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Photodetectors based on heterojunctions of metal - chalcogenide vitreous semiconductors

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A method for preparation of photodetectors based on SnO_2-$As_2(Se_{0.9}Te_{0.1})_3$ and SnO_2-$(As_{0.67}Sb_{0.33})_2Se_3$ heterojunctions is described. The results of investigation of the current–voltage, lux-ampere and spectral characteristics of the photodetectors obtained are presented.

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1. Introduction

Photoreceivers based on amorphous semiconductors, particularly, chalcogenide vitreous semiconductors (ChVS)) are interesting for use in microelectronics, since it is possible to control their parameters by varying purposefully the combination of components in ChVS films [1,2]. Moreover, the fabrication technology of these photodetectors is simple and cost-effective.

This paper is devoted to the preparation and investigation of the characteristics of photodetectors based on SnO_2-$As_2(Se_{0.9}Te_{0.1})_3$ and SnO_2-$(As_{0.67}Sb_{0.33})_2Se_3$ heterojunctions.

It is remarkable that both As-Se-Te [3] and SnO_2 have been proved to exhibit good properties of sensing the vapour and gasses.

2. Experimental details

Briefly, the samples were prepared for the investigations as follows. First, SnO_2 layer was formed on a glass substrate. This layer served as a transparent collecting electrode. Layers of ChVS and aluminum partially overlapping each other were then deposited using masks at room temperature. The sample was illuminated through the SnO_2 electrode. The aluminum layer was the second electrode and the voltage was applied between these electrodes. The polarity of the voltage was determined by the sign of the voltage on SnO_2. The thickness of chalcogenide film varied from 1 μm to 10 μm.

For both types of samples current–voltage characteristics were obtained. These characteristics were measured under illumination of the sample in the range of maximum spectral sensitivity and without illumination. The spectral sensitivities were measured at forward and at reverse bias. A forward current flows through the heterojunction when the SnO_2 electrode is biased positively with respect to the aluminum one. To obtain the photosensitivity spectra of the samples the photocurrent versus wavelength of incident light was measured in the range between 400 nm and 900 nm. Spectral sensitivity of the sample was determined according to the formula

$$S(\lambda) = J_{ph}(\lambda) / I(\lambda),$$

where $J_{ph}(\lambda)$ is the photocurrent in the sample in amperes and $I(\lambda)$ is the power of the lamp in watts in the wavelength interval $\Delta\lambda$. The photocurrent was determined according to the voltage drop across a known resistance.

Lux-ampere characteristics have also been measured by us at maximum sensitivity of the photodetectors at reverse and at forward bias. Applied voltage was $U_C = -8V$ and $U_C = +2V$.

3. Experimental results and discussion

Current–voltage characteristics for the samples based on both heterojunctions are asymmetrical and nonlinear. For current–voltage characteristics obtained with and without illumination the forward current is higher than the back current. This is due to a hole barrier which is formed at the interface between metal and chalcogenide film [3]. There is another barrier in the contact region between ChVS and SnO_2. Accordingly, current through the structure is determined by physical processes proceeding in the region near these barriers. At forward bias the current is determined by the height of barrier existing at the interface metal-ChVS and at the reverse bias – by the height of barrier existing at the interface between ChVS and SnO_2. In the last case the current through the structure is determined by recombination velocity of holes and electrons at the interface between ChVS and SnO_2 because electrons are the major carriers in SnO_2. Thus, the increase of current as the voltage increases at forward bias is faster than at reverse bias, as this is observed in Fig. 1, were current–voltage characteristics of photodetectors based on $(As_{0.67}Sb_{0.33})_2Se_3$ are shown. Analogous behavior is observed for the detectors based on $As_2(Se_{0.9}Te_{0.1})_3$.

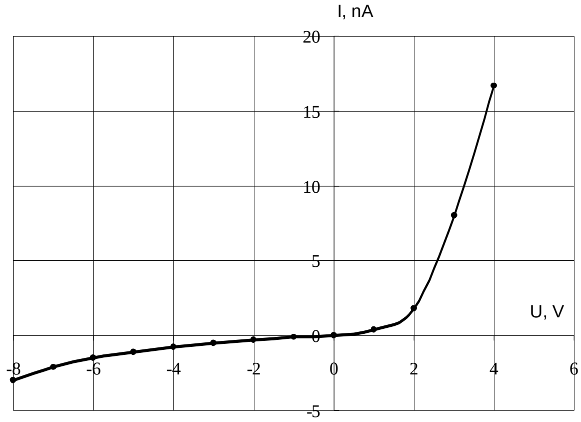

Fig. 1. Current–voltage characteristics of a $(As_{0.67}Sb_{0.33})_2Se_3$ based photodetector.

