Distribution of components in epitaxial graded band gap heterostructures Cd(Mn,Zn)Te – Cd(Mn,Zn)HgTe and their photoelectrical properties

O. I. Vlasenko, V. M. Babentsov, Z. K. Vlasenko, A. V. Ponedilok
Institute of Semiconductor Physics, NAS Ukraine, 45 prospekt Nauki, Kyiv, 252028, Ukraine zvlas@isp.kiev.ua

I. V. Kurilo, I. O. Rudyj
State University «Lvivska Politekhnika», 12 Stepan Bandera St., Lviv, 290646, Ukraine

V. V. Kremenitskiy
Technical Center, NAS Ukraine, 13 Pokrovska st., Kyiv, 254070, Ukraine

Abstract. By using the method of VPE CdMnTe-CdMnHgTe, CdZnTe-CdZnHgTe heterocompositions were fabricated. Increase of their photo-sensitivity in comparison with the CdTe-CdHgTe structure is explained by removal of deformation stresses due to introduction of isovalent component (Mn, Zn) of smaller size and due to reduction of recombination activity of non-equilibrium charge carriers in the film. Photo-sensitivity increase in the field of metallurgical boundary in the CdMnTe-CdMnHgTe structure under increase of the Mn contents up to $y \leq 0,08$ in comparison to the CdZnTe-CdZnHgTe structure is connected with more precise matching of lattices matching of the initial materials. Other models of this phenomena are also discussed, conditioned in particular, by the influence of micro- and macro- heterogeneities of the diffusion interface, peculiarities of P-T diagrams, etc. On the basis of comparison of experimental and calculated profiles of the components distribution, the values of diffusion coefficient in the substrate and growing film were obtained.

Keywords: graded band-gap films, photoconductivity, CdHgTe, CdMnHgTe, CdZnHgTe, vapor phase epitaxy, diffusion.

Introduction

Graded band-gap films used for infrared photoelectric devices with predetermined spectral characteristics are usually based on epitaxial heterostructures CdTe-CdHgTe [1, 2]. A number of methods have been developed to create structures with a tailored potential profile (vapor-phase, liquid-phase, or molecular beam epitaxy, metal-organic chemical vapor deposition, etc.), but one of the least expensive techniques is still the vapor phase epitaxy (VPE) [3, 4], with solid-phase substitution of Cd by Hg dominating in the substrate, and substitution of Hg by Cd taking place in the HgTe film being grown (simultaneously, the lattice constant is changing). In spite of the lattice constants being almost identical for the two limiting (binary) cases of CdHgTe (6,482–6,480 Å for CdTe and 6,460 Å for

