RESEARCH of INITIAL STRUCTURES FOR SOLAR ELEMENTS

A.V. Karimov, D.A.Karimova, O. Khimmatkulov, E.N. Yakubov

Physical-Technical Institute of the Scientific Association "Physics-Sun" of the Academy of Sciences of the Republic of Uzbekistan, Tashkent, Mavlanova 2b, Tashkent 700084
Fax:++ 998-712-354291, e-mail. karimov@physic.uzsci.net

Abstract

The results of research of active area and itself heterostucture $pAl_xGa_{1-x}As$-pGaAs-nGaAs-n^+GaAs are given, in which the area nGaAs represents a buffer layer. The pGaAs area of structure is formed automatically at escalating of a top large-band-gap layer $pAl_xGa_{1-x}As$ from quasi-closed volume, for the account duffusion of p-type impurity, of a solution-melt (Al+Ga+GaAs:Zn) and formed firm solution $pAl_xGa_{1-x}As$, in a buffer nGaAs-layer. The offered approach can be used for creation of effective heterostructure solar elements such as $pAl_xGa_{1-x}As$-pGaAs-nGaAs-n^+GaAs.

Keywords: surface; structures; solar elements; epitaxial; photosensitivity.

1. Introduction

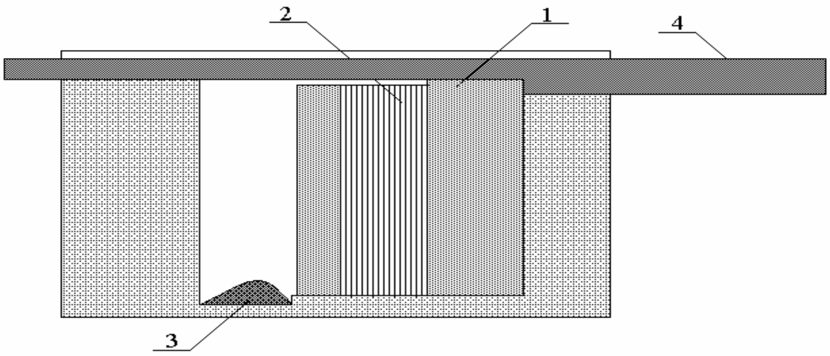
The wide circulation in space power stations was received by solar elements on a basis of heterostructure $pAl_xGa_{1-x}As$-pGaAs-nGaAs-n^+GaAs, where n^+GaAs represents a substrate of arsenide gallium n-type conductivity with concentration of carriers $\sim 10^{18}$ см$^{-3}$. In the given structure top the large-band-gap layer $pAl_xGa_{1-x}As$ serves as a window and simultaneously reduces superficial recombination. If for reduction of losses ($S_i < 10^{\ 4}$ cm/s) the thickness of the top layer is necessary for making as small as possible (0.2-0.4 microns), for preservation of required consecutive resistance ($4{\cdot}10^{-5}$ - $4{\cdot}10^{-4}$ Ohm·cm^2) its minimal thickness has the restrictions. Besides the basic active area nGaAs in many respects determines final parameters of solar elements, than more perfectly this area, the is less than losses (e.g. Fahrenbruch et al., 1983). The researches of properties of this area can be carried out both in ready $pAl_xGa_{1-x}As$-pGaAs-nGaAs-n^+GaAs-structure, and on the basis of preliminary structure with a barrier Shottky such as m-nGaAs-n^+GaAs (e.g. Shur 1987). At the same time, in base homo-pGaAs-nGaAs-junction it is necessary to receive small return currents.

Thus, in $pAl_xGa_{1-x}As$-pGaAs-nGaAs-n^+GaAs structure of a solar element the increase of efficiency of transformation to decide a task of optimization of parameters of its active areas.

