PHOTOTENZOELECTRIC PROPERTIES OF POLYCRYSTALLINE FILMS OF CHALCOGENIDES OF CADMIUM AND ZINC, PRODUCED BY PORTIONAL EVAPORATION IN VACUUM

O. Nurmatov  
_Fergana Polytechnic Institute_, uzferfizika@mail.ru

T. Rahmonov  
_Fergana Polytechnic Institute_

Kh. Sulaymonov  
_Fergana Polytechnic Institute_

N. Yuldashev  
_Fergana Polytechnic Institute_

Follow this and additional works at: [https://uzjournals.edu.uz/semiconductors](https://uzjournals.edu.uz/semiconductors)

**Recommended Citation**
Available at: [https://uzjournals.edu.uz/semiconductors/vol2/iss5/10](https://uzjournals.edu.uz/semiconductors/vol2/iss5/10)

This Article is brought to you for free and open access by 2030 Uzbekistan Research Online. It has been accepted for inclusion in Euroasian Journal of Semiconductors Science and Engineering by an authorized editor of 2030 Uzbekistan Research Online. For more information, please contact sh.erkino@edu.uz.
PHOTOTENZOELECTRIC PROPERTIES OF POLYCRYSTALLINE FILMS OF CHALCOGENIDES OF CADMIUM AND ZINC, PRODUCED BY PORTIONAL EVAPORATION IN VACUUM

O. Nurmatov, T. Rahmonov, Kh. Sulaymonov, N. Yuldashev

Fergana Polytechnic Institute, Uzbekistan. E-mail: uzferfizika@mail.ru

Abstract. The technology of producing thin films with an anomalous photovoltaic property from tellurides, cadmium and zinc selenides by evaporation in separate portions vacuum on transparent dielectric substrates is investigated. It was shown that the fabricated polycrystalline films from CdTe, ZnTe, and CdSe have linear I – V characteristics, L – A characteristics, temperature (T≈120-320 K), and deformation characteristics (ε≈-3·10^{-4}-3·10^{-3} rel units), of which CdTe is the most promising material for obtaining photodetectors sensitive to mechanical deformation in the near IR region of the radiation spectrum.

Keywords: thin polycrystalline films, photovoltaic properties, method of discrete evaporation in vacuum, relative deformation, strain-sensitivity coefficient, current-voltage, lux-amp, lux-volt and spectral characteristics.

Currently, there are quite a few works devoted to a comprehensive study of the effect of generation of an abnormally large photovoltage (or anomalous photovoltaic) effect, \( V_{APV} \approx 10^2-10^4 \) V/cm) in various semiconductor films with intrinsic and impurity absorption of light (see, for example, [1-5]). The aim of this work is to obtain new information on the mechanism of APN generation by means of a comprehensive study of the effect of technological conditions for obtaining films on their electrophysical, photoelectric, and tenzoelectric properties. Below we will consider the fundamental issues of improving the technology of obtaining thin films with the APV property from tellurides and selenides of cadmium and zinc. The results of an experimental study of the current-voltage, lux-ampere, lux-voltage and deformation characteristics of the films produced are presented. To identify the type of barriers responsible for the high-voltage photovoltaic effect, a new method is proposed here, in which films are subjected to elastic mechanical deformations. It is taken into account that homojunctions have a low sensitivity to mechanical stress, and heterojunctions exhibit a relatively high tensosensitivity.

Method for obtaining film structures. Based on the analysis of literature data [4-7] on the method of obtaining photovoltaic films and taking into account the peculiarities of evaporation and condensation, we used the method of open vacuum deposition of certain portions of the evaporated material, i.e. discrete evaporation method.

To obtain the films, we used, firstly, fine powders of cadmium and zinc tellurides, as well as cadmium selenide with the “Extra pure” stamp, and secondly, mechanical mixtures of individual components of the above binary compounds. As shown by the analysis of the literature data, when producing film photovoltaic elements from cadmium and zinc telluride and cadmium selenide, the composition of the vapor phase has a significant effect on their structure and properties. Therefore, taking into account that the vapor phase depends on the composition of the sample, the
characteristics and conditions of its evaporation, we obtained film elements from the following materials: 1. Sample of CdTe, CdSe, CdS, mechanical mixtures of stoichiometric composition. 2. Defined portions of evaporated material. 3. Mechanical mixtures of CdTe, CdS powders with an excess of metal or metalloid components up to 20 wt. %. 4. Mechanical mixtures of CdSe powders with an excess of metal or metalloid components up to 15 wt. %.

**Research methodology.** To study the effect of mechanical stresses on the properties of photovoltaic cells, a device was assembled with the help of which the samples were gradually or smoothly subjected to tensile or compressive deformation by bending the substrate. The magnitude of the relative deformation \( \varepsilon = \frac{3c\Delta y}{\ell^3} \) was calculated by the expression, where \( c \) is the distance from the neutral axis of the plate to the film, \( \ell \) is the length of the plate between the support point and the point of application of the force, \( \Delta y \) is the deflection of one free end of the plate at the point of application of the force, \( x \) is the distance from the point of application of the force to the middle of the film sample. The deformation values varied in the range from \( \varepsilon = +2 \cdot 10^{-3} \) rel. units, up to \( \varepsilon = -2 \cdot 10^{-3} \) rel. units, which made it possible to repeatedly deform the film without destroying it.

Figure 1a shows the I - V characteristic of the CdTe and CdS film elements under elastic deformations.

