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Properties of CdTe thin films prepared by hot wall epitaxy

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Abstract. CdTe thin films were grown on different substrates: BaF_2 (111), polished Si (100), SiO_2, bulk CdTe (110) and $Hg_xCd_{1-x}Te$ layers by hot wall epitaxy (HWE). Chosen temperature parameters and technological process of thin film fabrication provided the growth rate of about 0.03 mm/min. The current-voltage characteristics and transmission spectra were measured. X-ray diffraction data (XRD) measurements were carried out as well.

Keywords: CdTe, hot wall epitaxy, thin film.

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1. Introduction

In recent years considerable attention has been given to the growth of CdTe thin films and the control of their properties by different ways. CdTe possesses a wide range of applications ranging from photovoltaic conversion, high energy flux detectors – such as *x*-ray and *g*-ray detectors for elec-tronic and optoelectronic devices [1]. Also, this material is one of the most effective materials for producing solar cells with the efficiency of about 16% and with 90% absorption of incident light [2]. In addition, its close lattice match and chemical compatibility with $Hg_{1-x}Cd_xTe$ ($0 \le x \le 1$) make CdTe an ideal substrate for growing the variable band gap material for IR detectors. On the other hand, CdTe thin films are among the most suitable materials for passivation $Hg_xCd_{1-x}Te$ based detectors. In this application, CdTe films have such advantages as reliability during deposition onto $Hg_xCd_{1-x}Te$ layers and constant zero resistance area product values in the different points of array surface [3, 4]. The current deficiency of availability of high quality, large area bulk CdTe substrates is generally considered as a major problem for various applications. This problem can be overcome by growing CdTe on an alternative substrate which could then serve as a buffer layer for the subsequent synthesis [5].

Therefore, there is a large amount of investigations that are carried out to improve the existing CdTe thin film growth methods for manufacturing the perfect thin films with reproducible thickness and morphology.

2. Experimental results and discussion

In this article, we reported initial results for the growth of CdTe films on bulk CdTe, BaF_2, SiO_2 and Si substrates using hot wall epitaxy (HWE). The hot wall epitaxy (HWE) technique has been extensively applied to narrow gap IV–VI compounds. It has been very successful in producing heterostructures for laser and photovoltaic detector fabrication [6]. Important feature of this method is the growth conditions that can be close to the thermodynamic equilibrium. Such conditions are provided by quasi-close growing area and by the appropriate choice of three temperature parameters. These parameters are T_{SOURCE}, T_{WALL}, $T_{SUBSTRATE}$, and they help to keep the constant temperature gradient in the growing reactor (Fig. 1) [6,7].

The films were deposited on the several types of substrates: cleaved BaF_2 (111), polished Si (100), SiO_2 and CdTe (110). To investigate the properties of fabricated films as passivating material for infrared technology, we carried out CdTe film deposition on $Hg_{1-x}Cd_xTe$

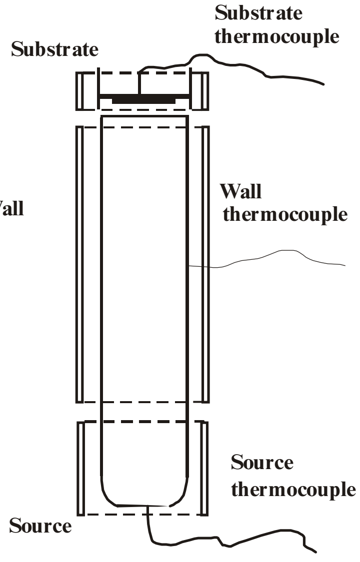

Fig. 1. The hot wall epitaxy reactor construction.

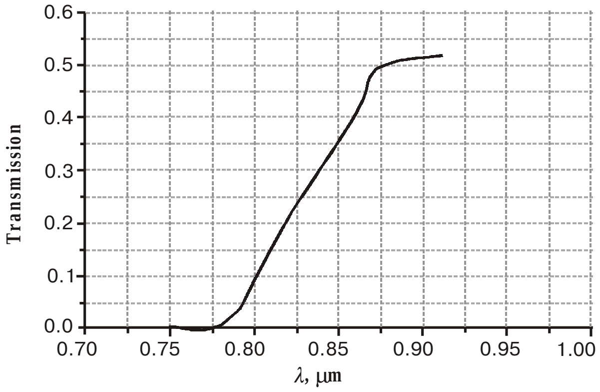

Fig. 2. CdTe film transmission spectra near the cut-off region at 300 K.