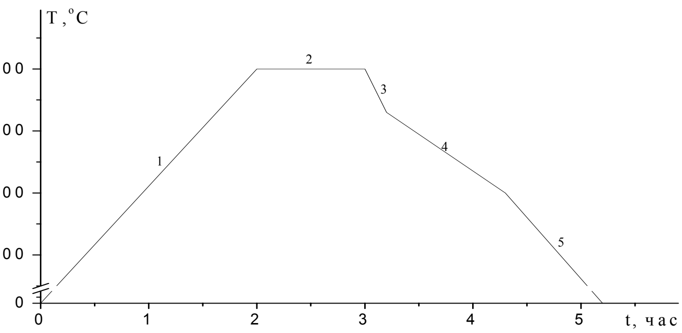
In the present work the results of research heterostructures for photoconverters are given, in which the pGaAs difussion area is generated in the buffer epitaxial nGaAs layer in uniform technological process of cultivation of a superficial $pAl_xGa_{1-x}As$ layer.

2. Experimental samples

The layers $pAl_xGa_{1-x}As$-pGaAs-nGaAs-n^+GaAs forming of heterostructure can be received by various ways, including method of liquid-phase epitaxy. We design the device of epitaxial cultivation of arsenide gallium and its connections from the liquid phase for reception $pAl_xGa_{1-x}As$-pGaAs-nGaAs-n^+GaAs structure of a solar element (fig. A1). With this device carried out growth of epitaxial layers in installation with is horizontal located (inside the furnace of resistance) quartz reactor, blown flow of the cleared hydrogen. Unalloyed polycrystalline arsenide gallium used as a source for saturation melts (Ga+GaAs). As substrates the monocrystal plates GaAs with concentration of carriers n~$10^{17}cm^{-3}$ and thickness 350-400 microns served.



(a)



(b)

Figure 1. a) Cross-cut of device of luqiud epitaxy.
1-susceptor, 2-substrates, 3-solution-melt, 4-pusher.

b) Temperature-temporal diagram of technological process

Initial crystals - the substrates of arsenide gallium consistently ground by powders M10, M3 and M1. Grinding carried out mechanically on glass at mixing the above-stated powders with distilled water. After polishing samples were carefully washed out in a flow of water, and then in distilled water and were dried on filter papers.

The polishing of substrates carried out suede through diamond paste (ACM-1 and ACM-0,5) and spirit by circular movements such as figure-of-eight to reception of a mirror surface. The final polishing was carried out on the following to suede with the help of zirconium's dioxide and distilled water. Before loading in debiteuse, the polished substrates chemically were processed in etchant $5H_2SO_4+H_2O_2+H_2O$ during 20-30 seconds, were washed out in CCl_4 and deionized water, were dried.

Deposition of epitaxial layers GaAs and AlGaAs on GaAs substrates carried out from limited volume of a solution-melt, with the appropriate additives, compulsory cooling (not isothermal liquid epitaxy) with the help of the graphite container - cartridges of "stick" type, Fig. 1. The attitude gallium to a source made Ga/GaAs=16. Height of a solution-melt got out at the rate of

$$h = 2 \cdot 10^{-1} (D\, t)^{1/2} \qquad (1)$$

where, D - diffusion coefficient of impurity in the liquid phase, t - diffusion length of the impurity.

For realization of process of growth the polished substrates GaAs focused in crystal direction {100} with concentration of carriers n~10^{17} cm^{-3} area 10x10 mm^2 established in the graphite container. In the source of the solution–melt (Ga+GaAs), in one case, at growth of a buffer layer GaAs of a n-type added Sn, and in the other case for escalating top large-band-gap layer $pAl_xGa_{1-x}As$ in the solution–melt added Al and metal zinc, cleanliness 99.9999 %.

Here it is necessary to note, that the difference of the device for escalating top of the large-band-gap layer pAlxGa1-xAs is, that the solution-melt (Al+Zn+Ga+GaAs), from which is carried out deposition of epitaxial layer, settles down inside the chamber, where are established nGaAs-n^+GaAs. In result would be diffusion of acceptor impurity from solution-melt Al+Ga+GaAs:Zn into buffer nGaAs-layer from the moment of a set of initial temperature of crystallizing (section 2, Fig. 1b). Then during the process of growth $pAl_xGa_{1-x}As$ upper layer (section 3, Fig. 1b). So would be additional diffusion of impurities from growth solid solution.

In Fig. 1, the temperature-temporary diagram of technological process is shown. The intervals 2 and 3 correspond to process of homogenization of a solution–melt and growth of epitaxial layers.

