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 5.5·10^{-3} V·K^{-1}. From \(\ln I_{inv} = f(1/T)\) 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.

1. Introduction

In the concentration region of \(0 \leq x \leq 0.5\) 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 cm²) coated by a low resistivity (\(\rho \approx 10^{-3}\) Ohm·cm) and optical transparent (\(T \approx 82\%\)) SnO₂ 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. SnO₂ 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 CdCl₂ + CH₃OH (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 5.5·10^{-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
extrapolation of these linear segments to the intersection with the current axis the saturation currents were
determined, which at 293 K have value of 3,5·10⁻⁸ A and are increasing to 1,0·10⁻⁷ A at 353 K. The analysis
of I-V dependencies at direct biases and temperature dependence of saturation current witnesses that in CdS /
Cd₀.₆Mn₀.₄Te HJ a thermally activated generation-recombination mechanism occurs, at which the HJ I-V
dependence can be given by the expression

\[ I = I_s \left[ \exp\left(\frac{eU}{A k T}\right) - 1 \right], \]

(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;

\[ I_s = I_{so} \exp\left(-\frac{E_a}{kT}\right), \]

(2)

where, \( E_a \) is activation energy [2].

From \( \ln I_s = f\left(\frac{1}{T}\right) \) dependence (Fig. 2) the \( E_a =0.63 \text{ eV} \) was determined and it could be related to the level
through which the recombination occurs. At the reverse biases on to \( ln I_{inv} = f\left(\frac{1}{T}\right) \) 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 \( ln I_{inv} = f\left(\frac{1}{T}\right) \) 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.
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 $U_{oc} = 0.68\div0.72$ V, short circuit current $I_{sc} = 25.8\div26.4$ mA/cm$^2$, fill factor $FF = 0.55\div0.57$ the efficiency of light energy conversion into electrical one makes $10.1\div10.6 \%$. The photosensitivity spectral dependencies of CdS/Cd$_{1-x}$Mn$_x$Te 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÷0.83$\mu$m 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 0.47$\mu$m to 0.79$\mu$m. 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 $\sim10^{-4}$eV/K, which is in a good agreement with the data for CdTe [3].

3. Conclusions

1. The variation of the ideality coefficient in I-V dependencies of CdS/Cd$_{1-x}$Mn$_x$Te 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$_x$Te HJ load dependence indicates that $U_{oc}=0.68\div0.72$ V, $I_{sc}=25.8\div26.4$ mA/cm$^2$, fill factor $FF=0.55\div0.57$, efficiency $\eta = 10.1\div10.6 \%$.
4. The Cd$_{1-x}$Mn$_x$Te solid solutions composition, estimates from the photosensitivity spectral dependence shows that $x \leq 0.1$.

Bibliography:


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