THE OBTAINING AND INVESTIGATION OF PHOTOELECTRIC PROPERTIES OF HETEROJUNCTION ON THE BASE InP – CdS STRUCTURES

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The technology of epitaxial growth of the layers of CdS on the substrate of InP with the transversal layer p^+InP and without one is developed. The electrical, photoelectrical properties of the obtained heterojunctions are investigated and also the influence of the technological factors on *p*InP – *n*CdS heterostructure properties is studied.

The task of the widening of spectral range of the useable sources and radiation-measuring instrument appears during the development of the semiconductor electronics. As the semiconductor compounds $A^{III}B^{V}$ and the solid solutions on their base can't satisfy the demands of science and technique, so the creation of the "hybrid" heterojunctions, where the layer of $A^{III}B^{V}$ compound is used in the capacity of the one of the components, and the layer of the $A^{II}B^{VI}$ compound is used in the capacity of the another one, is the one of the ways of the task solving.

The heterojunctions InP-CdS′ present the special interest between many different variants, as the compounds, used in the given case, have the small disparity of lattice parameters $\frac{\Delta a}{a} = 0.3\%$ at 25°C, which practically doesn't change with the temperature increase.

Thus, the paper is dedicated to the treatment of the technology of epitaxial growth of the layers of CdS on the substrate of InP with the transversal layer p^+InP, to the investigation of the electrical, photoelectrical properties of the obtained heterojunctions and also it will study the influence of the technological factors on *p*InP – *n*CdS heterostructure properties [1].

The growth from the gas phase with the help of the transport reactions is the main method of the obtaining of the monocrystalline films of CdS nowadays. We prefer the open lubricating system in the equipment design, as the more technological one in the comparison with the soldered ampoule. The open system allows to rule more effectively by the growth and doping processes of the film, and also to carry out several consistent operations in the one installation.

Her main knots are:

1) The systems of purification, stabilization and measurement of helium flow; 2) gas-distribution system with the source of three-chlorine phosphate; 3) quartz reactor with the volume Cd or S; 4) four-band resistance furnace with the system of the regulation and temperature measurement.

The plates by the size $5\times10\times0.5 mm^3$, cut from InP monocrystal on the plane (I I I) with the exactness lower than 1°, were used in the capacity of the substrates.

As it is known, the state of the surface of the semiconductor substrate defines significantly the quality of the produced devices, their longevity and durability. That's why the obtaining of the high-quality surfaces of the semiconductor substrates, maximally perfect by the structure, geometry, homogeneous by the chemical nature and purity, is the especially important condition at the production semiconductor heterostructures.

On the assumption of the above mentioned, the influence of the composition of the isotopic chemical etchant, time and etchant temperature on the substrate was considered by us. It has established, that the best results are obtained in the case of the use of the green etchant on the base of sulphuric acid, hydrogene peroxide and water [1]. It significantly improves the quality the initial polish surface of the substrates, oriented in the planes (111) and (100) in optimal conditions at room temperature at volume ratio H_2SO_4:H_2O_2:H_2O=3:1:1.

The reactor with the sources of CdS, S or Cd and InP was put into cool furnace and the expulsions were carried out by the dosed helium flows, which were directed on the CdS source and flowed around it, the furnace bands were heating till given temperature and it was possible to carry out the growth process.

The special attention was paid to the creation of the fluent temperature gradient between furnace bands, that was the solving factor of the prevention of the spontaneous crystallization of CdS on the reactor walls. The temperature gradient depended on the temperature difference in the bands, but it was constant in all points of the furnace between bands (as at ΔT=50°C the gradient was 3°C/cm). Before the grafting the substrate was fixed in quartz holder and was put into cool corner of the reactor.

After the finishing of the grafting the substrate slowly was moved into cool corner of the reactor, cooled there and taken together with the holder. On this step the experiment was over, but the installation allowed us to carry out several experiments consistently without furnace cooling.

The growth velocity was defined on the results of substrate weighing before and after the experiment on the half-microanalytical weights with delicacy $1\cdot10^5$gr. The estimation of the value of the grown layer CdS was carried out on the formulae $d = \frac{\Delta m}{\rho \cdot S}$, where ρ are densities, Δm is CdS layer mass, S is sample square. In order to consider the decrease of the substrate weight because of the gas etchant, the prior experiments, in which the carry-over of InP from the substrate in the etchant conditions was investigated, were carried out. Further, the obtained average value of carry-over was summed to the all results.