Morphology of a surface and the borders of the unit of the received structures investigated with the help microscope MIM-7.The results of researches have shown, that epitaxial layers of better quality (mirror surface, the equal border undressed a lamina-substrate) it turn out at temperature began crystalization 800 ^{0}C and speed of cooling (0.25-0.5) ^{0}C/minutes. The growth rate of lamina AlGaAs in an interval of temperatures 700-830 ^{0}C makes ~ (0.5-1) microns/minutes. Density of defects in laminas was (10^3 cm^2) on the order less, than in a substrate ($3{\cdot}10^4$ cm^2). The thickness of layers could be varied from 0.1 up to 3 microns and more micrometers.

The structures with a barrier Shottky Ag-nGaAs-n^+GaAs were made for research of photo-electric properties of active area nGaAs. Here thickness of a layer nGaAs makes 4-5 microns. On a surface of a layer nGaAs evaporation in vacuum rendered a translucent layer Ag, and on the back party Sn.

3. Results and discussion

3.1 Structure with a barrier Shottky such as m-nGaAs-n^+GaAs

In structure with a barrier Shottky determined concentration of carriers in base nGaAs of area, spectral characteristics, and also dependence of a current of short circuit on capacity of a falling flow.

a) b)

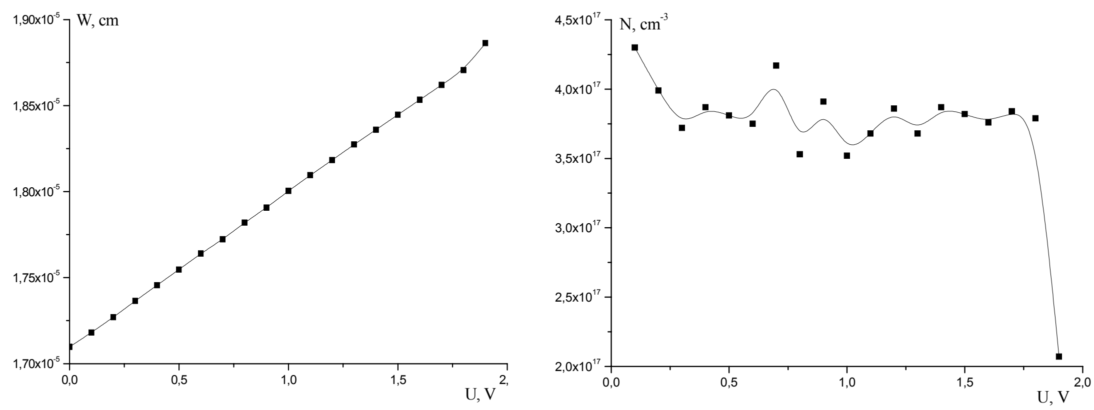


Figure 2. a) Changing of bulk charge under barrier
b) profile of allocation carriers b surface of lamina

The concentration of carriers in epitaxial layer nGaAs was determined on the basis of researches volt of the capacitor characteristics with the help of dependences (e.g. Fahrenbruch et al., 1983)

$$d_x=\frac{\varepsilon\varepsilon_0 S}{C(V_0)}\ (2),\ N_{dx}=\frac{2dV}{\varepsilon\varepsilon_0 q S^2 d(1/C^2)}(3).$$

First (2) and the second (3) dependences are given in Fig. 2 a, b. As shown in Fig. 2 b the concentration of carriers from a surface of lamina is within the limits of $3,5\text{-}4\cdot10^{17}$ cm^{-3}.

The spectral characteristics (Fig. 3) testify that a barrier Shottky really works. The maximum of photosensitivity is reached at ~0.45 microns. Thus the photocurrent with increase of intensity of the flow of falling capacity grows linearly (Fig. 4).

