PHOTOELECTRIC PROPERTIES OF GaAs-As_2Se_3 HETEROSTRUCTURE

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ABSTRACT

In the given article the photoelectrical features of the contact of crystal and amorphous materials As_2Se_3-GaAs are considered. The complex of investigations of this heterostructure, including volt-ampere and lux-ampere characteristics, spectral distribution of the photosensitivity and thermostimulated conductivity was carried out.

Analysis of the results of investigations shows that it is observed the forming of rectifying contact on the interface of crystal and amorphous materials and the formation of specific centers of capturing and recombination on the interface that is confirmed by the temperature distribution of the thermostimulated currents.

Possibility of the practical application of the given heterostructure in the systems of optical information recording is considered.

The heterostructures based on the contact of crystalline and amorphous semiconductors attract attention of researchers from the point of view of their technical applications as well as objects for study of contact phenomena in amorphous materials.

The results of photoelectric property examination of the heterostructures formed by the contact of arsenic selenide thin films with chromium doped gallium arsenide monocrystalline wafers are presented. Amorphous As_2Se_3 layers were deposited by vacuum evaporation onto GaAs substrates, which were preliminarily polished through routine methods. The thickness of deposited layers and substrates were 1 and 300μm correspondingly. GaAs resistivity was $2{,}5 \cdot 10^7$ Ohm·cm, but the resistivity of As_2Se_3 films was on the level 10^{11} Ohm·cm. Transparent Au layers on As_2Se_3 and In on GaAs sides correspondingly were used as electrical contacts.

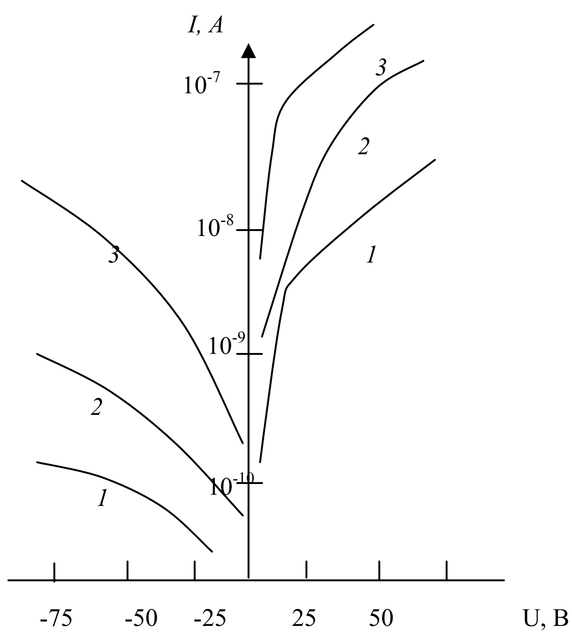

Fig.1. Dark I-V characteristic of the heterostructures GaAs-As_2Se_3 at different temperatures T°C: 1 – 20; 2 – 50; 3 – 75

Current-voltage characteristics (Fig.1) study of the given structure has shown that they are non-linear and asymmetrical relative to the applied voltage polarity. The rectification factor is ~10^2 for the reverse direction at the application of positive potential to As_2Se_3. With the temperature growth from 20 to 100°C the usually accepted laws are kept. The analysis of the trend of I-V dependences at the direct applied voltage U≤1 V allows concluding that for this region it is characteristic the emission recombination charge transfer. For the field of higher voltages the I-V dependence is transformed to the shape typical for injection processes so characteristic for thin layer's structures with high resistivity. [1-3]. The I-V behavior at the reverse voltage U≤10V demonstrates the possibility of over-barrier passing.

Proceeding from the emission-recombination charge transfer model and I-V temperature dependence for direct voltages U≤1 V, the barrier height was estimated from the temperature dependence for "zero current" [4]. Its value was 0,4 eV.

The investigation of photosensitivity spectral distribution under illumination from arsenic side has shown that the sensitivity region is in the interval λ=600-1100 nm and is stipulated by the contribution of both materials to the photoresponse. As it follows from Fig.2, the largest contribution to the photoresponse at the reverse voltage direction (curve 1) is conditioned by the arsenic selenide layer that indicates that space charge region is partially situated in amorphous layer. In the case of direct voltage bias (curve 2), the contributions of both materials are comparable that is connected with the equal voltage distribution till both sides of heterojunction. The observed photosensitivity at λ=1100 nm, connected with the impurity states in GaAs, is characteristic of spectral distribution of photoresponse.