HgTe) [5,6], the metallurgical interface is usually enriched with structural defects, in particular, mismatch dislocations, elastic deformations, gettered impurities, etc. [7, 8]. As shown in [8], this results in a significant deformation of the photoconductivity (PC) spectra of such structures. It is known that presence of smaller atoms in the crystal lattice may facilitate relaxation of elastic deformations and improvement of the structural perfection [9]. Particularly, $Cd_{1-y}Zn_yTe$ ($y = 2$–4 %) and $Cd_{1-y}Mn_yTe$ ($y < 10\%$) are known to exhibit the block-type structure to a lesser extent than CdTe [10,11]. In order to improve the structural perfection and recombination parameters of epitaxial CdHgTe films, particularly near the metallurgical interface, we used in this work ternary compounds $Cd_{1-y}Zn_yTe$ and $Cd_{1-y}Mn_yTe$ ($y < 10$ %) as substrates for growth of graded-gap films.
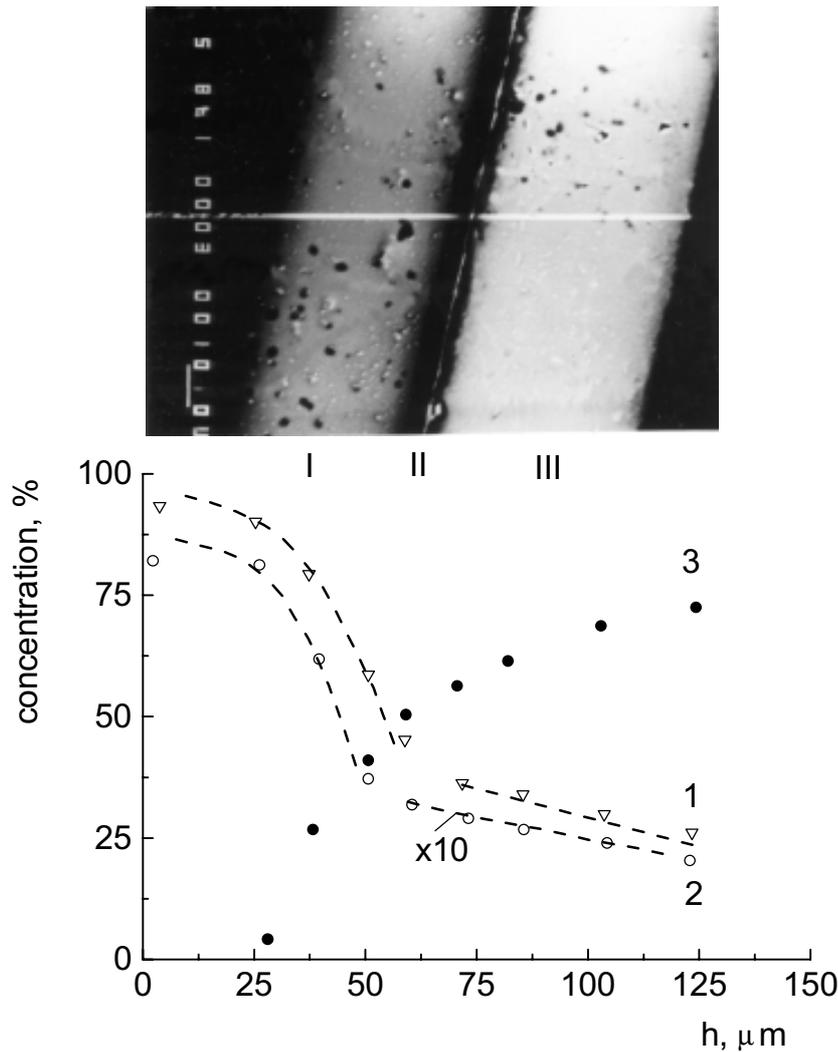
Fig. 1. Secondary electron image of a cleaved surface of a $Cd_{1-x-y}Mn_yHg_xTe/Cd_{1-y}Mn_yTe$ structure – a; experimental (dots) and calculated (solid lines) distribution of concentration of Cd(1), Mn(2), and Hg(3) over $Cd_{1-x-y}Mn_yHg_xTe$ layer – b.

Experimental technique

Epitaxial films of $Cd_{1-x-y}Mn_yHg_xTe$ (CMMT) and $Cd_{1-x-y}Zn_yHg_xTe$ (CZMT) were deposited by isothermal-mode VPE [3] on (111)-oriented substrates made from single crystals of $Cd_{1-y}Mn_yTe$ (CMT) and $Cd_{1-y}Zn_yTe$ (CZT) (y = 2–10 %), with finely divided HgTe powder used as source. The films grown by this technique had a thickness varying from 120 to 150 μm and a mirror-smooth surface, with mercury content at the surface corresponding to the composition x ~ 70-75 %.

For measurements of photoelectrical characteristics, ohmic contacts were deposited using the conventional technique (see, for example, [12]) on the end planes of the film, including also the end planes of the substrate, or on the film surface, depending on the experimental conditions.

The composition of the substrates and the composition profile in the films were determined by electron beam probe X-ray spectral microanalysis (using X-ray microanalyser

GEOL ICXA-733), with electron beam diameter ~ 2 μm, X-ray return depth < 3 μm, and measurement step from 10 to 15 μm. The profile of Cd, Mn, Zn, Hg and Te distribution in CMMT and CZMT films was measured using a cleaved surface perpendicular to the film plane. Photoconductivity and optical transmission spectra were measured in the range from 2 to 15 μm.

Experimental results and discussion
Composition profiles of epitaxial films

Analysis of the composition profiles using transversal cleaved surfaces revealed the presence in the films, in addition to the main components (Cd and Hg), of isovalent impurities (Mn or Zn) contained in the substrates (CMT and CZT, respectively). This is caused by diffusion of the isovalent component from the substrate to the film during the process of epitaxial growth. As a result, the films consist

of a quaternary material (CMMT or CZMT) with the content of metallic components varying over the depth. Therefore, the films have a graded band gap. This is illustrated by fig. 1 (a, b), which shows the secondary electron image of a cleaved surface of a CMT-CMMT structure, with Mn content in the substrate of 8 %, and the profiles of Cd, Mn, and Hg distribution. These structures have three distinct regions (fig. 1): I - the diffusion region, II - the metallurgical interface, and III - the epitaxial diffusion region. The metallurgical interface between the substrate and the film divides the heterostructure into the diffusion region (D) with the thickness $H_d(t)$ and the epitaxial diffusion region (ED) with the thickness $H_{ed}(t)$.

The diffusion coefficients for Cd, Mn and Zn were estimated by comparison of the distribution profiles measured by electron beam probe X-ray spectral analysis to the profiles calculated for diffusion of impurities from the uniformly doped substrate to the film [13].