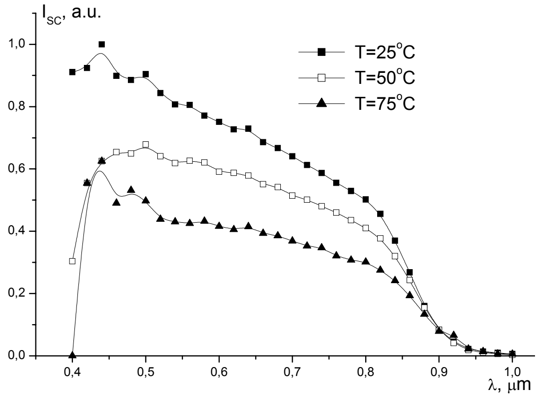


Figure 3. The spectral characteristic of structure with barrier Shottky m-nGaAs-n^+GaAs

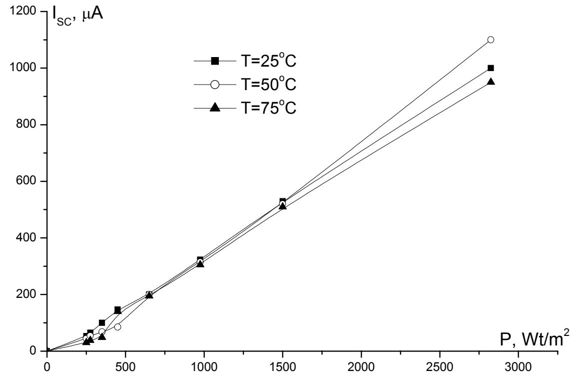


Figure 4. The dependence current of short circuit on falling capacity

The experimental values of concentration of carriers determined directly from a surface nGaAs of a layer are close to settlement $\sim10^{17}$ cm^{-3}. The observable linear dependence of a current of short circuit on size of falling capacity testifies to absence in base area of the compensated areas. Hence, such transitions can be used for creation of heterostructures solar elements.

3.2 Solar elements such as $pAl_{0.75}Ga_{0.25}As$-pGaAs-nGaAs-n^+GaAs

The heterostructure solar elements such as $pAl_{0.75}Ga_{0.25}As$-pGaAs-nGaAs-n^+GaAs were made on the basis of received nGaAs-n^+GaAs transitions. In them the area pGaAs, as mentioned above, is formed in epitaxial layer nGaAs for the account diffusion of alloyed impurity from of quasi-closed volume during direct escalating on it of the top layer $pAl_{0.75}Ga_{0.25}As$ with concentration of carriers $p\sim10^{18}$ cm^{-3} and thickness ~1 microns. From microphotos having chopped off have defined, that p-n-junctions heterostructures have equal border, look an insert Fig. 5.

After termination process of growth the back party of a substrate was ground for distance of diffusion layer, then scour superfluous transition. Thus the working surface was protected chemically proof is delicious. The etching was made in the heated up solution $24H_2O$:35% NaOH:$1H_2O_2$ with speed 0.5 microns for 10 secunde. Then on the part of a substrate rendered continuous ohmic contact from Ni, and on an active surface ohmic contacts as a comb from an alloy AgSn. The area of ready structures makes 5x6 mm^2.

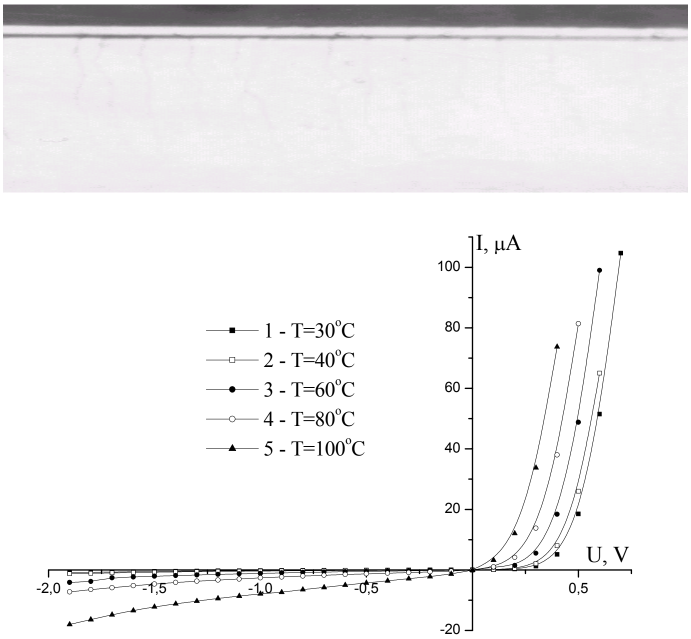


Figure 5. The boader of section pGaAs-nGaAs (insertion) and voltage-current characteristic of heterostructure $pAl_xGa_{1-x}As$-pGaAs-nGaAs –n^+GaAs

As shown in a Fig. 5 the straightening properties p-n-junction (pGaAs-nGaAs) are kept in all the investigated range of temperatures (30-100 ^{0}C). The observable steepness of growth of a direct current from a voltage testifies to sharpness p-n-junction. At change of temperature in the specified range the mechanism of current passing remains constant. Here it is necessary to note, that for reduction of a return current it is expedient to reduce concentration of carriers of base area up to settlement values $3\text{-}6 \cdot 10^{16}$ cm^{-3}.