Fig.3 demonstrates the influence of temperature and voltage bias on the photoresponse multiplity under integral exposition $E=10^3$ Lx. As one can see the applied voltage increase leads to the photoresponse growth in the interval up to 10 V with the following drop at the continuing growth of applied voltage. It can be explained by the fact that starting from the U=10V the injection processes become overwhelming in the mechanisms of current passage that is confirmed by the I-V characteristics behavior. In this case, the dark charge carrier concentration is increased and corresponding multiply decrease is observed. For direct biases the photoresponse multiply decreases by 3 orders when temperature varies from 80 to 300K but for reverse biases the photoresponse decreases insignificantly in the same temperature region.

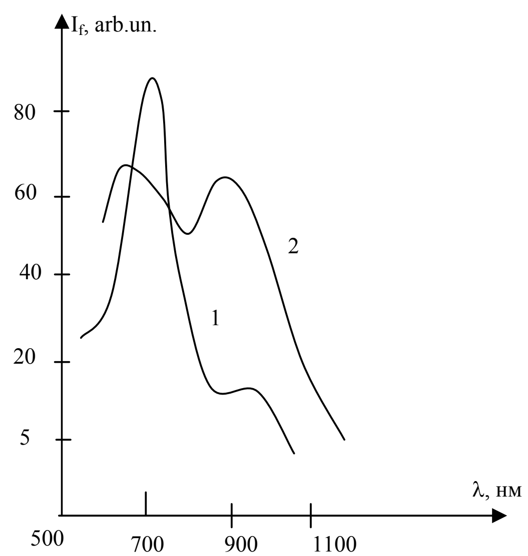

Fig.2 Spectral distribution of the photosensitivity of the $GaAs-As_2Se_3$ heterostructures at T=300 K and at the direct (1) and back (2) bias of applied voltage

The photocurrent long-term relaxation for reverse biases after switching on/off light exposure is typical for investigated heterostructures. It can be assumed that under the illumination the capturing of light generated carriers occurs onto the traps situated at the interface and in the space charge region.

The energetic diagram of the heterojunction was plotted using experimental data and it is taken into account that Fermi level in GaAs is situated at 0,74 eV from the valence band top, the conductivity, charge carrier concentration and their mobility estimated from Hall measurements are correspondingly: $\sigma=3{,}17\cdot10^{-8}$ $Ohm^{-1}\cdot cm^{-1}$, $n=5{,}2\cdot10^8$ cm^{-3}, $\mu_n=500$ $cm^2/V\cdot s$.

The carried out study has shown that the presence of high resistivity, photoresponse multiplity and wide range wavelength photosensitivity makes the $GaAs-As_2Se_3$ heterostructure perspective for different systems of optical information recording, particularly in the transducers of liquid crystal photoconductive semiconductor type.

At the investigation of the L-I characteristics and spectral characteristics of the photoconductivity it was observed the phenomena of residual conductivity, i.e. after the light excitation switching off the returning of the dark current to its initial value was not observed or happened only in long interval of time (at the room temperature). Here the value of the residual conductivity was a function of polarity of applied voltage. Apparently, that at the back bias, the field of the space charge is formed. One can suggest that light generated carriers are trapped to the trap centers and due to that create the space charge, which is slowly relaxing after light is switched off. However, the cross section of some trap centers capturing can be very large and relaxation from such centers can be extremely slow.

Proceeding from these suggestions we made attempts to estimate the deepness of local center position through the method of study of thermostimulated currents (TSC).

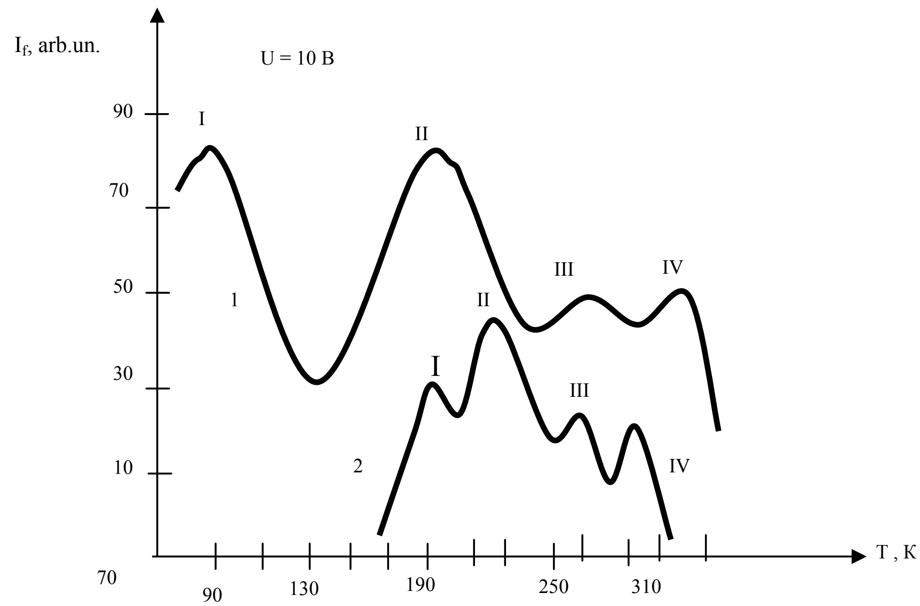

Fig.5. Thermostimulated currents of the GaAs-As_2Se_3 heterostructures: 1- back bias; 2- direct bias.

