Semiconductor Physics, Quantum Electronics & Optoelectronics, 2005. V. 8, N 4. P. 33-34.

PACS 68.55.Ac, 81.15.-z

p-n junctions obtained in $(Ge_2)_x(GaAs)_{1-x}$ varizone solid solutions by liquid phase epitaxy

B. Sapaev, A.S. Saidov, I.B. Sapaev
Physical and Technical Institute of Uzbek Academy of Sciences,
2b, G. Mavlanov str.,700084 Tashkent, Republic of Uzbekistan
E-mail: bayram@physic.uzsci.net

Abstract. $(Ge_2)_x(GaAs)_{1-x}$ graded gap layers were grown using the method of liquid phase epitaxy on GaAs substrates. Investigated are distributions of chemical components along the thickness of the epitaxial layer. In accord to the scan patterns obtained in characteristic X-rays, the layers have a perfect structure, and the component distributions both along the thickness and the interface are rather monotonous, macroscopic defects and metal inclusions are absent. In the epitaxial layers, we created *p-n* junctions by diffusion of Zn from a gas phase. We studied the possibilities of using the GaAs-$(Ge_2)_x(GaAs)_{1-x}$ structures as solar converters including the near infra-red region. In this case, the GaAs substrate serves as a filter for light quanta with the energy $h\nu < E_{gGaAs}$. The conversion efficiency dependences on the gradient x and the *p-n* junction position inside the $(Ge_2)_x(GaAs)_{1-x}$ graded gap layer are also shown.

Keywords: liquid phase epitaxy, solid solution, *p-n* junction.

Manuscript received 15.07.05; accepted for publication 25.10.05.

Multilayer cascade solar cells are one of the promising cells of modern photoenergetics due to their high efficiencies. Current investigations on the subject are directed to increasing the spectral range of sensitivity and to finding the most suitable cascade elements. The majority of authors [1, 2] used Ge as a bottom element of the cascade, which results in widening the spectral sensitivity to long-wave side of the solar radiation. In the works [1, 2], the solid solutions were prepared by the gas and molecular beam epitaxy methods. In this paper, we report on the solid solutions made up by the liquid phase epitaxy and the investigations of dependences of the main output parameters of $(Ge_2)_x(GaAs)_{1-x}$ cascade solar cells on the variability of the bandgap width. We constructed the graded gap structures *p*-$(Ge_2)_x(GaAs)_{1-x}$ – *n*-$(Ge_2)_x(GaAs)_{1-x}$ – *n*-GaAs, where x varies from 0 to 1 (Fig. 1).

The structure was grown by the liquid phase epitaxy method in an isolated cassette from confined volume of bismuth solutions in the pure hydrogen flow with the dew point of 213 to 218 K, which was controlled. ⟨111⟩ oriented *n*-GaAs plates with the diameter of 20 mm, thickness of 350 to 400 μm were used as substrates with pure Bi solvents. The *p-n* junction was formed during the crystal growth of the autodoping *p*-type layers and by diffusion of Zn from a gas phase.

To define the optimal position d of the *p-n* junction in the graded gap of $(Ge_2)_x(GaAs)_{1-x}$ solid solutions, we studied the dependence of short circuit current J_{sc}, open circuit voltage V_{oc}, spectral sensitivity and efficiency η on the ratio of d to the net thickness of the variable gap solution w. For this aim, several samples were prepared with different positions of *p-n* junction in the layer. The gap width of the layer was varied between $0.6 < E_g < 1.43$ eV. Consequently, the peak of photosensitivity (Fig. 2), short circuit current, and efficiency were different for these layers.

In Fig. 3, the dependence of output power of the samples on the parameter d is given. It increases with the displacement of the *p-n* junction to the low bandgap region. The power increase is not so high as was expected.

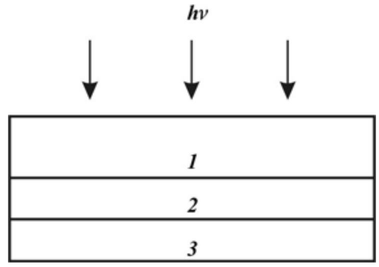

Fig. 1. Scheme of the cascade solar cell based on $(Ge_2)_x(GaAs)_{1-x}$ graded gap structure:
1 – *n*-GaAs-substrate, 2 – variable gap solid solution *n*-$(Ge_2)_x$(GaAs), 3 – *p*-$(Ge_2)_x(GaAs)_{1-x}$.

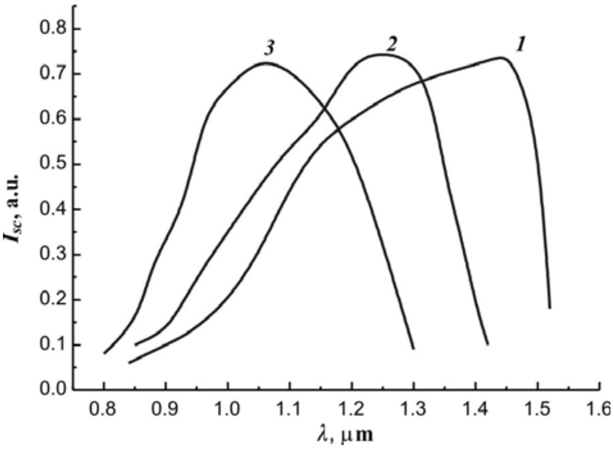

Fig. 2. Spectral characteristics of the solar cells based on solid solution $(Ge_2)_x(GaAs)_{1-x}$ with various *p-n* junction positions *d*: 1 – 12…13, 2 – 7…8, 3 – 3…4 μm.

