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SURFACES, INTERFACES, AND THIN FILMS

On the Growth, Structure, and Surface Morphology of Epitaxial CdTe Films

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Abstract—The structure and surface morphology of epitaxial CdTe films grown on glassy substrates with and without compensation with an additional Te vapor source during growth are studied. The optimal conditions of the production of structurally perfect epitaxial films with a pure smooth surface with no inclusions of another phase (T_{so} = 1000–1100 K, T_{su} = 570–670 K) are determined. It is established that, on glassy substrates, the epitaxial films grow via the (111) plane of the face-centered cubic (fcc) lattice with the parameter a = 6.481 Å. By varying the temperature of the main and compensating sources, CdTe films with n- and p-type conductivity are produced.

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1. INTRODUCTION

In the last few years, cadmium telluride (CdTe) films have attracted attention in the context of prospects for producing solar cells and radiation sensors. The advantage of these materials is that they possess high absorption coefficients (>10^5 cm^{-1}) and optimal band gaps (>1.5 eV) [1–3].

The efficiency of such devices heavily depends on the structural quality of the films. Various methods for producing CdTe films have been developed. In recent years, many papers concerned with the fabrication [4–7] and studies of the optical and electrical properties of CdTe films [8–18] have been published. However, only a few comprehensive studies of the specific features of growth, the structure, and the surface morphology have been conducted so far.

It is known that the devices are created in the thin surface layers of crystals. In this context, for the production of high-efficiency solar cells and high-sensitivity radiation detectors, studies of the structure and surface morphology of the films are of scientific and practical interest.

2. EXPERIMENTAL

In this study, we consider the structure and surface morphology of CdTe films grown on glassy substrates by the condensation of molecular beams in vacuum (at a residual pressure of (1–2) × 10^{-3} Pa. The glassy substrates were 15 × 15 × 1 mm in dimensions. For the source we used preliminarily synthesized CdTe compounds.

The films were produced with a UVN-72P3 vacuum setup at substrate temperatures of T_{su} = 300–670 K, with and without the compensation of Te vapor during growth.

The structures of the films were studied by the X-ray diffraction (XRD) technique. The XRD patterns were obtained with a Bruker XRD D8 Advance X-ray setup.

The surface morphology of the films was studied by scanning electron microscopy (SEM) using a JEOL JSM-7600F Field Emission SEM microscope.

The shape and structural characteristics of the CdTe films were analyzed by atomic-force microscopy (AFM) using an NTegra Prima (NTVDT) AFM microscope. The AFM technique is widely used to analyze the microstructural features of film surfaces. This technique provides a means for determining the particle dimensions and shape as well as the topographic features of the surface.

3. RESULTS AND DISCUSSION

By the XRD method, it is shown that the films grown on glassy substrates at a temperature of T_{su} = 300 K are amorphous in structure. An increase in the

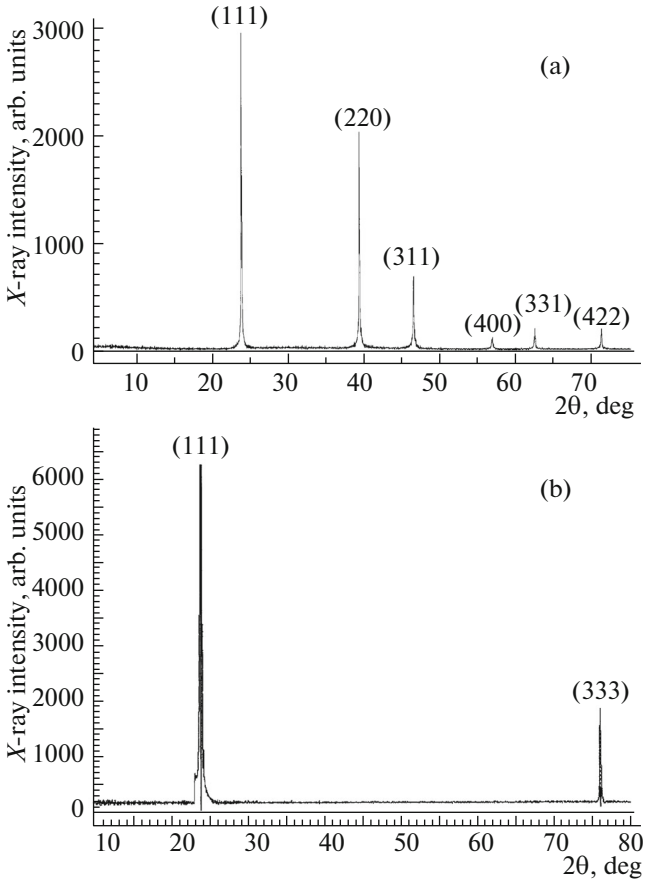

Fig. 1. XRD patterns of CdTe films grown on glassy substrates: (a) a polycrystalline film (T_{su} = 470 K) and (b) an epitaxial single-crystal film (T_{su} = 670 K).