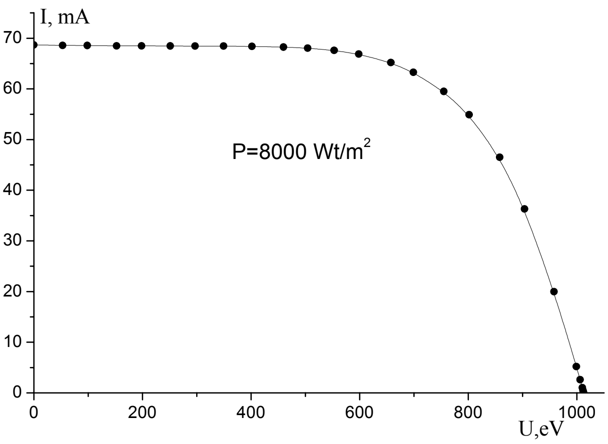


Figure 6. Load characteristic of heterostructure $pAl_xGa_{1-x}As$-pGaAs-nGaAs-n^+GaAs

Photocurrent of short circuit (Fig. 6) at falling capacity 8000 W/m^2 makes 68 mA at the area of structure 4 cm^2, and the voltage of a single course is equal 1.1 eV, that is a good parameter.

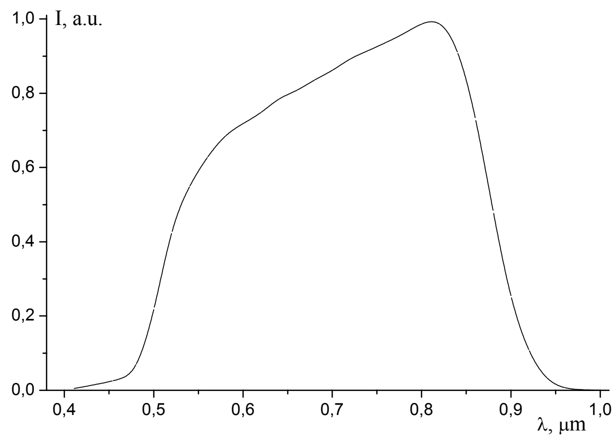


Figure 7. The spectral characteristic of structure with heterojunction $pAl_xGa_{1-x}As$-pGaAs-nGaAs-n^+GaAs

The spectral characteristic (Fig. 7) testifies about homophase p-n-junction. The maximal sensitivity takes place at ~0.83 microns. In short-wave area of a spectrum the a little bit smaller spectral response is observable. For increase of sensitivity in short-wave area of a spectrum alongside with width of the forbidden zone of the top layer, also it is necessary to increase diffusion length of the not basic carriers in p-area (e.g. Sze 1981). Besides for reception of the wide area of spectral sensitivity the thickness of the top layer (d_{AlGaAs}) should satisfy to a condition

$$d \approx L_n/4 , (4)$$

Where L_n -diffusion length electrons.

The preliminary researches show, that heterostructure solar elements made on base nGaAs-n^+GaAs of transitions at individual light exposure AM1.5 can have efficiency up to ~22 %. This parameter, apparently, can be increased further at the expense of improvement of technological processes.

4. Conclusions

Due to the offered approach of creation of area pGaAs in epitaxial buffer layer nGaAs, in particular, for the account diffusion of alloyed impurity from quasiclosed volume during direct escalating from a liquid phase on nGaAs of the top layer $pAl_{0.75}Ga_{0.25}As$ it is possible to receive heterostructure solar elements such as $pAl_xGa_{1-x}As$-pGaAs-nGaAs-n^+GaAs in rather reproduced parameters.

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