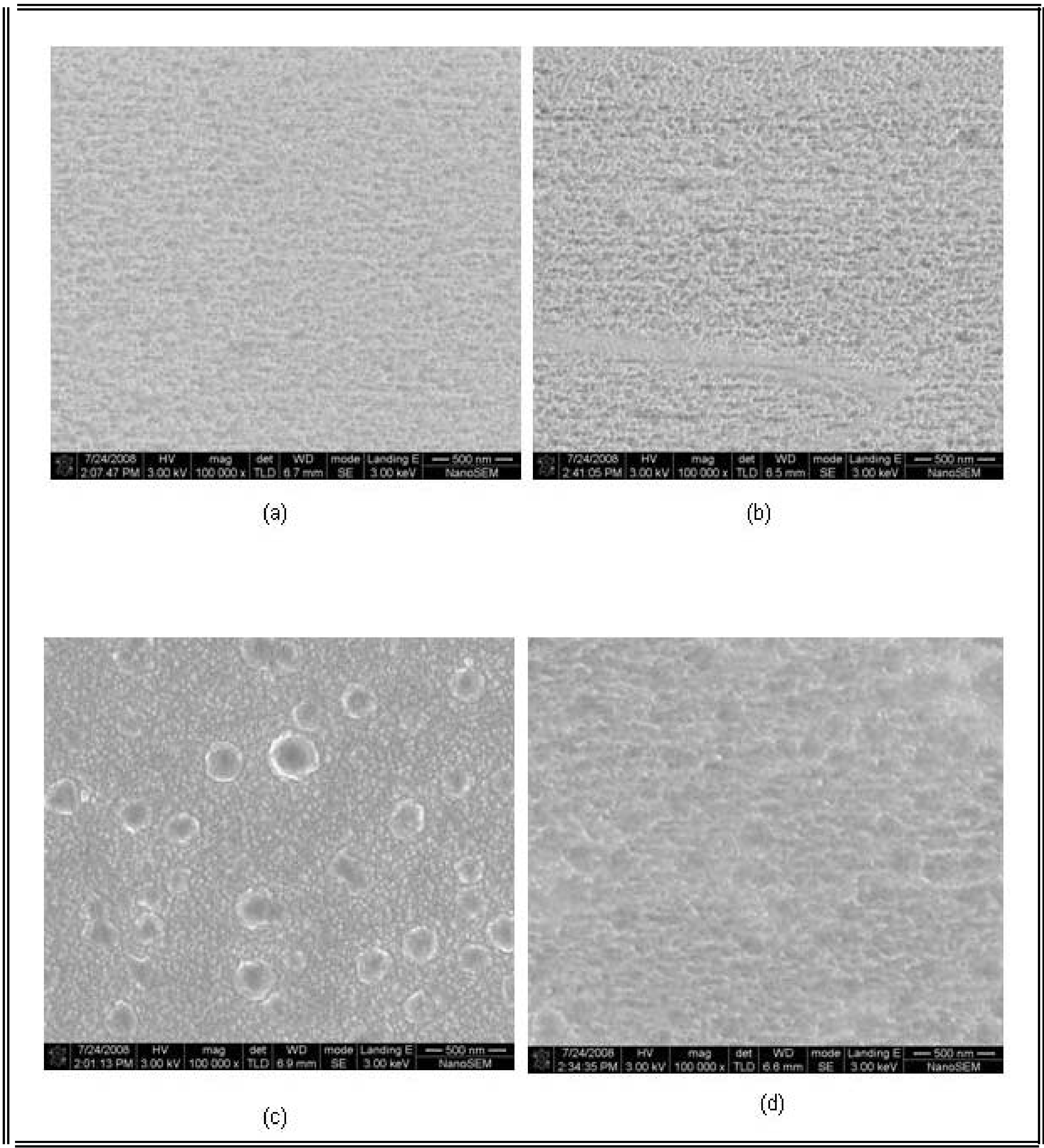


Fig. 4 (a-d): NanoSEM images of CdTe/p-GaAs heterojunction doped with 0.5% Sb deposited at (a) RT (b) 423 K. and with 2.5% Sb deposited at (c) RT (d) 423 K.

Fig. 4 (a-d) illustrates the morphology of doped (0.5 and 2.5% Sb) CdTe/p-GaAs heterojunction deposited at RT and 423 K. (Fig. 4 (a)) depicts the heterojunction doped with 0.5% Sb deposited at RT . The outward appearance of the film structure is homogenous with more necking and the average grain size is greater than that shown for heterojunction doped with 0.5% Al (Fig. 3 (a)). However, the average grain size of the films doped with 0.5% Sb heterojunction deposited at 423 K (Fig. 4 (b)) becomes greater than those deposited at RT, but less than shown for the heterojunction films doped with 0.5% Al at 423 K (Fig. 3 (b). The morphology of doped (2.5% Sb) CdTe/p-GaAs heterojunction deposited at RT is shown in Fig. 4 (c). As it can be seen from this figure, there are no adsorbed colloidal particles exposed as white-grey boulders on the surface, and there was a remarkable difference in average grain size, which was greater than that shown for pure CdTe/p-GaAs heterojunction deposited at RT (Fig. 2 (a)). Also, this image has average grain size less than that for 0.5% Sb CdTe/p-GaAs heterojunction as seen in Fig.(4 a) and it is more homogenous than both pure and doped (0.5%Sb) CdTe/p-GaAs heterojunctions as demonstrated in Figs. (2a & 4a) respectively. The surface morphology for doped 2.5% Sb CdTe/p-GaAs heterojunction deposited at 423 K (Fig. 4 (d)) shows higher growth and average grain size than heterojunction deposited at RT (Fig. 4(c)). The same is also true for both pure (Fig. 2 (b)) and doped with 0.5% Sb CdTe/p-GaAS heterojunctions deposited at 423 K (Fig. 4 (b)). However the homogeneity of these heterojunction were less than those depicted for pure (Fig. 2(b)) and 0.5% Sb doped CdTe/p-GaAs heterojunctions as shown in Fig. 4 (b).

General outcomes from the analysis of the structural feature of the images displayed at Figs.(3) and (4) indicate that the average grain size for 2.5% Al-doped CdTe/p-GaAs heterojunction deposited at 423 K is greater than the films doped with 2.5% Sb deposited at the same temperature. The morphology of film doped with Sb is less uniform compared with the homogeneity of 2.5% Al doped CdTe/p-GaAs heterojunction.

4. Conclusion

The pure and doped CdTe thin films with both percentages of Al and Sb were grown on glass and (100) GaAs p- and n-types wafers substrate using a thermal evaporation method. Film composition and deposition parameters were investigated for their bearing on film surface morphology properties. The results showed the following:

All films are homogenous and the average grain size of film doped with Sb is higher than for pure film

In general, the average grain size for doped film with Al and Sb is more than for pure film.

For pure CdTe/p-GaAs heterojunctions, as the substrate temperature increases, the average grain size of CdTe thin film are enlarged and become more homogenous.

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