Though this approach is essentially simplified, we would like to note that the process of mutual diffusion of Cd (Zn, Mn) and Hg in the region of the substrate material and in the region of the HgTe film being grown is satisfactorily described by two values of the diffusion coefficient $D_1(y)$ i $D_2(y)$ which are quasi-independent of the composition. It is seen from fig. 1 that cadmium diffusion in the diffusion layer $H_d(t)$ in the case of $N_{Cd} \gg N_{Hg}$ is described by the diffusion coefficient $D_1 = 10^{-9}$ cm^2/s. The numerical value of D_1 obtained for this film is quite close to the diffusion coefficient of Cd by the case of vacancy mechanism in the case of CdTe annealing in Cd vapors [14], which indicates a similarity of the diffusion processes, despite the great difference of the concentrations of the diffusing components (10^{16} cm^{-3} and 10^{23} cm^{-3}).

The layer of epitaxial and diffusion origin ($H_{ed}(t)$) can be described by Cd diffusion with a quasi-constant value of the diffusion coefficient $D_2 = 10^{-7}$ cm^2/s, which is almost by two orders of magnitude larger than D_1.

Fig.1 (b) shows also the calculated and experimentally measured curves of Mn distibution. A satisfactory agreement between the experimental and computed curves for Mn and Zn distribution (D_{Mn} and D_{Zn}) is obtained for the same values of the diffusion coefficients as in the case of cadmium. To match the experiment and theory more exactly, one should take into account also the effect on the diffusion of the elastic deformation, internal electric field in the films being grown, and other factors.

One can see from table 1 that the thickness of the diffusion region in the case of growing a narrow-gap semiconductor film on the CMT substrate is, on the average, much larger (by 25–30 %) than that in the case growing a narrow-gap semiconductor film on the CZT substrate. This effect can be associated with the fact that the process of solid-phase substitution of Cd with Hg is easier in the case of CMT substrate in comparison to the CZT substrate, so that the diffusion border moves over the same period of time more deeply into the substrate. It is likely that the rate of the solid-phase substitution process depends on the presence of the isovalent impurity (Mn), which results in a higher plasticity of the crystal [15].

Comparison of the parameters of Mn and Zn atoms (table 2) shows that the significant difference between them consists in the structure of the next-to-last electronic layers. This difference is likely to result in the influence of the d-shell electrons on the weakening of the bond between Cd and Te in the case of CMT. Strengthening of CZT in comparison to CMT is explained by reduction of the bond length between the atoms (in the two extreme cases of CdTe and ZnTe, the lattice constants are very different: 6,482 Å for CdTe and 6,1037 Å for ZnTe [5]). This is manifested also through the difference in the melting temperatures of ZnTe ($T_{melt} = 1290°C$ [5]) and CdTe ($T_{melt} = 1092°C$ [5]). For MnTe, $T_{melt} = 1167°C$ [5] and the lattice constant (6,345 Å [16, 23]) do not agree with the dependence mentioned above; this can be caused by the fact that the lattice struc-

Table 1. Geometrical sizes of diffusion and epitaxial diffusion regions in CMHT, CHT, and CZHT films.

Sample	$Cd_{1-r-y}Mn_yHg_rTe$, Mn = 8%	$Cd_{1-r-y}Mn_yHg_rTe$, Mn = 3,2 %	$Cd_{1-r}Hg_rTe/CdTe$	$Cd_{1-r-y}Zn_yHg_rTe$, Zn = 5,2 %	$Cd_{1-r-y}Zn_yHg_rTe$, Zn = 3,7 %
$H_d(t)$, μm	33	29	27	20	22
$H_{ed}(t)$, μm	45	38	50	32	30

Table 2. Comparative characteristcs of constituent atoms for solid alloys CdMnTe, CdZnTe [6].

Atoms	Atomic weight	Atomic radius, nm	Ion radius E^{+2}, nm	Structure of atom outer layers
Cd	112,40	0,156	0,099	$4s^2 4p^6 4d^{10} 5s^2$
Te	127,60	0,170		$4s^2 4p^6 4d^{10} 5s^2 5p^4$
Zn	65,38	0,139	0,083	$3s^2 3p^6 3d^{10} 4s^2$
Mn	54,94	0,130	0,091	$3s^2 3p^6 3d^5 4s^2$

ture in CMT changes from cubic to hexagonal at $y \geq 0,7$. The lower strength of CMT in comparison to CdTe or CZT may also result from the likely presence of $MnTe_2$ inclusions formed at T = 735°C [17], which is lower than the melting point of CdTe. Microinclusions of $MnTe_2$ are quite likely to appear in the presence of excess Te in the material. The effect of Mn-enriched inclusions on the electrical properties of CdMnTe was reported in [11].

