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CURRENT FLOW MECHANISM IN ZnSe-ZnO-Pd STRUCTURES

Roman SCURTU, Petru GAŞIN, Petru CHETRUŞ

Semiconductor Physics Lab, Moldova State University

Structurile MOS au fost obţinute folosind ca suporturi plăcuţe monocristaline de ZnSe orientate în direcţia [110] cu grosimea 3-5mm. Monocristalele de ZnSe au fost tratate în zinc +0,1%Al la 950ºC timp de 100 ore, în vid. Concentraţia electronilor la 300 K este de 1,85•10^{16}cm^{-3}, iar mobilitatea – 466 cm^2/VS. În calitate de oxid s-au folosit straturi subţiri de ZnO, obţinute prin tratarea cristalelor de ZnSe în apă oxigenată. Grosimea stratului de ZnO depinde de timpul de tratare chimică şi alcătuieşte 4-13 nm. Contactul metalic, strat subţire din Pd, a fost obţinut prin evaporare termică în vid. Ca contact ohmic la cristalele de ZnSe s-a folosit In obţinut prin tratare în aer la 370ºC timp de 30-120 sec.

La polarizări directe, curentul depinde exponenţial de tensiunea aplicată şi, la tensiuni de până la 0,7 V, e determinat de curentul de tunelare, iar mai mare de 0,7 V – de procesele de recombinare. Factorul de idealitate variază de la 2,86 – la 93 K la 1,47 – la 333 K. Potenţialul de difuzie variază între 0,8 V şi 1,28 V, corespunzător la 353 K şi 113 K. La polarizarea inversă este o funcţie de putere şi are factorul de putere 3,93 la 113 K şi de 2,42 la 353 K.

La polarizări directe 2÷3 V şi T=77 K structurile Pd-ZnO-ZnSe radiază în regiunea albastră. La 77 K se observă două fâşii: prima mai intensivă, cu maximul 2,7 eV, şi alta – cu maximul 2,06 eV.

1. Introduction

Photo-detectors and light sources in the blue-violet spectral range can be used in various commercial and military devices (e. g. space communications, ozone layer monitoring etc.). Zinc selenide having a band gap of 2.69 eV at 300 K, high photosensitivity and high probability of radiative recombination (direct optical transitions) as well as zinc oxide (ZnO) (band gap 3.37 eV at room temperature), are perspective materials for use in above mentioned fields. Pd has good conductive properties and a superior thermal and chemical stability and it is often used for production of Schottky diodes based on ZnO and GaN [1-3].

A strictly mono-polar conductivity is characteristic for zinc selenide, determined by self-compensation [4] that impede to obtain p-n junction. This problem can be solved by making metal-oxide-semiconductor structures or heterojunctions. In this work we study electrical properties of In-ZnSe-ZnO-Pd structures, which can be considered as a Me (Pd) oxide (ZnO) semiconductor (ZnSe) structure.

2. Experimental details

MOS structures was obtained by using ZnSe [110] oriented single crystal as a substrate with 3-5 mm thickness. ZnSe single crystal was treated in zinc +1.1%Al at 950 ºC for 100 hours, in vacuum. The electron concentration at 300 K was 1.85 10^{16}cm^{-3} and electron mobility was 466 cm^2/VS. As a oxid layer was used ZnO, fabricated by ZnSe treatment in oxygenate water. ZnO layer thickness depends on a chemical treatment time and it's 4-13 nm. Pd film, metallic contact, was obtained by vacuum thermal evaporation. As a ZnSe ohmic contact In alloyed on air at 370 ºC for 30-120 s was used.

3. Results and discussion

In-ZnSe-ZnO-Pd structures current-voltage curves are sharply asymmetrical, the current at direct bias is higher than at reverse bias by 10^5-10^6. At direct biases higher than built-in voltage, current- voltage slope is linear. From I=f(U) dependence can be estimated by extrapolation at I=0 the potential barrier at 300 K that is about 0.99 eV. At temperature variation from 353 K to 113 K the built-in voltage linearity decreases from 0.8 V to 1.28 V. The thermal coefficient of built-in voltage is 2×10^{-3} V/K.

The In-ZnSe-ZnO-Pd structures ln$I$=f(U) dependencies at forward biases and different temperature, are shown in Fig.1. As one can see, at biases less than built-in potential ln(I)=f(U) dependence has two linear segments, that indicate to an exponential dependence of current on applied voltage. This dependence is characteristics to structures in which along to generation-recombination current a tunnelling processes have an influence on current flow [5].

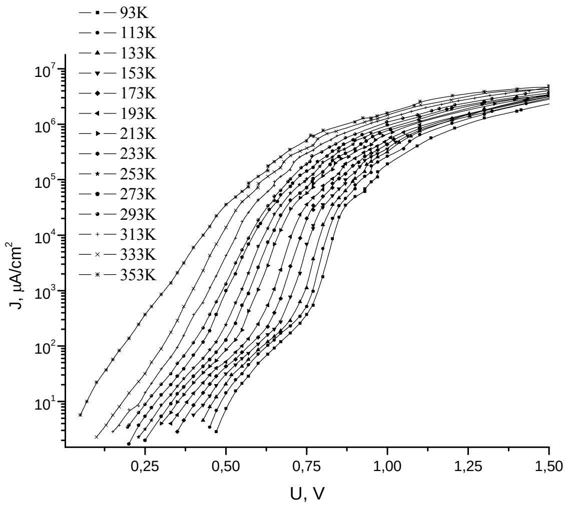

Fig.1. LnI=f(U) dependencies at direct bias.

