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ELECTRICAL AND PHOTOELECTRICAL PROPERTIES OF CdS/$Cd_{1-x}Mn_xTe$ HETEROJUNCTIONS

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Electrical and photoelectrical properties of CdS/$Cd_{1-x}Mn_xTe$ heterojunction at different temperatures from 293 K to 393 K were studied. The potential barrier at 293 K makes 0,78 V and is linearly decreasing with temperature increase with a temperature coefficient of $5{,}5\cdot10^{-3}$ V·K^{-1}. From $lnI_{inv} = f(1/T)$ dependence at U=1V the activation energy of 0,61 eV was determined. CdS/$Cd_{0,6}Mn_{0,4}Te$ heterojunction spectral sensitivity at 300 K covers the wavelength region.

Keywords: *heterojunction, CdS / $Cd_{1-x}Mn_xTe$, photoelectrical and electrical properties.*

PROPRIERĂŢILE ELECTRICE ŞI FOTOELECTRICE ALE HETEROJONCŢIUNILOR CdS/$Cd_{1-x}Mn_xTe$

În intervalul de temperaturi de la 293K până la 393K au fost cercetate proprietăţile electrice şi fotoelectrice ale heterojoncţiunilor CdS/$Cd_{1-x}Mn_xTe$. La 293K potenţialul de difuzie constituie 0,78 V şi cu creşterea temperaturii mărimea lui se micşorează linear cu coeficientul termic egal cu $5{,}5\cdot10^{-3}$ V·K^{-1}. Din dependenţa $lnI_{inv} = f(1/T)$ la tensiunea de 1V a fost determinată energia de activare care este egală cu 0,61 eV. Spectrele fotoconductibilităţii denotă că la 300 K heterojoncţiunile CdS/$Cd_{0,6}Mn_{0,4}Te$ sunt fotosensibile în regiunea de lungimi de undă 0,52÷0,83µm.

Cuvinte-cheie: *heterojoncţiune, CdS / $Cd_{1-x}Mn_xTe$, proprietăţi electrice şi fotoelectrice.*

1. Introduction

In the concentration region of $0 \le x \le 0{,}5$ ternary composition $Cd_{1-x}Mn_xTe$ forms solid solutions with a blend crystalline structure the band gap of which monotonously varies from 1,54 eV for CdTe to 2,25 eV for $Cd_{0,5}Mn_{0,5}Te$ [1]. These band gap values make the named compounds suitable as active materials for fabrication of barrier structures for solar energetic. CdS (E_g=2,4 eV) was used as a "window" material.

CdS/$Cd_{1-x}Mn_xTe$ heterojunctions (HJ) were fabricated by successive deposition of CdS and $Cd_{1-x}Mn_xTe$ thin layers by "quasiclosed volume" on glass substrates (2x2 cm^2) coated by a low resistivity ($\rho \approx 10^{-3}$ Ohm·cm) and optical transparent (T≈82%) SnO_2 thin layer. CdS of " For semiconductors" mark and $Cd_{0,6}Mn_{0,4}Te$ crystals grown by Bridgeman method were used as evaporation sources. The sources temperature was of 530-540°C and of the substrate temperature was of 300-370°C for CdS layers and of 350-370°C for $Cd_{0,6}Mn_{0,4}Te$. SnO_2 for CdS layers and Mo deposited by vacuum evaporation for $Cd_{0,6}Mn_{0,4}Te$ were used as an ohmic contacts. For to enhance the photosensitivity heterostructures were processed in $CdCl_2$+ CH_3OH (methyl alcohol) solution and thermally annealed at 380°C during 30 min.

One should note that the difference between the saturated vapors pressure of $Cd_{1-x}Mn_xTe$ ternary compound components (at the layer deposition temperature this difference makes up to 10 orders of magnitude) makes difficult obtaining of the layers of the same composition as the composition of the evaporation source. For the verification of the obtained layers composition the photocurrent spectral dependence of CdS/$Cd_{1-x}Mn_xTe$ HJ was studied.

2. Experimental results

Current intensity vs voltage dependence of the studied HJ is sharply asymmetrical one (Fig. 1). At 293 K and voltage of 1V the direct current exceeds the inverse one by 10^2 -10^3 times.

For to establish the current flow mechanism through CdS/$Cd_{1-x}Mn_xTe$ HJ current-voltage dependencies at different temperatures from 293K to 393K were studied. By extrapolation of the linear segments of I-V dependencies to the intersection with voltage axis the height of the HJ potential barrier at different temperatures was determined.