The border of the diffusion layer in the substrate

As the graded band gap structures described above are promising as a material for photosensitive IR elements employed in optoelectronic systems, it is important to study the issue of the abruptness of Hg-enriched diffusion border in the substrate and its effect on the optical properties of the structure, particularly, on the additional reflection and scattering of light, which may reduce the quantum efficiency and result in peculiarities of the photoelectrical spectra.

The homogeneity of the Hg diffusion front in the substrate can be assessed by characteristic lines of the low-temperature photoluminescence (LTPL) spectra. Fig. 2 shows the LTPL spectra of the initial substrate material CdTe (curve 1) and its layer at the border of the diffusion region in the surface after etching off the CdHgTe layer (curve 2). The line marked I_1 is associated with recombination of excitons bounded to neutral excess acceptors, such as Li_{Cd}, Na_{Cd}, Cu_{Cd} or P_{Te}, As_{Te}; the weak line marked I_2 is attributed to excitons bounded to neutral donors (same residual impurities in the interstitial sites).

We would like to note that LTPL spectra after growth deep in the substrate are not significantly different from those for the initial material, which indicates the absence of essential transformation of the intrinsic defect structure in CdTe under the action of annealing in the process of growth.

At the border of the diffusion region located in the bulk of the substrate, the LTPL spectra are essentially different (compare curves 1, 2 in fig. 2): the halfwidth of I_1 line increases almost fivefold, while its intensity drops by a factor of more than 50. The change in the intensity can be explained by substitution of the group I atoms (Li, Na, Cu, Ag) with Hg in cadmium sublattice and, therefore, reduction of the acceptor concentration, similarly to the case of p-CdTe annealing in Cd vapors [14]. The light donor impurity coming from A_2 sites, which is responsible for the I_2 line, in the process of growth diffuses back from the crystal through the «fluffed» diffusion and epitaxial diffusion layers, thus decreasing the intensity of I_2. This agrees with the data [18] obtained for p-CdTe annealed in Hg vapors.

A significant widening of the I_1 line towards longer wavelengths may be associated with microscopic inhomogeneities of this region, caused by distortions of CdTe lattice upon accommodation of Hg atoms, i.e. microfluctuations with narrowed band gap (similar spectra
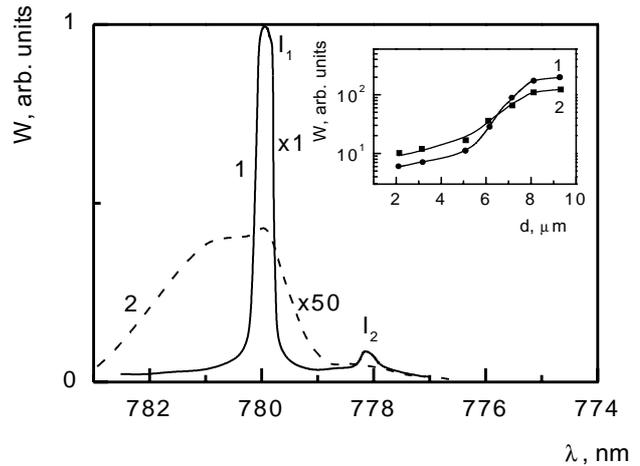
Fig. 2. Low temperature photoluminescence (LTPL) spectra (lines I_1, I_2): deep in the substrate CdTe – curve 1, layer at the border of the diffusion region located in the bulk of the substrate – curve 2. Inset: intensity distribution of (LTPL) lines I_1, I_2 over the distance from diffusion border, d is the thickness of etched layer.

of LTPL were observed in CdHgTe with $x \geq 0.99$ [19]), local inhomogeneities of the impurity content (formation of regions with acceptor concentration exceeding 10^{18} cm^{-3} – spectra of this type were reported in [20] for the case of impurity gettering on the surface in the process of annealing). If the material is enriched with Hg or doping impurity inhomogeneously, the position of I_1 varies, resulting in a widening of this line. Therefore, as the X-ray spectral analysis data show that the diffusion border in the substrate is uniform, this may indicate its inhomogeneity by front and depth.

The thickness and the doping profile of the CdTe layer transformed in the process of epitaxy may be assessed by the distribution of intensity of I_1 and I_2 LTPL lines while the sample is subjected to step-by-step etching (see insert in fig. 2). The thickness of this layer is seen to be as high as 10 μm. A faster reduction of the I_1 intensity in comparison to I_2 when moving from the substrate to the diffusion border may indicate the different rates of Hg substitution for light impurities in Cd sites (reduction of acceptor concentration, and thus of I_1 intensity) and its subsequent rediffusion through the «fluffed» layers to the free volume of the capsule (reduction of donor concentration, and thus of I_2 intensity).