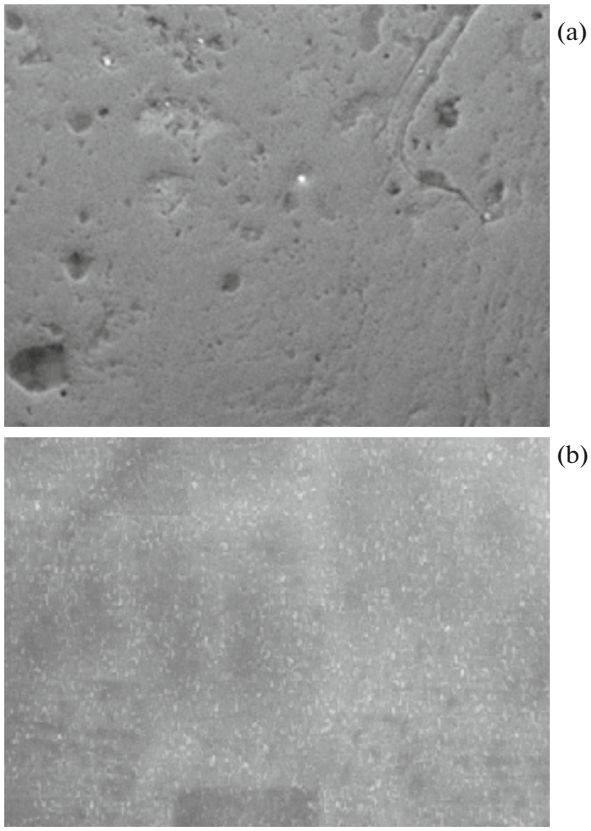

Fig. 2. SEM micrographs of the surface of epitaxial CdTe films produced (a) without and (b) with the compensation of Te.

substrate temperature (≥470 K) brings about the production of cubically structured polycrystalline films (with the lattice parameter a = 6.481 Å) (Fig. 1a). As the temperature is elevated above 570 K, the films start to grow through epitaxial process, and in the XRD patterns of the films produced at 670 K we observe only (111) reflections (Fig. 1b). We determined the particle dimensions of the obtained films, which were found to be 122 nm.

SEM studies made it possible to gain information on the surface morphology of epitaxial CdTe films grown without and with compensation with an additional Te vapor source during growth. The surface was scanned with 16 000-times magnification. The SEM results are shown in Figs. 2a and 2b. From the micrographs shown in Figs. 2a and 2b, it can be seen that, at the surface of the films produced without the compensation of Te, we observe dark aggregates that are indicative of oxidation products formed because of the partial decomposition of CdTe during growth. These aggregates disappear in films grown with the compensation of Te. As a result, films with a pure smooth surface are formed, with no inclusions of the second phase.

By the AFM method, we obtained three-dimensional (3D) images of the surface and the size distributions of particles (histograms) that describe the surface structure of the epitaxial CdTe films produced with and without the compensation of Te vapor during growth (Figs. 3, 4). As can be seen from Fig. 3a, the particle dimensions in the CdTe film produced without the compensation of Te are 0.14–0.7 μm, and the spaces between the particles are 0.6 μm. After Te compensation, the particle dimensions are 0.5–1.0 μm, and the spaces between the particles are 0.5 μm (Fig. 4a). Thus, after compensation, the structure is improved; i.e., the particle dimensions are increased and the roughness is decreased. From the 3D images (Figs. 3b, 4b) and histograms, we determined the distribution of particles in terms of height. The maximum height is found to be ~122 nm, which is in agreement with the XRD results. The 2D and 3D images show that the films produced with the compensation of Te are of higher structural quality.