It is established, that in the case of S excess in the gas phase under stoichiometric composition of the morphology, the surfaces of the CdS layer and crystalline structure change. It is shown, that with the help of the type of crystalline structure and morphology of epitaxial films of CdS it's possible to rule by the creation of the chalcogenide excess in

the gas phase at the one and the same temperature of the substrate.

Further, it is shown, that the possibility of the growth of the transversal layer of InP P^+ -type on the interface of *p*InP-*n*CdS heterojunction was foresaw in the device and the corresponding technological mode was chosen with the aim of the exclusion of the possibility of the erosion of surfaces of InP substrates.

For the investigation of the influence of the back *p*-*n*-homojunction on the *p*InP-*n*CdS properties of heterostructures, the technology was treated and *n*InP- *p*InP-*n*CdS heterohomojunctions are prepared by thermal evaporation in the vacuum of the epitaxial layer of CdS on *p*InP-*n*CdS homojunction. Moreover, the new method of obtaining of *p*InP-*n*CdS heterojunctions [2], which includes CdS precipitation in the closed volume at *T*=140-160°C on InP from the source, consisting its second half.

The roentgen-structural analysis showed that films have cubical structure and *p*InP – *n*CdS heterojunctions, prepared by the correspondence of the lattice parameters are close to the "ideal" ones.

The microroentgen-spectral, roentgen-difractional analysis and usual metallographical methods, which show, that the obtaining of *p*InP – *n*CdS structure has the strong heteroborder and mutual diffusion of the constituents is small in the chosen technological mode, are used with the aim of the study of the interface of the prepared heterojunctions, the definition of the composition and character of the distribution of main components in the epitaxial layers [2].

The typical volt-ampere characteristics of *p*InP – *n*CdS heterojunction with the transversal layer in the dynamic mode (*T*=300°K) is given on the fig.1. As it is seen from the fig.1 the investigated structure has the strongly expressed straightening: the rectification factor achieves the value 10^2 at *U=1V*.

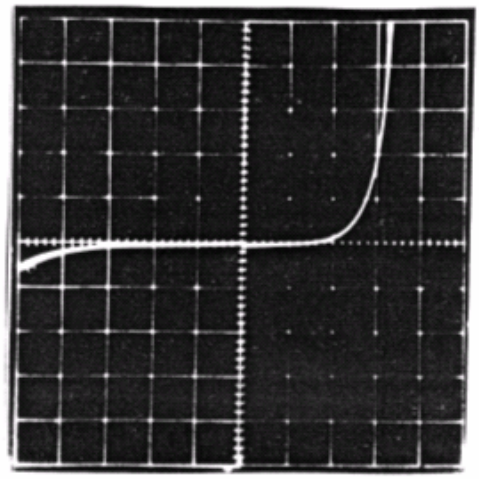

Fig.1. VAC of InP - CdS heterojunctions at *T*=300°K, on the point *J*=2mA; *U*=0.5V.

The volt-ampere characteristics have been investigated in the wide interval of the densities of the current and temperatures (80-300°K). The straight branches of these characteristics in the half-logariphmic scale are shown on the fig. 2. As it is seen the rectilinear regions, proving the exponential dependencies of the direct current on the voltage are observed on the straight branches of VAC at the all studied temperature range.

From the analysis of the tempo volt-ampere characteristics of *p*InP – p^+InP - *n*CdS structures with the transversal layer, investigated in the wide interval of densities of the current and temperatures (150-300K) is followed, that the current passing through in the temperature range 150-190K is explained by the method of the intraband tunneling of the thermally excited carriers. The mechanism of current passing through connects with the generation-recombination processes in the region of the volume charge in the temperature interval 240-300K and forward voltage $\frac{3KT}{q} < U < 0.5V$. The current passing through at the more high voltages (*U>0.5V*) is defined by Zener tunneling of the electrons from the valence band of the narrow-band material InP in the conduction band of wide-band CdS [3].

The volt-ampere characteristics of pInP – nCdS heterojunction at the different intensities of the lightening is shown on the fig.2.

