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Electrophysical properties of (Cd,Mn)(Te,Se) crystals

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Properties of Cd(Zn)Te solid solutions can be potentially improved by adding to the initial charge several percent of Se. In this work we report on the study of electro-physical properties of undoped Cd(Mn)Te crystals with 4 % of Mn and 2 or 4 % of Se (CMTS), which can be promising for improved radiation detectors. Pure components of Cd, Mn, Te and Se (with purity of no less than 99.999 %, except Mn (99.99 %)), were used for synthesis, which was performed by gradually heating the charge to a temperature of 1130 °C. The crystallization rate was 3 mm per hour. The single crystals had a p-type conductivity and a resistivity ρ~400 ohm-cm at 293 K. The resistivity was determined from the linear portion of the I-V curve using the samples with two ohmic contacts, made by thermal spraying of nickel. From the optical transmission measurements, the band gap of single crystals was found to be E_g = 1.51 eV at 293 K. The Schottky rectifying barrier structures were also fabricated and tested. CMTS wafers were etched in a bromine-methanol solution. After the cleaning in argon plasma, a thin chromium layer (d≈20 nm) was deposited on the surface to make the translucent rectifying contact. The Ohmic nickel contact was applied to the opposite side of the semiconductor wafer. The areas of the ohmic and rectifying contacts were ~4 mm^2. Analysis of the IR images revealed that the sizes of the second phase inclusions were 7-20 µm with a density notably lower than in typical Cd(Zn)Te or Cd(Mn)Te crystals. The fabricated structures showed good rectification and strong photosensitivity responses. The rectification coefficient at a voltage of 1 V was found to be 10^3-10^4, and the photo-electromotive force upon illumination by an incandescent lamp with a power of 20 W reached 0.5 V. These results demonstrate the feasibility of making radiation detectors and photo-sensors using this material.

The properties of Cd(Zn)Te solid solutions can be sufficiently improved by adding to the initial charge several percent of Se [1]. In this work we report on the study of electro-physical properties of undoped Cd(Mn)Te ingots with 2 and 4 % of Se (CMTS), which can be promising material for radiation detectors.

Pure components Cd, Mn, Te and Se (with purity not less than 99.999 %, except Mn (99.99 %)) were used for synthesis. The composition of the grown ingots was $Cd_{0.96}Mn_{0.04}Te_{0.96}Se_{0.04}$ and $Cd_{0.96}Mn_{0.04}Te_{0.98}Se_{0.02}$. All the components were placed in a graphitized ampoule and evacuated to a pressure of $3.4\cdot10^{-2}$ Pa before sealing. The process of alloy synthesis and crystal growth was performed in a three-zone vertical Bridgman furnace. The synthesis of the alloy was performed by slow heating of the charge to a temperature of 1130 °C at the bottom of the ampoule. The crystallization of the melt occurs as the ampoule is lowered into the colder zone of the furnace at a rate of 3 mm per hour. The process of crystal synthesis and growth took place under conditions of real-time temperature monitoring in the upper and lower parts of the ampoule.

The single crystals had a p-type conductivity and a resistivity ρ≈ 400 Ω-cm at 293 K (Fig. 1). The resistivity was determined from the linear section of the I-V curves using the structure with two ohmic contacts. Ohmic contacts were made by thermal spraying of nickel.

Analysis of the obtained IR images revealed that the size of the inclusions of the second phase was 7-20 μm, and their density was much lower than in typical Cd(Zn)Te or Cd(Mn)Te crystals (Fig. 2).

From the optical transmission measurements, the band gap of single crystals was found to be E_g = 1.51 eV at 293 K. Fig. 3 shows the spectrum of CMTS single crystal optical transmission with T_{max}=68 %. To determine the band gap, three samples with a thickness of d_1 = 3 mm, d_2 = 0.5 mm, and d_3 = 0.28 mm were prepared. The dependence of the absorption coefficient α_ω on the photon energy $\omega\hbar$ was measured for each:

$$\alpha_\omega \sim \left(\hbar\omega - E_g\right)^n \quad (1)$$

where n = 2 for a straight-band semiconductor. Then we plotted the dependence $\alpha_\omega^{-2} - \hbar\omega$ (Fig. 4). The band gap, found by their extrapolation to the intersection of the rectilinear section of the dependence with the energy axis, turned out to be a function of d. This dependence within the accuracy of the experiment is quite well described by the empirical formula [2]:

$$E_g\text{=}1{,}5035 - 0{,}0035 \ln d \quad (2)$$

The dependences of E_g according to (2) on the thickness of samples CMTS were determined from the absorption spectra (Fig. 4). Expression (2) in semi-logarithmic coordinates is approximated by a line that cuts off the required value E_g = 1,504 eV at d = 1 μm on the abscissa axis (Fig. 5).

The Schottky rectifying barrier structures were also fabricated and tested. CMTS wafers were etched in a bromine-methanol solution, and after treatment in an argon plasma, a thin chromium layer (d≈20 nm) was deposited on the surface as a translucent rectifying contact. The Ohmic nickel contact was applied to the opposite side of the semiconductor wafer. Contact area of both ohmic and rectifying contacts was ~4 mm^2. The fabricated structures showed good rectification and strong photosensitivity responses. The rectification coefficient at a voltage of 1 V was found to be 10^3-10^4, and the photo-electromotive force during illumination by an incandescent lamp with a power of 20 W reached 0.5 V. These results demonstrate the feasibility of creating radiation and photoconductive detectors using this material.