Photosensitivity spectra of the detector based on $As_2(Se_{0.9}Te_{0.1})_3$ at reverse bias are shown in Fig. 2. At reverse bias the region of spectral sensitivity of detectors at the level of $0.1S_{max}$ - the maximum value, extends from λ = 0.4 μm to λ= 0.7 μm with a maximum at λ = 0.53 μm (d = 1 μm), from λ = 0.47 μm to λ = 0.71 μm with a maximum at λ = 0.58 μm (d = 7μm) and from λ = 0.53 μm to λ = 0.76 μm with a maximum at λ = 0.65 μm (d = 10 μm). Average value of maximum sensitivity in the group of samples with chalcogenide film thickness d = 1, 7 and 10 μm is 25, 13.3 and 3.7 mAW^{-1} accordingly. Spread in values of maximum sensitivity in this group is 20%. At forward bias the sensitive region is shifted towards a short-wavelength region of the spectrum relative to the sensitivity curve obtained at reverse bias. The sensitivity curve is substantially wider than that obtained at reverse bias. At forward bias the maximum is shifted by 0.6 eV.

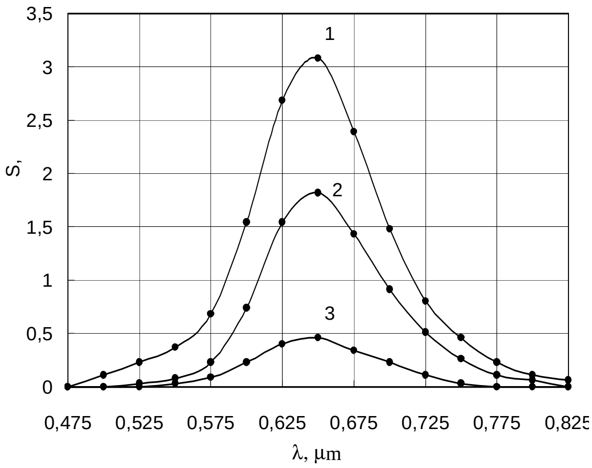

Fig. 2. Photosensitivity spectra of a $As_2(Se_{0.9}Te_{0.1})_3$ based photodetector (d = 10 μm): 1 - U_C= -8V; 2 - U_C= -4V; 3 - U_C= -2V.

For detectors based on $(As_{0.67}Sb_{0.33})_2Se_3$ at reverse bias the sensitive region determined at the $0.1S_{max}$ level extends from λ = 0.515 μm to λ = 0.730 μm with a maximum at λ = 0.65 μm (d = 1 μm) and from λ = 0.575 μm to λ = 0.725 μm with a maximum at λ= 0.625 μm (d = 10μ m). Average value of maximum sensitivity in the group of samples with chalcogenide film thickness d = 1 and 10 μm is 13.3 and 2.3 mAW^{-1} accordingly. Spread in values of maximum sensitivity in this group is 15%. Change of the form of sensitivity curve in going to forward bias is lake for detectors based on $As_2(Se_{0.9}Te_{0.1})_3$. In this case the maximum is 0.5 eV shifted. As already noted, there is a hole barrier at the interface between aluminum and ChVS film. The height of this barrier according to photoemission measurements [4] for present compositions is about 0.6 eV. The shift of the maximum of sensitivity curve at forward bias is an additional corroboration of the existence of this barrier. The more photon energy of light is absorbed the less is the depth of photon penetration and closer to the barrier the main fraction of photons is absorbed. Therefore, it is necessary to expend more energy on the generation of holes and this leads to a high-frequency shift of the maximum.

At reverse bias the lux-ampere characteristics for both types of detectors are linear in the investigated region, where irradiance varies from 0 to 1.6 Wm^{-2}. At forward bias this characteristics are nonlinear. This feature is characteristic for heterostructures operating at reverse and at forward bias accordingly. The lux-ampere characteristics of detectors based on SnO_2-$As_2(Se_{0.9}Te_{0.1})_3$ heterojunction at reverse and at forward bias are shown in Fig. 3.

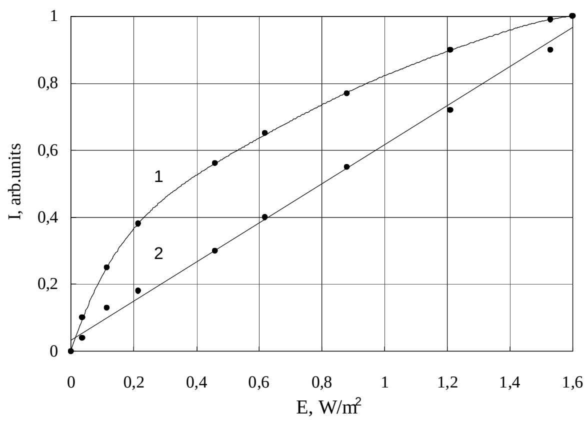

Fig. 3. Lux-ampere characteristics of a $As_2(Se_{0.9}Te_{0.1})_3$ based photodetector: 1 - at forward bias; 2 - at reverse bias.

4. Conclusions

Photodetectors based on SnO_2-$As_2(Se_{0.9}Te_{0.1})_3$ and SnO_2-$(As_{0.67}Sb_{0.33})_2Se_3$ heterojunctions were prepared and studied. The photosensitivity spectra, current–voltage characteristics and lux-ampere characteristics were measured. Sensitive region and values of maximum sensitivity for both types of detectors were determined. At forward bias the maximum of the sensitivity curve is shifted towards the short-wavelength region of spectrum. Lux-ampere characteristics are nonlinear at forward bias, but linear at reverse bias in the region extending from 0 up to 1.6 Wm^{-2}.

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