![Fig. 1a. I - V characteristics of (1) CdTe and (2) ZnTe under compression deformations: \( \varepsilon=0 \) (o), \( 2,0 \cdot 10^{-3} \) (\( \Delta \)-tension), \( -2,0 \cdot 10^{-3} \) (x-compression) rel.](image)

It can be seen from the characteristics that the linear character of the I – V characteristic does not change upon deformation. When compressed, the conductivity of the film increases, and when stretched, it decreases. Apparently, this is due to a change in the height and width of potential barriers during deformation, since the height and width of the barrier decreases during compression, and increases during tension. Tensosensitivity coefficient \( K \) of film samples was estimated by the...
expression $K = \Delta I / I$, where $\Delta I$ is the absolute change in the current strength during deformation, $I$ is the current through the undeformed sample, $\varepsilon$ is the value of the relative deformation. Estimates have shown that the value of $K$ reaches from 60 to 100 rel. units for the investigated films. The $I - V$ characteristics were also recorded under illumination and under the action of mechanical deformation. When the film elements are illuminated, the slope of the $I - V$ characteristic changes; the films exhibit appreciable photoconductivity. The dark and light resistance of films obtained under optimal conditions is greater than similar resistances of films obtained using a known technology [3,7]. Fig. 1b shows the $I - V$ characteristic of deformed cadmium telluride films under illumination. It can be seen from the obtained characteristics that the value of the photocurrent increases during compression, and decreases during stretching.

A typical deformation characteristic of CdTe, CdSe, and CdS photovoltaic films is shown in Fig. 2, from which it can be seen that the magnitude of the photovoltage decreases under compression, and increases under tension.

Changes in the photocurrent and photovoltage upon deformation are obviously associated with a change in the height of the micropotential barriers in the intracrystalline structures of APV films. In CdSe, when the stoichiometry is violated towards an excess of cadmium up to 5 wt%, the value of the tensosensitivity coefficient increases, and with an increase in the excess of Cd (above 5 wt%), it slowly decreases.

**Luxvolt and luxampere characteristics.** The most important characteristic of the APV effect is the dependence of the photovoltage $U_{APV}$ (V) on the intensity of the exciting light. The study of the lux-volt characteristics during deformation provides the necessary information about the nature of this effect. For this purpose, the effect of deformation on the lux-volt characteristic of a film element made of CdTe and ZnTe was investigated. The obtained characteristics are shown in Fig. 3a. It can be seen from the figure that the lux-volt characteristics of cadmium and zinc tellurides
Fig. 2. Deformation characteristics of (a) CdTe, (b) ZnTe, and (c) CdSe at room temperature at a light illumination value of $E = 2 \cdot 10^4 \text{lx}$

Fig. 3. a. Dependence of the photovoltage on the light intensity for CdTe (1) and ZnTe (2) at the value of the relative deformation: $\varepsilon = 0$ ($\bullet$), $2 \cdot 10^{-3}$ rel. ($\Delta$-stretching)

Fig. 3. b. Luxampere characteristic of CdTe (1) and ZnTe (2) at: $\Delta$ (x-compression) and $\varepsilon = 2 \cdot 10^{-3}$

consist of two sections within the range of the exciting light illumination variation from 0 to $5 \cdot 10^4 \text{lx}$. First, in the region $E = (0 \div 10^4) \text{lx}$, a very rapid increase in the photovoltage is observed, and a further increase in the light intensity to a value of $5 \cdot 10^4 \text{lx}$ leads to an increase in the photovoltage by only 20%. It is also seen there that the lux-volt characteristics of zinc and cadmium telluride do
not qualitatively change during deformation, but only shifts along the ordinate: under compression downward, and under tension - upward.

Luxampere characteristics of CdTe, ZnTe, and CdSe films were also obtained at room temperature in the range of illumination values from 0 to $5 \times 10^4$ lx with and without deformation. As can be seen from Fig. 3a, in the range of illumination values from 0 to $5 \times 10^4$ lx, the characteristic is linear both in the presence and in the absence of deformation. During deformation, the qualitative form of the characteristic does not change, but only moves down the ordinate when stretched, and up when compressed. The photocurrent increases during compression, and decreases during stretching.

Spectral characteristic. It is known [3,6,7] that the magnitude of the photovoltage depends on the wavelength of the incident light. The effect of mechanical stresses on the spectral characteristics of photovoltaic films of telluride, selenide, and cadmium sulfide has hardly been studied. Typical $V_{APP}(\lambda)$ curves for these films have the same shape, which is shown in Fig. 4 for CdTe.

![Fig. 4. Effect of mechanical deformation on the spectral characteristics of CdTe. $\varepsilon=0$; $\varepsilon=2 \times 10^{-3}$ rel. units (stretching) and $\varepsilon=-2 \times 10^{-3}$ rel. (squeeze) for lines with dots $\bullet$, $\blacksquare$ and $\blacktriangle$, respectively.](image)

It can be seen from the figure that the polarity of the photovoltage did not change with a change in the wavelength of light, both with deformation and without deformation. The maximum photovoltage for CdTe is located in the deformation range (510-580) nm. As a result of the influence of mechanical stresses, the qualitative shape of the spectral distribution curve of the photovoltage does not change significantly, it only shifts downward under compression and upward under tension. The results of the study show that the sensitivity of film photovoltaic cells to mechanical stress depends on the wavelength of the incident radiation and has a maximum near the intrinsic absorption edge of the film material.

Conclusion. Based on the results of the study, it can be concluded that the built-in chains of microphotocells, the potential barriers of which are obviously in the form of heterojunctions of the $TeP-CdTeP$, $SeP-CdSeP$, $Sn-CdSn$ types, can be responsible for the high-voltage photovoltaic effect in
thin-film cells obtained from cadmium chalcogenides. The produced polycrystalline films of CdTe, CdSe, CdS with the APV property exhibit linear deformation characteristics. Of these, CdTe is the most promising material for the manufacture of photodetectors, the most strain-sensitive in the near infrared region of the radiation spectrum.

References