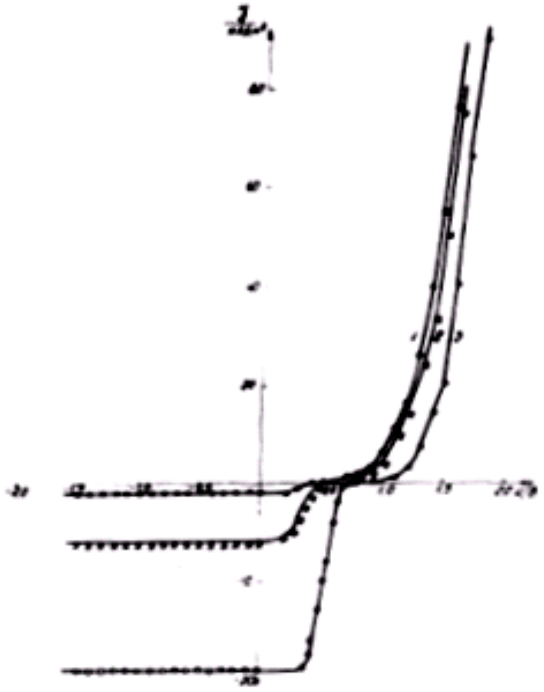

Fig.2. The volt-ampere characteristics of *p*InP - *n*CdS heterojunction with transversal layer at the different powers of the incident light:1 - 10MVt/cm^2; 2 - 25MVt/cm^2; 3-70MVt/cm^2.

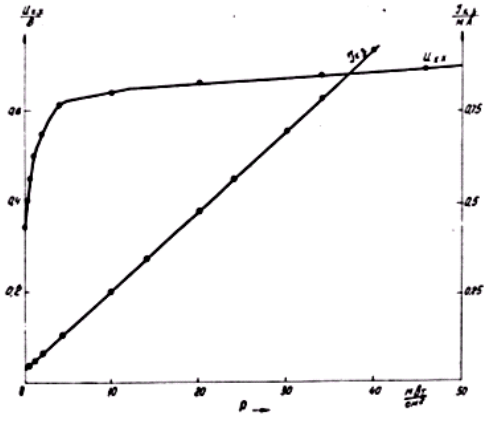

Fig.3. The dependence of open-circuit voltage U_{xx} and short-circuit photocurrent I_{sc} on the lightening.

The dependences of the open-circuit voltage U_{xx} (I) and short-circuit photocurrent density $J_{s.c.}$ (2) on the power of the fallen white light on the sample are shown on the fig.3. It is shown, that short-circuit photocurrent density linearly increase and the open-circuit voltage achieves the saturation with the increase of the power of the incident light.

The investigation of the open-circuit voltage dependence (U_{xx}) on the temperature showed, that the voltage (U_{xx}) in the range 77÷300K linearly decreases with the increase of the temperature coefficient $2 \cdot 10^{-3}$V/grad.

The open-circuit voltage and short-circuit photocurrent density for the best samples are U=750÷780mV and $J_{s.c.}$=30÷32mA/cm at the lightening of heterojunctions with the transversal layer by the white light of the power 90mV/cm^2.

The value of the open-circuit voltage and short-circuit photocurrent density are correspondingly equal to 740÷770mV and 15-17mA/cm^2 for *p*InP – *n*CdS heterojunction without transversal layer at the lightening by the light of the power 70mV/cm^2.

It is shown, that the strongly slump of the quantum output value in the short-wave region of the spectrum (λ<0.55mkm) is caused by the light absorption in the "thick" layer of CdS (5 mcm), the slow slump is observed at the decrease of the photon energy of recombination losses and at the increase of the scattering from the generation place of electron-hole till interface.

The photoelectric properties of *n* – Cd - *p*InP – *n*InP heterohomojunctions have also investigated.

The accumulation of the photocurrent sign and the appearance of the strongly negative maximum at the photon energy, which is equal to 1.35eV is characteristic for the samples with *n*InP – *p*InP - *n*CdS heterohomojunction. Moreover, the positive short-wave maximum saves (fig.4). As it is seen, the strong junction from maximal positive value till minimal negative value on the narrow region of the spectrum is observed in spectral characteristics, and the region of the sign change of short-circuit photocurrent is linear in the dependence on the wave length of fallen radiation. The analogical results have obtained for the spectral dependence of the photo-electromotive force also. The negative and positive maximums at photon energy 1,4eV are caused by two different competitive mechanisms. Whereas the negative maximum connects only with the separation of electron-hole couples on *p*InP - *n*InP homojunction, the positive maximum is caused by the accumulation in the conditional *n*CdS - *p*InP heterojunction. For the confirmation of the above mentioned the experiment, in which the spectral distribution of photocurrent of the sample with *p-n*-homojunction after co-polishing of CdS of main *p*InP - *n*CdS heterojunction was carried out. Moreover, the positive short-wave maximum disappears and negative maximum at 1,4 eV saves and doesn't change the sign. The analogical co-polishing on the samples without *p-n* homojunction has led to the total disappearance of the sensitivity.