The potential barrier at 293 K makes 0,78 V and is linearly decreasing with temperature increase with a temperature coefficient of $5{,}5\cdot10^{-3}$ V·K^{-1}. On current-voltage dependencies measured at direct biases, represented in a semi-logarithmic scale, up to the voltages equal to the potential barrier height, one can observe linear segments, which indicates to an exponential dependence of the direct current on the applied voltage. The

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extrapolation of these linear segments to the intersection with the current axis the saturation currents were determined, which at 293 K have value of $3,5 \cdot 10^{-8}$ A and are increasing to $1,0 \cdot 10^{-7}$ A at 353 K. The analysis of I-V dependencies at direct biases and temperature dependence of saturation current witnesses that in CdS / $Cd_{0,6}Mn_{0,4}Te$ HJ a thermally activated generation-recombination mechanism occurs, at which the HJ I-V dependence can be given by the expression

$$I=I_s\,[exp(eU/AkT) - 1], \quad (1)$$

where, I_S-is the saturation current; U-bias voltage; A -ideality coefficient which varies with the temperature from 3,4 to 1,56; k-Boltzmann constant; T- temperature;

$$I_s=I_{so}\exp(-E_a/kT), \quad (2)$$

where, E_a-is activation energy [2].

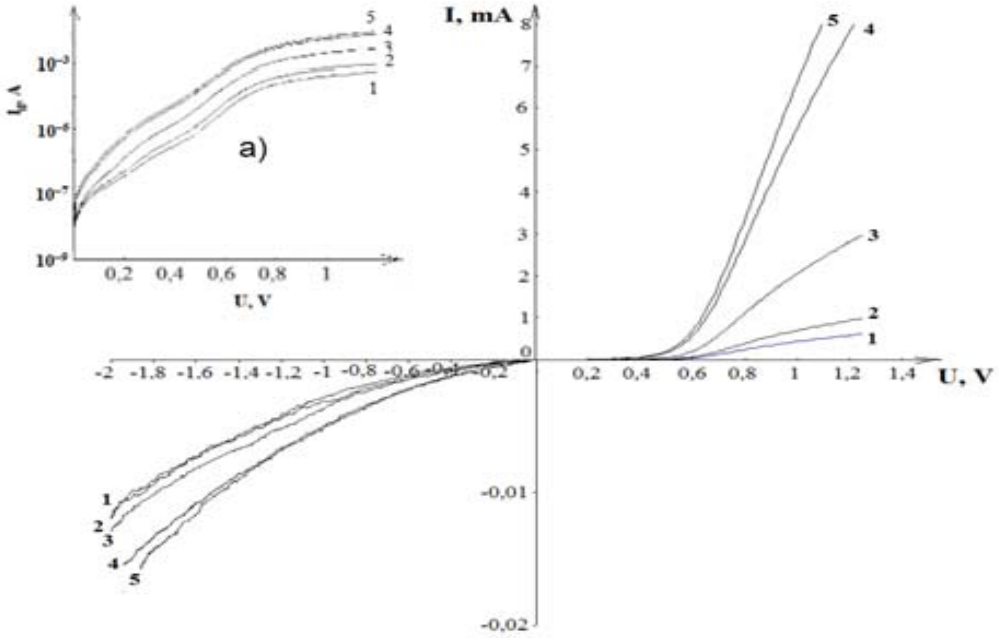

Fig.1. Current intensity vs voltage dependence of the $CdS/Cd_{1-x}Mn_xTe$ HJ and I-V dependencies at direct biases (a) at different temperatures: 1 – 293 K, 2 – 303 K, 3 – 323 K, 4 – 343 K, 5 – 353 K.

From $lnI_s=f(1/T)$ dependence (Fig. 2) the E_a =0,63 eV was determined and it could be related to the level through which the recombination occurs. At the reverse biases on to $lnI_{inv}= f(1/T)$ dependence two rectilinear segments are observed, which indicate to a power dependence of the reverse current on voltage ($I \sim U^m$).Up to the biases of 0,4÷0,5 V the power coefficient m≈1 which witnesses about predomination of leakage currents. At higher voltages m=2÷3. From $lnI_{inv}= f(1/T)$ dependence at U=1V the activation energy of 0,61 eV was determined. This value is in good agreement with the energy position of the recombination level found from the analysis of direct I-V dependencies. Therefore in the formation of reverse current the same current flow mechanism as at direct bias is involved and namely the thermal generation through the deep energy level.