layers. The substrate material choice was made considering the lattice parameters, chemical properties and surface morphology to get films with different strain and defects structure and thus with different physical properties. Silicon substrates are used because of their transparency to IR radiation and their availability as large area wafers with higher structural perfection. Before inserting into the growth reac-tor the Si and SiO_2 substrates were redoxed in HF solution for 1 minute. Monocrystalline CdTe and $Hg_{1-x}Cd_xTe$ layers were etched in HCl solution for 1 minute as well. Then all the substrates, except for $Hg_{1-x}Cd_xTe$ layers, were preheated to the temperature 393 K in the vacuum of 10^{-2}Torr for final cleaning of the substrate surface. For heteroepitaxial processes, the lattice mismatch between substrate and grown film is a serious problem preventing growth of high-quality films.

To get the films of the same morphology, but with different thicknesses, the different deposition time and the same temperature parameters were used. The main goal of the investigation was to fabricate CdTe thin films with a perfect crystal structure at relatively low substrate temperatures. The following temperature parameters were used: $T_{SOURCE} = 653$ K; $T_{WALL} = 673$ K; $T_{SUBSTRATE} =$ = 323–393 K. The values of these parameters were chosen from the known data [7–15] and optimized experimentally. The deposition process was carried out under the high vacuum ($\sim 10^{-7}$ Torr).

Two methods to identify the films thickness were used: optical method (investigation of the transmission spectra interference in 0.5…15 μm spectral range at 300 K) and mechanical (using an electronic profilometer). These investigations identified that chosen temperature parameters allowed to get CdTe thin films with the growth rate of 0.03…0.05 μm/min.

Current-voltage characteristics (I–V) and transmission spectra of the obtained CdTe films were investigated. The structural properties were examined by XRD.

Transmission spectra of CdTe thin films (Fig. 2) were investigated in the spectral range of 0.2 to 1.2 μm with Shimatsu UF–3100 device. Exploration of the spectral range from 0.8 to 10 μm was carried out using IKS–31 device indicated that the cut-off wavelength of the obtained films lies within 0.8–0.85 μm with the transmission coefficient of about 55–60 %. These results corresponds to the known data for CdTe thin films prepared by other methods.The calculations showed that the band gap for the obtained CdTe thin films is equal to $E_g =$ = 1.48 eV, which is less than for the bulk crystal, and can be related to internal layer strains.

The current-voltage characteristics were carried out to investigate the electrical contact properties of CdTe films. As a contact metals Au and In were used. The contacts were created by the following two methods: the vacuum deposition of evaporated metals and chemical deposition from the solution. It was determined that the

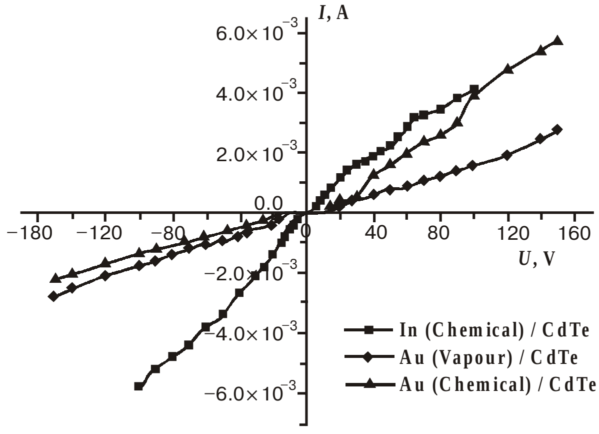

Fig. 3. CdTe film current-voltage characteristics at 300 K.

I–V characteristics of the prepared samples depend on the contact material and contact fabrication method. It was shown (Fig. 3) that In contacts prepared by chemical deposition exhibit the Schottky barrier-like characteristics. The Au contacts were prepared by both methods: chemical and vacuum deposition. It was determined that the contact properties of the Au contacts strongly depend on the contact preparation method. Au contacts formed by chemical deposition from the solution create the Schottky barrier. On the other hand, these Au contacts deposited onto CdTe films in vacuum displayed ohmic properties. Apart from the current-voltage characteristics, the specific resistance was measured. These measurements showed that the specific resistance depends on the contact material and preparation method and lies within $(4\ldots7)\cdot10^4$ Ohm·cm.

