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from Cd_{1-x}Zn_xTe**

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Recrystallization of ceramic material fabricated from $Cd_{1-x}Zn_xTe$

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INTRODUCTION

Binary and ternary A^mB^n compounds are conventionally grown from melt. This technique is very complicated and requires complex equipment to provide high pressures and high temperatures to grow stoichiometric compositions. New opportunities for designing materials used in the infrared technique and ionizing radiation detectors are opened by advantages in nanotechnology. In particular, difficulties in $Cd_{1-x}Zn_xTe$ (CZT) production can be overcome if melt growth is replaced by ceramic material fabrication from CZT nanopowder of a definite composition. $Cd_{1-x}Zn_xTe$ with various Zn content are traditionally used in infrared optics and as a material for ionizing radiation detectors. Zn concentration in the nanopowders produced by the new vapor deposition technique varies from $x = 0.02$ to $x = 0.1$, including the composition $Cd_{0.9}Zn_{0.1}Te$, which is the most promising as a material for ionizing radiation detectors working at room temperature without cooling.

GOALS OF THIS STUDY

- To produce $Cd_{1-x}Zn_xTe$ nanopowder through vapor deposition.
- To fabricate dense ceramic material from the nanopowder at room temperature.
- To study the effect of annealing on grain growth, phase transitions and some physical properties.

EXPERIMENTAL APPROACH

We developed the vapor deposition technique to produce CdTe nanopowders [1]. The same technique was used in this study to produce $Cd_{1-x}Zn_xTe$ of various compositions. It should be noted that this technique has great advantages in comparison with the traditional melt growth by Bridgman or high pressure vertical zone melting (HPVZM) techniques [2]. First of all, no high pressures are required, in contrast to the melt growth of these compounds, when dissociation below the melting point should be suppressed to reach a stoichiometric composition. Secondly, the temperatures required for evaporation are far lower than those for the melt growth. A synthesized compound is evaporated from a silica boat, driven by helium flow and deposited on a silica substrate. The temperature in the source zone of the evaporation was 800–850°C, the helium flow velocity was 1000–1500 m/min, the temperature in the deposition zone was 540–610°C. These temperature regimes and helium flow velocity are chosen to provide deposition of 10 nm CZT particles (Fig. 1). The composition of the evaporation source and that of the deposited nanopowder is not the same. This is because of a difference between partial pressures of the components and different diffusion coefficients in helium. For example, to obtain the nanopowder of the $Cd_{0.9}Zn_{0.1}Te$ composition, the $Cd_{0.7}Zn_{0.3}Te$ composition of the source was prepared. The problems of variation in chemical composition of II-VI compounds under evaporation are discussed elsewhere [2, 3].

- The ceramics were compacted at room temperature on an Instron machine as described in [4]. Pressures were varied in the range 300–500 MPa, time under load varying in the range 1–10 min.
- The phase analysis was performed on a Siemens D500 diffractometer (Fe K_{α} radiation).
- The crystal texture of the compacted samples was studied using the reflection (Schultz) technique. The tilt-angle range was 0–50°, the azimuth and the polar angle steps were 5°, and the exposure time at each point was 3 s. The background and the defocusing were taken into account when processing the obtained data.
- The light-transmission spectra were recorded within the wavelength range of 2.5–25 μ m using a Specord 75 IR spectrophotometer.



Fig. 1. TEM image of the $Cd_{0.9}Zn_{0.1}Te$ nanopowder

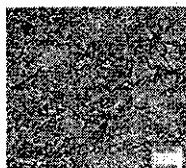


Fig. 2. As-compacted $Cd_{0.9}Zn_{0.1}Te$ ceramics produced from the nanopowder

The compacted $Cd_{0.9}Zn_{0.1}Te$ ceramics were annealed in a sealed silica tube at 300°C for 10–40 min. Grain structure becomes more homogeneous with a narrow Gauss distribution, which has the extreme at 40- μ m grain size (Fig. 3) that occupies 50% of the sample.

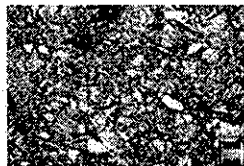


Fig. 3. $Cd_{0.9}Zn_{0.1}Te$ ceramics after annealing at $T = 300^\circ C$ for $t = 40$ min

RESULTS

Pole figures of $Cd_{0.9}Zn_{0.1}Te$ ceramics made of the nanopowder

The textural analysis showed that the compacted CZT ceramics had the two-component texture: $\langle 100 \rangle$ axial texture and weak cubic texture (Fig. 4a). However, both are less pronounced than in the CdTe ceramics fabricated from nanopowder [4]. As the annealing time increases, the textures become weaker and more scattered. After annealing at 300°C for 40 min no texture was observed (Fig. 4b). Relative intensity levels are shown in each pole figure (PF) as the ratio of a local to maximum detected intensity with account for background and defocusing.



Fig. 4a. CZT as produced

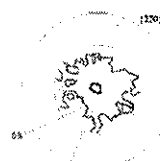


Fig. 4b. CZT after annealing, $T = 300^\circ C$, $t = 40$ min

Phase transition in the $Cd_{0.9}Zn_{0.1}Te$ ceramics caused by annealing

It is well known that both CdTe and ternary solid solution $Cd_{1-x}Zn_xTe$ are usually crystallized in the stable cubic lattice (sphalerite). However, there also exists a metastable hexagonal phase (wurtzite). It should be noted that in the CZT nanopowder we detected a significant fraction of the hexagonal phase (Fig. 5a).

• About 10 vol.% of wurtzite phase is still present in the ceramics after compaction (Fig. 5b). The observed twins in the compacted ceramics also indicate that there is some hexagonal phase in the material.

• The peaks associated with the hexagonal phase disappear after 40 min annealing and the sample consists only of the stable cubic phase (Fig. 5c).

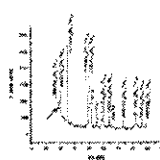


Fig. 5a. CZT nanopowder prior to compression

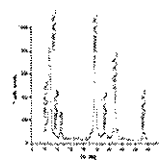


Fig. 5b. CZT nanopowder after compression

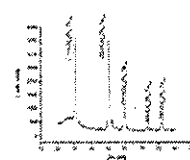


Fig. 5c. CZT nanopowder after annealing

A tablet made of $Cd_{0.9}Zn_{0.1}Te$ nanopowder

• Light transmission of the compacted material in the IR region is initially about 25–30% and it increases by 10–15% after the annealing due to recrystallization in the CZT ceramics.

• A sample of CZT ceramic produced from the nanopowder is shown in Fig. 6.

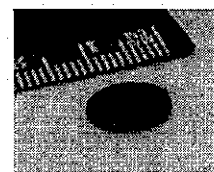


Fig. 6. CZT Ceramic produced from nanopowder

CONCLUSIONS

- Nanopowders of the ternary solid solution $Cd_{1-x}Zn_xTe$ ($x = 0.02$ – 0.1) were produced directly through vapor deposition.
- The ceramic material was compacted from the nanopowder at room temperature.
- It has been shown that annealing at 300°C results in more uniform grain structure and, consequently, higher light transmittance in the IR region.
- The annealing at 300°C causes the wurtzite—sphalerite phase transition in the $Cd_{0.9}Zn_{0.1}Te$ ceramics made of the nanopowder.

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