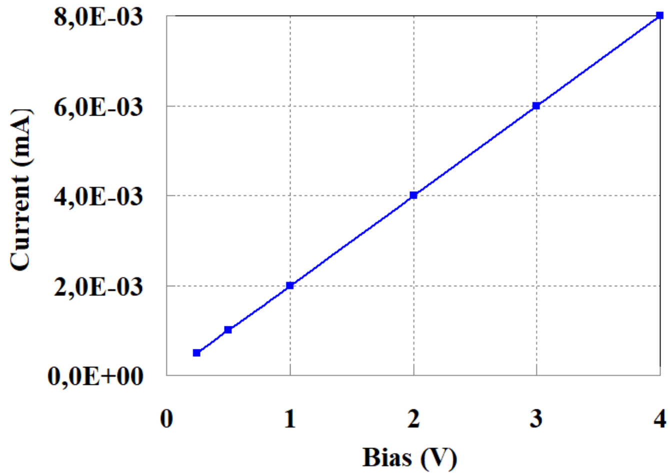

Fig. 1. I-V curve measured for the Ni/CMTS/Ni structure at 293K.

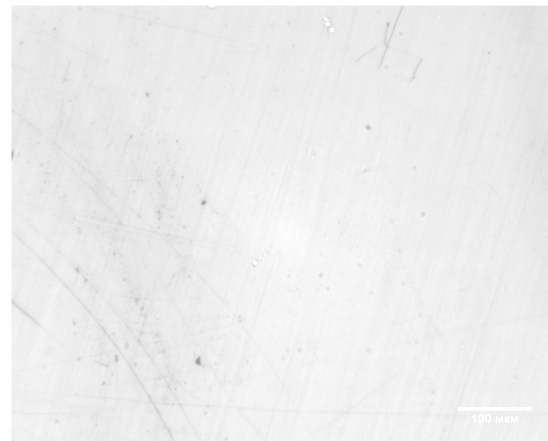

Fig. 2. IR image of the sample cut from the middle part of the ingot.

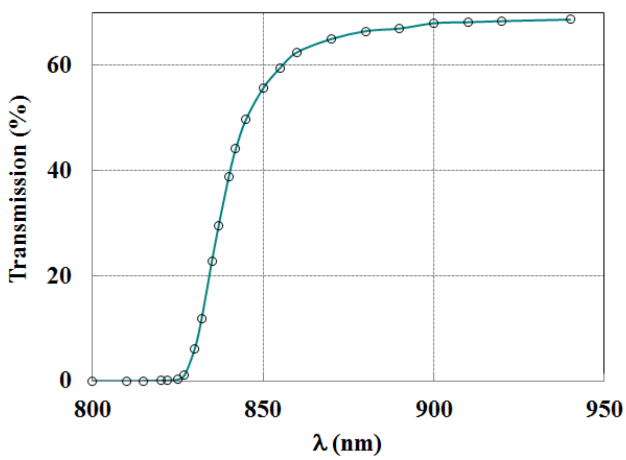

Fig. 3. Optical transmission spectrum of CMTS crystal (thickness d=0.5 mm, 297 K).

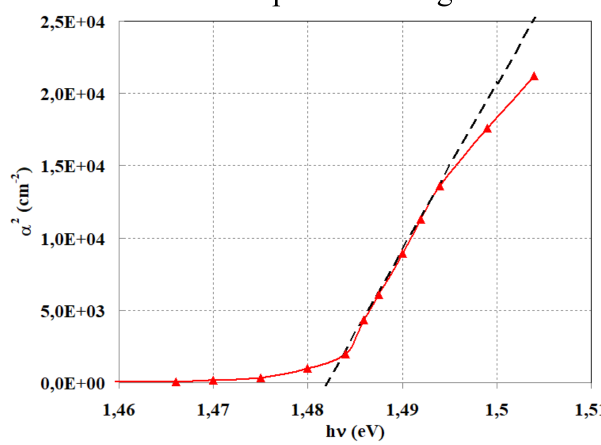

Fig. 4. Dependence $\alpha_\omega^{-2} - \hbar\omega$ for CMTS crystal (thickness d=0.5 mm, 297 K).

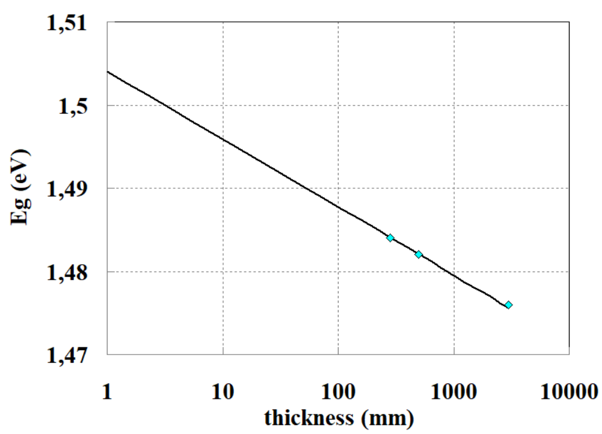

Fig. 5. Dependence of E_g according to (2) vs the thickness of CMTS single crystals, determined from the absorption spectra (Fig. 4).

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