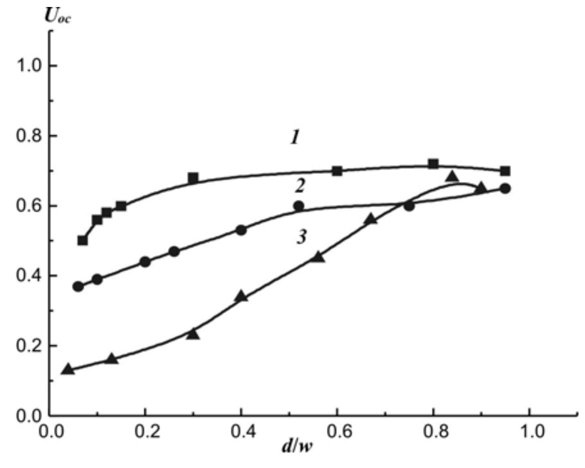

Fig. 4. Open circuit voltage as a function of the *p-n* junction position, *d*. Values of *d* are the same as in Fig. 2.

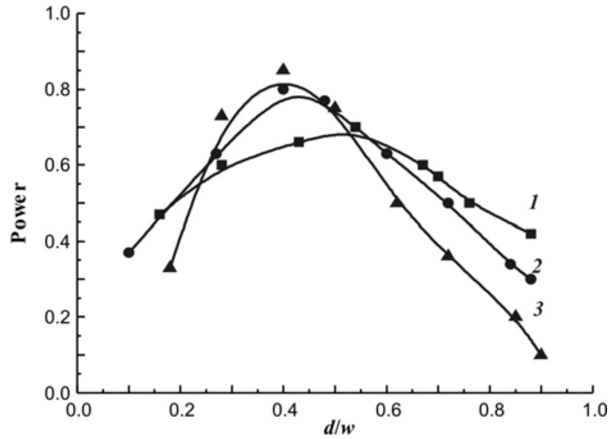

Fig. 3. Dependence of the output power for the solar cells $(Ge_2)_x(GaAs)_{1-x}$ on the *p-n* junction position. Values of *d* are the same as in Fig. 2.

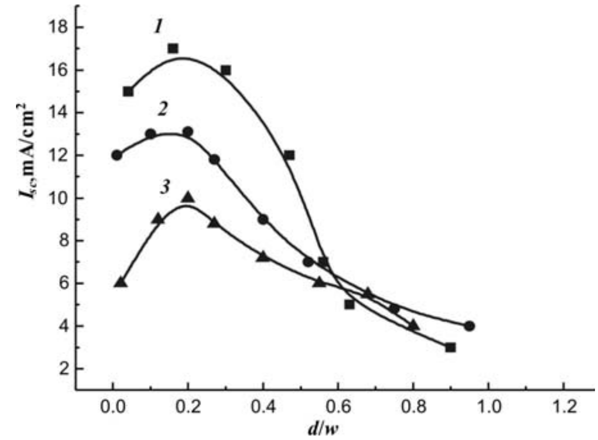

Fig. 5. Short circuit current of the variable gap $(Ge_2)_x(GaAs)_{1-x}$ solar cells as a function of the relative *p-n* junction position *d/w*. Values of *d* are the same as in Fig. 2.

Dependences of J_{sc} and V_{oc} on *d/w* are presented in Figs 4 and 5, respectively. The analysis show that the short current increases from 3…4 to 15…17 mA/cm^2 and open circuit voltage from 0.67…0.72 to 0.21…0.25 V with increasing *d*. Then the maximum efficiency value can be obtained for *d* between 3 and 4 μm, which corresponds to *d/w* between 0.23 and 0.26. The solar cell performance considered (Figs 4 and 5) depends on the area only quantitatively and not qualitatively. The increase of J_{sc} with increasing *d* at its low values can be explained as a decrease in the open circuit voltage and efficiency. As it follows from Fig. 5, the open circuit voltage decreases linearly with increasing the thickness of the variable gap semiconductor.

Values of *d* are the same as in Fig. 2.

Our results have demonstrated that the variable gap solid solutions $(Ge_2)_x(GaAs)_{1-x}$ can be succesfully used for cascade solar cells as bottom elements. By varying the thickness of the graded gap layer and by creating the solar cells with an upper wide gap window on the opposite of substrate, the efficiency of cascade cells can be increased significantly.

The main problem in the technology of designing the cascade cells is balancing the short circuit current of cascade elements. The construction proposed in the paper simplifies the problem significantly and can be utilized successfully in further developments of the similar cascade solar cells.

It is known that the cascade GaAs-Ge solar cells must be spectral sensitive in the wide wavelength region from 0.4 up to 1.7 μm of solar radiation. The values of the photogenerated current in GaAs and Ge cells allow to obtain high photovoltages with minimum losses even at their series connection. The obtained results show that the investigated cascade cells are effective and reproducible as compared with the currently available data.

References

1. L.D. Partain, M.S. Kurula, R.E. Wiess *et al.*, 26.1 % solar cell efficiency for Ge mechanically stacked under GaAs // *J. Appl. Phys.* **62**, N 7, p. 3010-3015 (1987).
2. J.N. Bullock, C.H. Wu, J.F. Wise, Interface contribution to GaAs/Ge heterojunction solar cell efficiency // *IEEE Trans. Electr. Devices* **36**, N 7, p. 1238-1243 (1989).