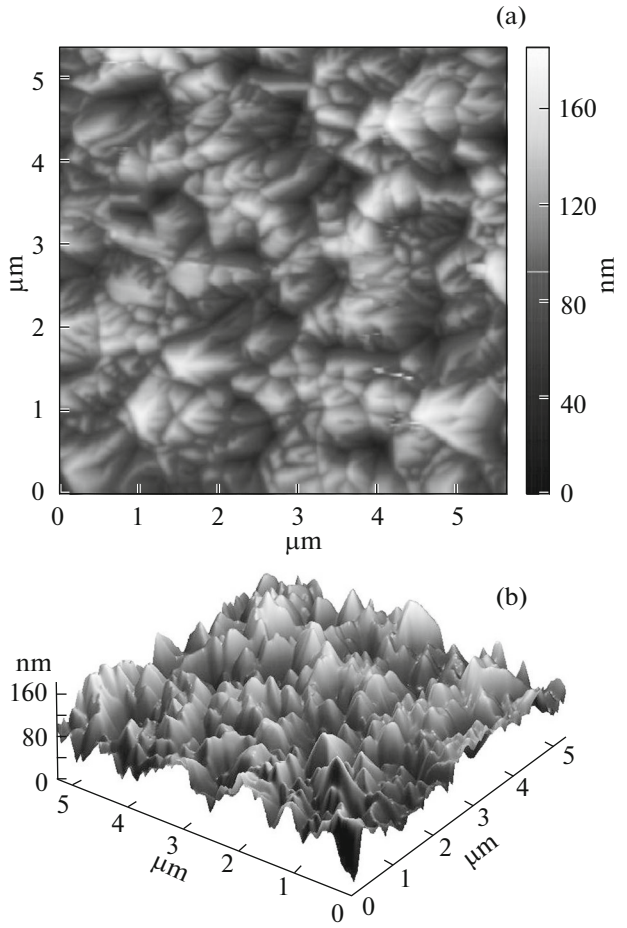

Fig. 3. AFM images of CdTe films produced without the compensation of Te: (a) 2D and (b) 3D images.

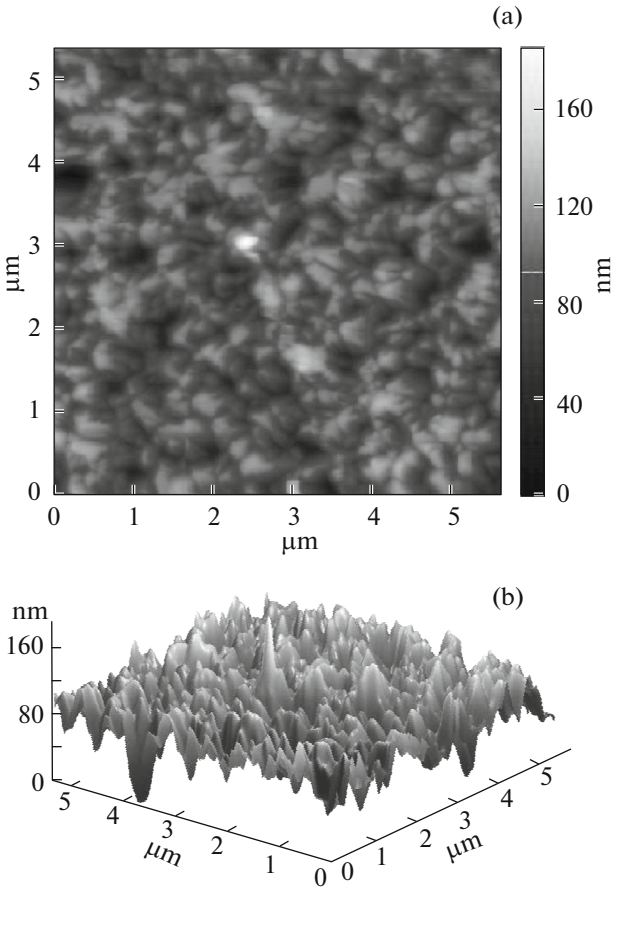

Fig. 4. AFM images of CdTe films produced with the compensation of Te: (a) 2D and (b) 3D images.

4. CONCLUSIONS

By the method of condensation of molecular beams, structurally perfect epitaxial films of CdTe are grown on glassy substrates. The optimal conditions of production of the epitaxial films (T_{so} = 1000–1100 K, T_{su} = 570–670 K) are determined. The films are fcc in structure, with the lattice parameter a = 6.841 Å, and grow via the (111) plane.

The epitaxial films produced with compensation with an additional Te vapor source during growth are of higher structural quality.

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