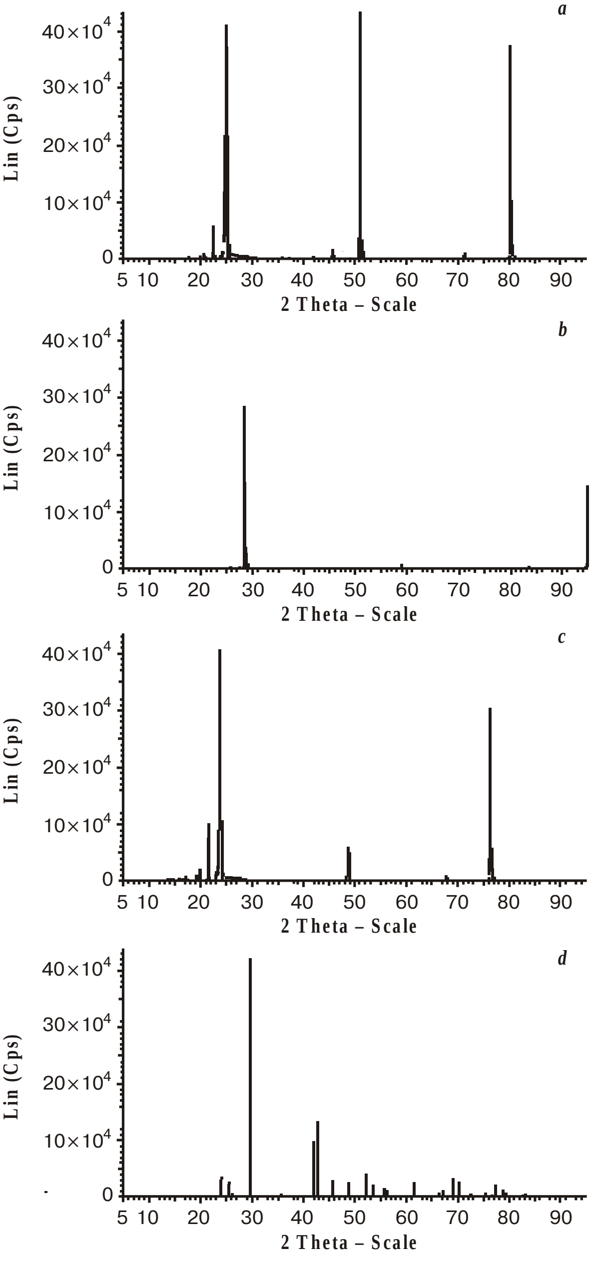

Fig. 4. XRD data obtained for CdTe thin films: *a* – on fresh cleaved BaF_2 (111); *b* – on polished Si (100); *c* – on $Hg_{1-x}Cd_xTe$/CdZnTe; *d* – on polished CdTe (110).

XRD measurements were carried out to make the conclusion of the structural properties. CdTe films prepared on the cleaved BaF_2 substrates had a polycrystalline structure with (111), (211) and (511) orientations (Fig. 4*a*). Such structure can be explained by the damaged BaF_2 surface structure. It is known that cleaved BaF_2 surface is covered with steps and other defects. Thus, despite the rather close lattice parameters (6.48 Å for CdTe and 6.2 Å for BaF_2) the CdTe thin films have polycrystalline structure. XRD data of CdTe films on Si substrate is shown in Fig. 4*b*. In this case, the films have more perfect structural properties with two orientations: (111) and (511). Such difference between the samples prepared on Si and BaF_2 substrates can be explained by the surface perfection of used Si substrate that allowed obtaining high-quality CdTe films despite the large lattice mismatch (about 19 %). Investigations of the crystalline structure of CdTe films deposited on $Hg_{1-x}Cd_xTe$ layers (Fig. 4*c*) have shown that the films have the high quality single crystalline structure with (111) orientation .

3. Conclusions

CdTe thin films were prepared by HWE, which provides the growth conditions that are close to the thermodynamic equilibrium. The films were grown with the next temperature parameters: T_{SOURCE} = 653 K; T_{WALL} = 673 K; $T_{SUBSTRATE}$ = 323–393 K. These parameters provide the growing rate within 0.03…0.05 µm/min. Films obtained have the cut-off wavelength at 0.84–0.85 µm and the absorption coefficient of about 55–60 % outside the fundamental absorption region. The I–V investigations have shown that the contact properties strongly depend on the contact material and contact fabrication method. Chemically deposited In contacts form Schottky barriers and the chemically deposited Au does similary. On the other hand, Au contacts fabricated by the vacuum deposition method form only ohmic contacts. The samples obtained had the specific resistance $(4\ldots7)\cdot10^4$ Ohm·cm depending on the contact material and contact preparation method.

All the samples showed a well-pronounced crystalline structure as it follows from XRD measurements.

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