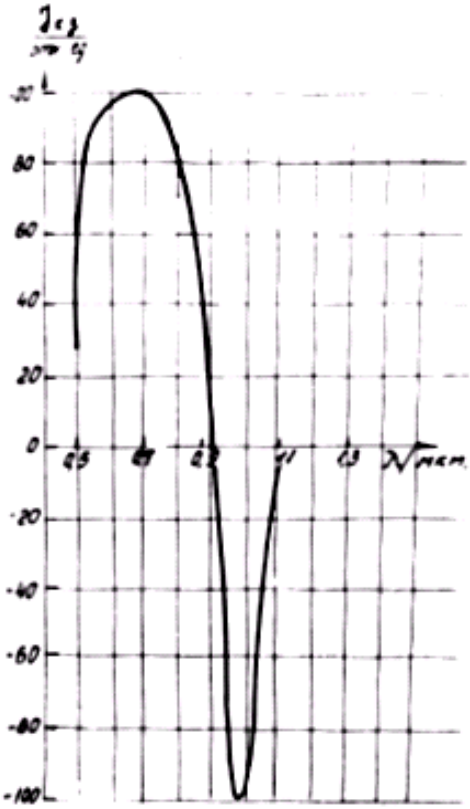

Fig.4. The spectral distribution of I_{sc} *n*InP - *p*InP - CdS heterohomojunction.

The energy band diagram of *p*InP - *n*CdS prepared heterojunctions with transversal layer on the interface and without it has constructed on the base of the experimental data. It is shown, that they describe Andersen midship, in which breaches of conduction band ΔE_c and valence band ΔE_g are equal to ΔE_c =-0.12eV; ΔE_g =1.26eV for the structure with transversal layer and ΔE_c =-0.06eV and ΔE_g - 1.20eV for the structure without transversal layer and energy "beam" is absent in the conduction band.

The main electrical and photoelectrical parameters (non-ideality coefficient of VAC, short-circuit photocurrent density, saturation current, surface recombination velocity, quantum efficiency, transformation efficiency of solar energy in electrical one) in *p*InP – p^+InP - *n*CdS heterostructures with transversal layer are better on 15-50% than in *p*InP – *n*CdS heterostructures without transversal layer. It is shown, that the improvement of the parameters of heterojunctions with transversal layer is caused by the decrease of the density of the recombination (defect) centers on the interface of *p*InP - *n*CdS structure, and also by the increase of contact electric field strength.

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InP – CdS STRUKTUR ƏSASLI HETEROKEÇİDLƏRİN ALINMASI VƏ ONLARIN FOTOELEKTRİK XASSƏLƏRİNİN ARAŞDIRILMASI

Fosfid indium altlığı üzərində keçidli p^+InP və keçidsiz laylı kadmiy sulfid laylarının epitaksial yetişdirilmə texnologiyası işlənilmişdir. Alınan heterokeçidlərin elektrik və fotoelektrik xüsusiyyətləri araşdırılmış, həmçinin texnoloji faktorların *p*InP – *n*CdS heterostrukturların xüsusiyyətlərinə təsiri öyrənilmişdir.

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ПОЛУЧЕНИЕ ГЕТЕРОПЕРЕХОДОВ НА ОСНОВЕ InP – CdS СТРУКТУР И ИССЛЕДОВАНИЕ ИХ ФОТОЭЛЕКТРИЧЕСКИХ СВОЙСТВ

Разработана технология эпитаксиального выращивания слоев сульфида кадмия на подложке фосфида индия с переходным слоем p^+InP и без переходного слоя. Исследованы электрические и фотоэлектрические свойства полученных гетеропереходов, а также изучено влияние технологических факторов на свойства *p*InP – *n*CdS гетероструктур.

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