Photoconductivity spectra

Fig. 3 (a, b) shows photoconductivity spectra of CdTe-CdHgTe, CdMnTe-CdMnHgTe and CdZnTe-CdZnHgTe illuminated from the substrate side.

We would like to note that structures containing Mn and Zn were photosensitive immediately after growth, structures containing Mn had even somewhat larger absolute
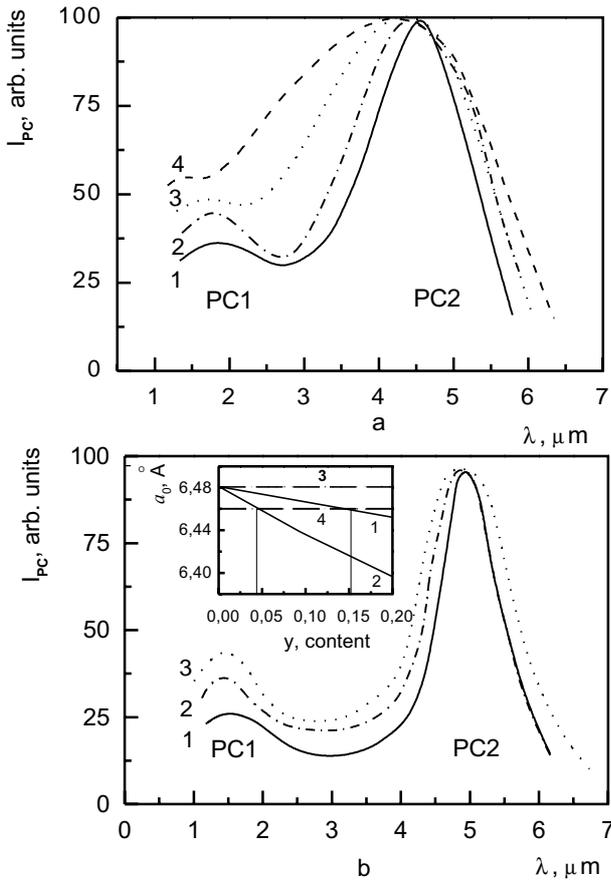
Fig. 3. Photoconductivity spectra of graded-gap films at 77K (illuminated from the substrate side): a – $Cd_{1-x-y}Mn_yHg_xTe$ (y, %: 1 – 0; 2 – 3,2; 3 – 6,7; 4 – 8,0), б – $Cd_{1-x-y}Zn_yHg_xTe$ (y, %: 1 – 0; 2 – 3,7; 3 – 5,2). Inset: lattice constant a_0, Å as a function of content y: CMT – curve 1, CZT – curve 2 (solid lines); 3, 4 – values a_0 for CdTe and HgTe relatively (dashed lines) [23].

2.5 μm is associated with photosensitivity of the substrate material in the diffusion region. The «dip» of photosensitivity in the range of medium wavelengths (2,5–3,5 μm) is caused by an increase of the recombination rate in the vicinity of the metallurgical interface. The long-wave photosensitivity band (PC2), caused by generation and recombination in the epitaxial film, is observed for the wavelength range from 3.5 to 6 μm, corresponding to Hg content ≈ 75 % near the film surface.

The higher photosensitivity near the metallurgical interface for CdMnTe-CdMnHgTe and CdZnTe-CdZnHgTe in comparison to CdTe-CdHgTe is obviously caused by a smaller difference between the lattice constants of the substrate and film in the case of structures containing Mn and Zn (see insert in fig. 3(b)). Also, addition of an isovalent impurity (Mn, Zn) with atom size smaller than that of the main component (see table 2) when growing single crystals of semiconducting compounds facilitates relaxation of lattice strains and results in a smaller density of macroscopic defects (dislocations, inclusions of a different phase, etc.). The mechanism of strain relaxation by adding smaller atoms to the melt is described, for example, in [9]. This mechanism is not specific for this case, and is observed for other semiconducting compounds as well. We should expect that at the initial stage of the growth the films of quaternary compounds CdMnHgTe and CdZnHgTe containing atoms of Mn i Zn have lower concentrations of defects in comparison to CdHgTe. This is a possible reason for a higher photosensitivity of the film region corresponding to the metallurgical interface.

One can see from fig. 3(a), the depth and spectral width of the photosensitivity «dip» observed between the PC1 and PC2 bands are significantly decreasing with the growth of Mn content. This effect is less pronounced in Zn-containing structures (fig. 3(b)).