In Fig.5 there are presented the curves of thermostimulated currents in the GaAs-As_2Se_3, obtained at the application of back (curve 1) and direct (curve 2) bias. The presence of maximums on the TSC curve confirms the existence of the four pronounced capture levels in our heterostructure (both back and direct voltage bias). As in the given case the traditional methods of calculation of the trap position deepness can be used, the estimating formulae of Randal, Wilkins and Fought were used for the estimation of energy position of the capture centers. Obtained values were included in estimation table. In accordance with the obtained data the traps are positioned in interval from 0,19 to 0,61 eV at the back bias and in the interval 0,47 to 0,6 eV at the direct one.

The observed difference can be explained as follows. At the TSC measurement at back voltage bias the imperfections of both the materials composing the heterostructures themselves and

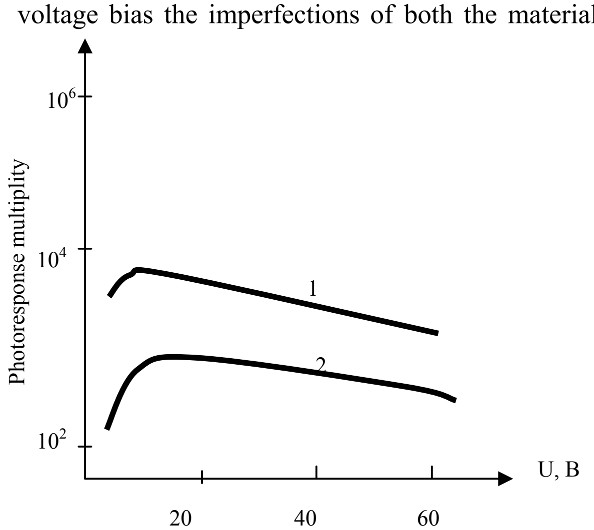

Fig.3. Dependence of the photoresponce multiplity of the GaAs-As_2Se_3 heterostructures at T=300K on applied direct (1) and back (2) bias.

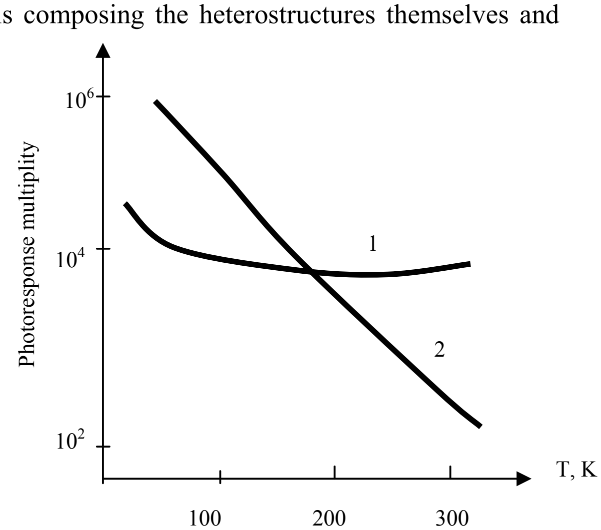

Fig.4. Dependence of the photoresponce multiplity of the GaAs-As_2Se_3 heterostructures on temperature for U =10V at the direct (1) and back (2) bias.

definite type states in the space charge layer on the interface can serve as trap centers. In the case of direct bias, the main role should be played, evidently, by trap centers of initial materials GaAs and layer of As_2Se_3 .

Table

No of maximum	Method of determination of the AE, eV			
	Randal and Wilkins		Fought	
I	0,47	0,19	0,34-0,47	0,14-0,19
II	0,49	0,43	0,35-0,49	0,31-0,43
III	0,53	0,58	0,39-0,53	0,41-0,58
IV	0,60	0,63	0,43-0,60	0,45-0,63
	direct	back	direct	back

High values of the specific resistivity (10^{12} Ohm·cm), multiplity of photoresponse and photosensitivity in wide spectral diapason make the GaAs-As_2Se_3 heterostructures perspective for the using in the different systems of optical information recording and, in particular, in the liquid crystal-photoconductive semiconductor transformer.

PVMS, of the photosemiconductor-liquid crystal type, prepared on the base of these heterostructures, have shown the possibility to register the optical images in the diapason 0,85-1 μm with sufficiently high resolution (some tens of lines per mm) and sensitivity 10^{-5} J/cm^2

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