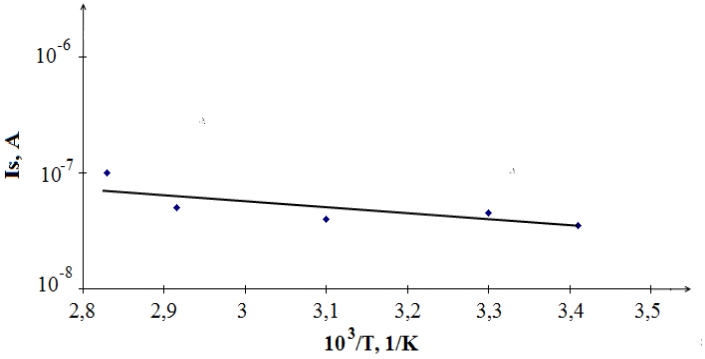

Fig.2. Temperature dependence of saturation current $CdS/Cd_{1-x}Mn_xTe$ HJ.

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At $CdS/Cd_{0,6}Mn_{0,4}Te$ HJ illumination with an integral light the open circuit voltage aspires to saturation and the short circuit current increases proportionally to the light intensity increase. At 300 K and illumination of 100 mW/cm^2 open circuit voltage is U_{oc} = 0,68÷0,72 V, short circuit current I_{sc} = 25,8÷ 26,4 mA/cm^2, fill factor FF = 0,55÷0,57 the efficiency of light energy conversion into electrical one makes 10,1÷10,6 %. The photosensitivity spectral dependencies of $CdS/Cd_{1-x}Mn_xTe$ heterojunctions were studied at the temperatures of 300 K and 80 K. $CdS/Cd_{0,6}Mn_{0,4}Te$ HJ spectral sensitivity (Fig. 3) at 300 K covers the wavelength region 0,52÷0,83μm and is determined by electron-hole pairs generation in both component materials. At the temperature decrease to 80 K the spectral sensitivity region is shifting to the shorter wavelength region and covers the region from 0,47μm to 0,79μm. By taking into account that the region of the structure photo-sensitivity region is determined by the components band gap, the composition of the obtained layers was estimated. The calculations show that the Mn content in the solid solutions layer is lower than in the evaporation source, particularly , x does not exceed the value of 0,1. The photosensitivity edge shift at the temperature decrease from 300K to 80K allows determining the temperature coefficient of band gap variation which makes ~10^{-4}eV/K, which is in a good agreement with the data for CdTe [3].

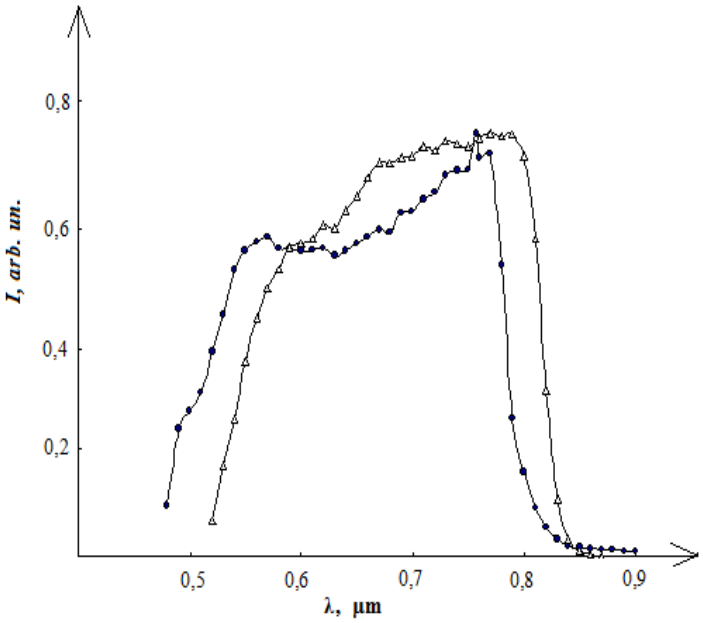

Fig.3. The photosensitivity spectral dependencies of $CdS/Cd_{1-x}Mn_xTe$ heterojunctions (Δ - at 300 K , ● – at 80 K).

3. Conclusions

1. The variation of the ideality coefficient in I-V dependencies of $CdS/Cd_{1-x}Mn_xTe$ HJ indicates to a thermally activated recombination mechanism of current flow in the studied structures.
2. The activation energy of the energetic level participating in the recombination processes is of 0,61-0,63 eV, which is confirmed by the calculations made from the studies of both direct and inverse I-V dependencies.
3. Analysis of $CdS/Cd_{1-x}Mn_xTe$ HJ load dependence indicates that U_{oc}=0,68-0,72 V, I_{sc}= 25,8-26,4 mA/cm^2, fill factor FF=0,55-0,57, efficiency η = 10,1 – 10,6 %.
4. The$Cd_{1-x}Mn_xTe$ solid solutions composition, estimates from the photosensitivity spectral dependence shows that x≤ 0,1.

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