In our opinion, the main reason for the difference between the PC spectra of the above-mentioned structures is a closer matching of the substrate and film lattices for CdMnTe than for CdZnTe (see insert in fig. 3(b)); this is manifested in a loss of photosensitivity in the medium-wavelength range for CdZnTe-CdZnHgTe hetero-structures. Note that for $y_{0Zn} \approx 0,04$ in the case of CdZnHgTe and for $y_{0Mn} \approx 0,15$ in the case of CdMnHgTe the lattice parameters a_0 of HgTe and these materials are equal. Therefore, in CdMnTe-CdMnHgTe for the range of Mn content in the substrate ($0 < y < 0.1$) studied by us, the lattice parameter a_0 of the substrate remains higher than that of the film, and this difference decreases when y rises up to $\approx y_{0Mn}$. In the case of CdZnTe-CdZnHgTe, for the substrate with Zn content $y \approx 3.7\%$ the lattice parameter a_0 of the substrate is higher than that of the film, for the substrate with $y \approx 5.2$ % it is, on the contrary, lower, and this difference rises with further growth of Zn content. These mismatches are associated, in particular, with deformations and bending of the structures, formation and location of dislocation fields, formation of cracks and so on. These issues were considered by us in [7]. As the dependence of $a_0(y)$ for CdZnHgTe is stronger than for CdMnHgTe, we should expect that the existing technologies are capable

values of photoconductivity, while CdTe-CdHgTe structures fabricated in similar conditions were not photosensitive without additional annealing in Hg vapors. This may be associated with the fact that the state of the defect structure (first of all, the concentration of vacancies in the cation sublattice), as shown by the P-T-x diagrams of these systems (see, for example, [21]), and thus the «dark» concentration of charge carriers in CdMnHgTe, CdZnHgTe, and CdHgTe with equal content of Hg obtained in the same conditions (P and T) will be different. This may be manifested through the differences in the spectral range and intensity of the photosensitivity. For example, reduction of the concentration of intrinsic carriers in the case of band-to-band impact mechanism of recombination will result in a lower rate of the Auger process and a higher photosensitivity of the material [12]. The same conclusion can be made for the Schokley-Read mechanism of recombination (see, for example, [22]).

Photoconductivity spectra have a complex shape (fig. 3). The photoconductivity band (PC1) in the range from 1 to

of achieving a more exact lattice matching for the case of CdMnTe-CdMnHgTe. The differences between the PC spectra of the above-mentioned structures can be caused also by different influence of the microscopically nonuniform diffusion surface in the substrate (see above) on the light scattering and transmission to the graded-gap region, and this surface can play the role of a rough internal surface with different roughness characteristics for the cases of CdTe-CdHgTe, CdMnTe-CdMnHgTe, CdZn-CdZnHgTe and, therefore, different intensities and spectra of reflection and scattering. The negative role of these regions is likely to increase in the case of formation of Hg-enriched coagulation inclusions with the band gap narrower than that of the matrix, where light will be complete absorbed before reaching the graded-gap layer. The contribution of microscopic nonuniformities to the formation of optical and photoelectrical characteristics of the structures invites further studies.

Another reason is that the ZnTe homogeneity region is always located on the side of Te excess and coincide with the HgTe homogeneity region, in contrast to MnTe which homogeneity region lies both on the side of Te and Mn excesses. Thus, in CZT and CMT the homogeneity regions close to stoichiometric compositions (with low concentration of charge carriers and dark photoconductivity) do not coincide, i.e. under the same growth conditions an insensitive region of CHT and CZHT (with high dark concentration of intrinsic carriers) can appear for some ranges of content x, y. In case of CMHT, it can have lower dark photoconductivity and be photosensitive.

In optical transmission spectra of CMT-CMHT and CZT-CZHT structures, the range of the long-wave increase of the transmission coefficient generally corresponds to photosensitivity band, however, this is not always the case. The reason can be explained by spectral features of optical density for the structures with different band gap gradients (for example, see [24]) and by micrononuniformity of diffusion border in the substrate.

Conclusions

• Graded band gap films of quaternary compounds CMHT and CZHT were grown by isothermal-mode VPE on the CMT and CHT substrates.
• The values of diffusion coefficient were obtained for Cd, Mn, Zn in the uniform layer of the substrate $D_1 = 10^{-9}$ cm²/sec and in the epitaxial diffusion region $D_2 = 10^{-7}$ cm²/sec.
• General increase of photosensitivity of CMT-CMHT and CZT-CZHT epitaxial structures in comparison with CT-CHT were detected which can be associated, particularly, with the presence of an isovalent component of smaller size (Mn, Zn) resulting in relaxation of elastic deformations and decrease of concentration of active recombination defects.
• Intensity decrease and line broadening for low-temperature photoluminescence caused by recombination of excitons bounded to acceptors and donors were detected in the CdTe substrate near the diffusion boundary indicating its microinhomogeneity by front and depth.