At low biases (first region) the current-voltage dependence can be described by the following expression, characteristic for the tunnelling current:

$$I = I_{00}\exp(\beta T)\exp(\alpha U) \qquad (1)$$

where α and β are constants and for this structures have values: α=15, β=0.016 and I_{00}=5 × 10^{-12} A.

For higher biases the exponential current dependence on the applied voltage has a slope which depends on temperature. In this region the ln$I$=f(U) dependencies can be described by expression:

$$I = A^{*}T^{2}\exp\left(\frac{-\varphi_{Bn}}{kT}\right)\exp\left(\frac{qU}{nkT}-1\right) \qquad (2)$$

where A^{*} is Richardson constant for ZnSe - 20.4 A·cm^{-2}·K^{-2}.

Ideality factor:

$n = \left.\frac{\Delta U}{\Delta(\ln I)}\right|_{T=const}$ at 300 K has the value of 1.63 and at temperature variations from 113 K to 333 K varies from 2.86 to 1.47. Saturation current I_s at different temperature was estimated by extrapolation of ln$I$=f(U) curves of second region to zero biases. From ln(I_s/T^2)=f($10^3/T$) diagram the band gap value of 0.82 eV was estimated.

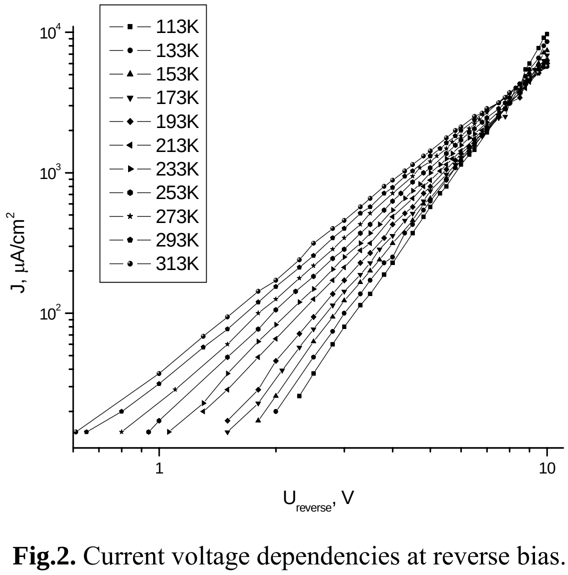

Fig.2. Current voltage dependencies at reverse bias.

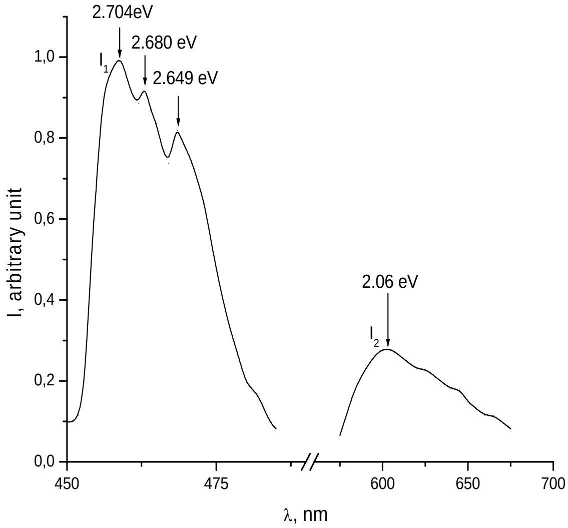

Fig.3. Electroluminescence spectrum of structures at 77 K (3-10 V).

From the value of the saturation current we determined that the value of φ_{Bn} is 0.94 eV at 300 K, that is in concordance with the value obtained by other methods.

The current voltage dependencies at reverse biases are described by a power function $I=AU^{m}$ with the power index varying from 3.93 at 113 K to 2.42 at 353 K, and where A is a constant.

At direct biases of 2 ÷ 3 V and T = 77 K Pd-ZnO-ZnSe structures emit blue light radiation. The electroluminescent spectrum of such structures at 77 K is shown in figure 3. Two luminescence bands can be observed: first is in the most intensive blue spectrum and the second in the red one. Electroluminescence probably is determined by the local centers formed in ZnSe by native defects (Zn or Se vacancies) and by the donor impurities. The red electroluminescence band can be related to so-called “self-activation”, caused by donor-acceptor radiation transitions. As centers of “self-activation” can serve the defects in ZnSe, formed by the Zn vacancy that with those of Se create complexes[6], and some donor impurities in group III and IV.

The blue band includes three peaks with the energies: 2.704 eV, 2.674 eV and 2.649 eV. First peak could be determined by the recombination of free electron with the holes formed by acceptor centers. The energy of the acceptor center was calculated by formula $E_{h\nu}=E_g-E_A+kT$, where E_g=2.812 eV at 77 K and it has the value of 0.12 eV and could be related to the crystal defects. The following peaks are located at distance 0.03 eV and are phononic replica [6].

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