• Photosensitivity «dip» decreasing with the growth of Mn content was observed in CMT-CMHT structures in the range of medium wavelengths corresponding to the metallurgical interface region. It can be associated primarily with closer matching of the substrate and film lattices than for CT-CHT and CZT-CZHT cases. Other possible reasons of this phenomenon were also discussed.

References:

1. L. A. Bovina, V. P. Meshcheryakova, L. K. Klyukin, V. I. Stafeyev, *FTP* (Soviet Phys. - Semicond., in Russian)*,* **7**(12), pp. 2301–2304 (1973)
2. A. I. Vlasenko, *Optoelectronics and semiconductor engineering* (in Russian), 31, pp. 191–194 (1996).
3. O. Tufte, E. Stelzer, «Growth and properties of epitaxial layer», *J. Appl. Phys.*, **40**(11), pp. 4559–4568 (1969).
4. V. Iovic, A. Vujanic, Z. Duric, «Determination of the composition profiles of (Hg,Cd) Te epitaxial layers», *J. Serb. Chem. Soc.,* 59(9), pp. 645–653 (1994)*.*
5. V. A. Rabinovich, Z. Ya. Khavin, *Short chemical handbook* (in Russian)*,* Leningrad: Khimia Publ., (1978).
6. A. V. Novoselova, V. B. Lazarev et al. *Physical-chemical properties of semiconductor materials* (in Russian). Handbook, Moscow.: Nauka Publ., (1979).
7. I. V. Kurylo, I. O. Rudoy, O. I. Vlasenko (in Ukrainian), *Ukr. Phys. J.,* **43**(2), pp. 207–212 (1998).
8. A. Vlasenko, V. Babentsov, I. Rudoy, Z. Vlasenko, «Advanced study of ISO VPE IR Photosensitive CdHgTe/Cd Te structure», *Proc. 20th International Conference on microelectronics (MIEL' 95),* NIS, Serbia, **1**, pp. 53–56 (1995).
9. W. Walukiewicz, «Dislocation density reduction by isoelectronic impurities in semiconductors», *Appl. Phys. Lett.*, (20), pp. 2009–2011 (1989).
10. P. Cheuvart, U. H. Hanani, D. Scheider, R. Tribulet, «CdTe and CdZnTe crystal growth by horisontal Bridgman technique», *J. Crystal Growth.,* **101**(1–4) pp. 270–274 (1990).
11. A. I. Vlasenko, V. N. Babentsov, Z. K. Vlasenko, S. V. Svechnikov et al., *FTP* (Soviet Phys. – Semicond., in Russian)*,* **31**(8), p.p. 1017–1020 (1997).
12. A. I. Vlasenko, Yu. N. Gavrilyuk, A. V. Lyubchenko, Ye. A. Salkov, *FTP* (Soviet Phys. – Semicond., in Russian)**, 13**(11), p.p. 2180–2185 (1979).
13. G. B. Abdullayev, T. D. Dzhafarov, *Atomic diffusion in semiconductor structures* (in Russian)*,* Moscow: Atomizdat Publ., (1980).
14. V. N. Babentsov, Z. K. Vlasenko, A. I. Vlasenko, A. V. Lyubchenko, *FTP* (Soviet Phys. – Semicond., in Russian)*,* **31**(5), pp. 523–525 (1997).
15. S.B. Qadri, E.F. Skelton, A.W. Webb, J. Kennedy, «The effect of Zn and Mn on Cd-Te bond strength in $Cd_{1-x}Zn_xTe$ (x = =0,04 ± 0,01) and $Cd_{1-x}Mn_xTe$ (x = 0,1 ± 0,005)», *Physica,* **139–140B**(1), pp. 341–342 (1986).
16. S. V. Kavertsev, A. Ye. Belyayev, *FTP* (Soviet Phys. – Semicond., in Russian)*,* **31**(3), p.p. 342–346 (1997).
17. L. P. Shcherbak, *Optoelectronics and semicondactor engineering* (in Russian), 31, p. 39–44 (1996).
18. K. Ohba, Y. Hiratate, T.Taguchi, A.Hiraki, «Photoluminescence of CdTe crystals annealed in Hg», *Nuclear Instrum. and Methods in Phys. Res.* **A283**(2), pp. 265–267 (1989).
19. A. Lusson, R. Legros, Y. Marfaing, H. Mariette, «Excitonic luminescence and exciton localization in alloys», *Proc. 19*[th] *Int. Conf. On Phys. Of Semicond.*, Warsaw, Poland, **2**, pp. 1319–1322 (1988).
20. V. Babentsov, S.Gorban, G. Zhovnir, L.Rashkovetskii, «Behavior of accidental Li impurities in high-resistivity cadmium telluride subjected to brief annealing», *Sov. Phys. Semicond.*, **25**(4), pp. 456–458 (1991).

21. N. P. Gavaleshko, P. N. Garley, V. A. Shenderovsky, *Narrow-gap semiconductors: production and physical properties* (in Russian), Kyiv: Nauk. Dumka Publ., (1984).

22. A. I. Vlasenko, Z. K. Vlasenko, A. V. Lyubchenko, *FTP* (Soviet Phys. – Semicond., in Russian),**31**(11), p.p. 1323–1326 (1997).

23. N.N. Berchenko, V.Ye. Krevs, V.G. Sredin. *Semiconductor solid alloys and their applications* (in Russian), Moscow: Voyenizdat Publ., (1982).

24. G.P. Peka, F.V. Kovalenko, A.I. Smolyar, Ch. 2 «Optical properties of graded band-gap semiconductors» in *Graded band-gap semiconductrors,* pp. 36–37, Kyiv: Vyshcha Shkola Publ., p. 252 (1989).

РОЗПОДІЛ КОМПОНЕНТ В ЕПІТАКСІЙНИХ ВАРІЗОННИХ ГЕТЕРОСТРУКТУРАХ Cd(Mn,Zn)Te – Cd(Mn,Zn)HgTe І ЇХ ФОТОЕЛЕКТРИЧНІ ВЛАСТИВОСТІ

О. І. Власенко, В. М. Бабенцов, З. К. Власенко, А. В. Понеділок
Інститут фізики напівпровідників НАН України

І. В. Курило, І. О. Рудий
Державний університет «Львівська політехніка», Україна

В. В. Кремениць кий
Технічний центр НАН України

Резюме. Методом ПФЕ одержані гетерокомпозиції CdMnTe-CdMnHgTe (КМТ-КМРТ), CdZnTe-CdZnHgTe (КЦТ-КЦРТ). Підвищення їх фоточутливості порівняно із структурою CdTe-CdHgTe (КТ-КРТ) пояснюється зняттям деформаційних напруг завдяки введенню ізовалентної складової (Mn, Zn) меншого розміру і зниженням рекомбінаційної активності нерівноважних носіїв заряду в плівці. Збільшення фоточутливості в області металургійної границі в структурі КМТ-КМРТ при збільшенні вмісту Mn до $y \leq 0,08$ порівняно із структурою КЦТ-КЦРТ пов'язується з більш прецизійним узгодженням параметрів кристалічних граток вихідних матеріалів. Обговорюються і інші моделі цих явищ, пов'язані, зокрема з впливом мікро- і макро неоднорідностей дифузійної границі, особливостями P-T-x діаграм і інш. На основі співставлення експериментальних і розрахункових профілів розподілу компонент отримані значення для їх коефіцієнтів дифузії в підкладці і наростаючій плівці.

РАСПРЕДЕЛЕНИЕ КОМПОНЕНТ В ЭПИТАКСИАЛЬНЫХ ВАРИЗОННЫХ ГЕТЕРОСТРУКТУРАХ Cd(Mn,Zn)Te – Cd(Mn,Zn)HgTe И ИХ ФОТОЭЛЕКТРИЧЕСКИЕ СВОЙСТВА

А. И. Власенко, В. Н. Бабенцов, З. К. Власенко, А. В. Понедилок
Институт физики полупроводников НАН Украины

И. В. Курило, И. О. Рудый
Государственный университет «Львовская политехника», Украина

В. В. Кремениц кий
Технический центр НАН Украины

Резюме. Методом ПФЭ получены гетерокомпозиции CdMnTe-CdMnHgTe, CdZnTe-CdZnHgTe. Повышение их фоточувствительности по сравнению со структурой CdMnTe-CdTe-CdHgTe объясняется снятием деформационных напряжений благодаря введению изовалентной составляющей (Mn, Zn) меньшего размера и снижением рекомбинационной активности неравновесных носителей заряда в пленке. Увеличение фоточувствительности в области металлургической границы в структуре CdMnTe-CdMnHgTe при увеличении содержания Mn до $y \leq 0,08$ по сравнению со структурой CdZnTe-CdZnHgTe связывается с более прецизионным согласованием параметров кристаллических решеток исходных материалов. Обсуждаются и другие модели этих явлений, обусловленные, в частности, влиянием микро- и макро неоднородностей диффузионной границы, особенностями P-T-x диаграмм и др. На основе сопоставления экспериментальных и расчетных профилей распределения компонент получены значения коэффициентов диффузии в подложке и нарастающей пленке.