Selectivity control of photosensitivity Au-AlGaN structures

M Yu Andreev¹, S A Tarasov¹, I A Lamkin¹, I I Mikhailov¹, A V Solomonov¹, S Yu Kurin²
¹Saint-Petersburg Electrotechnical University “LETI”, Prof. Popova 5, St. Petersburg 197376, Russia
²GaN-Crystals Ltd., 27 Engels Ave, St. Petersburg 194156, Russia,

E-mail: ialamkin@mail.ru

Abstract. The Created selective photosensitive structures based on the Schottky barrier Au-AlGaN are for different ranges of the ultraviolet region of the spectrum. The methods that has been shown here, of controlling the spectrum of photosensitivity, are due to the effect of the wide windows and the effect of above-barrier transport in the structures Au-AlGaN.

1. Introduction
Photosensitive structures and devices, at the present time, are widely using in almost all areas of human activity [1], [2]. In recent years, photodetectors, which are sensitive in the ultraviolet spectral range, are becoming more popular and requested for a number of military and civilian applications [3]. Systems of UV location is one of the most relevant examples of the use of such devices, that capable of effectively detecting apparatuses for various purposes by the ultraviolet radiation component of reactive jet, including in outer space [4]. Controlling the UV levels can be used for peaceful applications in disinfection of water and some medical procedures; environmental monitoring, including the studies of the ozone layer and finding of the ozone holes; building of security systems, in particular, flame detectors and pollution; and a number of other scientific and economic tasks. For most of these applications are required detectors, that are insensitive to radiation in the visible range of the spectrum, the so-called apparently blind photodetectors, while in some cases - solarblind photodetectors, that are capable of correctly detecting the UV light in the conditions of strong backlight by the sunlight [5]. Without the use of expensive optical filters, it can be implemented only by using the wide-band semiconductor materials with a band gap of 3 eV or more [6]. On the other hand for the successful implementation of such detectors in production, it is necessary to develop a technology of their building within which it is possible to achieve high parameters of devices at preservation of their low cost [7]. In addition, one of the current highly relevant branches of development photodetectors is the creation of selective photodiodes. Using the effect of the wide window allows you to create photodiodes with a short-wavelength of boundary photosensitivity in a given region. In the structure, a wideband window is a semiconductor layer, with the smallest band gap, through which light passes. The use of structures on the basis of Schottky barrier one of the promising options, which should enable the creation of highly efficient photodetectors by relatively simple and inexpensive methods [8].

2. Sample and experimental technique
Al,Ga1-xN epitaxial layers were grown by hydride vapour phase epitaxy (HVPE) technique [9]. The top doped n-Al,Ga1-xN layer had a carrier concentration of $10^{17}$ cm$^{-3}$. Metal layers were deposited by vacuum thermal evaporation at a residual gas pressure of 10$^{-5}$ Torr. Au was used as a rectifying contact material. Al with Ti underlayers were used to form Ohmic contacts [10]. Prior to metal deposition the structures were cleaned by potassium hydroxide (KOH) during 2 min and washed with distilled water. For good metal adhesion the structures were heated to a temperature of 300°C during deposition. Structure characteristics were measured using a set-up based on a monochromator with a diffraction grating and a xenon lamp as a light source.
3. Experimental results and discussions

The main focus in the work was given to the creation of the effect of the selective sensitivity in grown structures without needing for using optical filters, as well as studies the possibility of controlling this effect. When illuminated by the side of metal, spectrum of sensitivity of the photodetector has a broadband characteristic with a half-width greater than 40 nm.

On the fig. 1a shown the structure on the basis of epitaxial layer AlGaN, with proportion of AlN equaled to 0.1, that forming a Schottky barrier with Au.

![Figure 1](image1.png)

**Figure 1.** An example of the structure of the photodiode Au-\(\text{Al}_{0.1}\text{Ga}_{0.9}\)N and the measured spectra: a) structure of the photodetector, b) spectrum of photosensitivity.

When illuminating this structure from the back side of the solid solution layer AlGaN with proportion of AlN equaled to 0.06, It serves as the wide windows (Fig. 2b). Thus, it is possible to create a selective photodetector with high photosensitivity at 362 nm.

![Figure 2](image2.png)

**Figure 2.** An example of the structure of the photodiode Au-\(\text{Al}_{0.06}\text{Ga}_{0.94}\)N and the measured spectra: a) structure of the photodetector, b) spectrum of photosensitivity.

It is possible to controlling the sensitivity from two sides, by using an additional layer in the composition of the photodetector (Fig. 3a). GaN is used in this structure, as the wide-gap window layer,
which displaces the short-wave boundary of the photosensitivity at wavelength of about 360 nm. The long-wavelength boundary is determined by the high of the potential barrier contact Au-AlGaN with a proportion of AlN equaled to 0.1.

![Diagram](image)

*Figure 3.* An example of the structure of the photodiode Au-Al$_{0.1}$Ga$_{0.9}$N-GaN and the measured spectra: a) structure of the photodetector, b) spectrum of photosensitivity.

Although in this case the maximum of the photosensitivity is reduced, but this structure makes it possible to demonstrate how the combination of the effects of a wide-window and above-barrier transfer allows controlling the sensitivity range of the photodetector. By changing the composition of the solid solution, that performing the role of the wide windows, lead to changing the range of the photosensitivity in the shortwave region of the spectrum.

Thus, here it was demonstrated the possibility of controlling the selectivity of sensitivity structures based on Au-AlGaN (Fig. 4).

![Diagram](image)

*Figure 4.* Spectral characteristics of photodiodes Au-AlGaN. Selective photodetectors were obtained with the following parameters: half-width of 5-6 nm, 351-373 nm range of photosensitivity with a maximum at 355 nm, 362 nm, 366 nm and a sensitivity to 140 mA / W.
4. Conclusion

Selective photosensitive structures based on solid solution AlGaN were created. On the basis of structure with the upper epitaxial layer AlGaN and with proportion of AlN equaled to 0.1, that forming a Schottky barrier with Au, a selective photodiode with a maximum at 355 nm photosensitivity and a half-width 6 nm has been created. Reducing the proportion of AlN to 0.06 in the sold solution AlGaN caused the shifting of the photosensitivity maximum of the selective detector for a wavelength 362 nm, reducing the half-width of 5 nm. Adding an extra layer of GaN, performing the role of the wide windows in the structure Au-Al$_{0.1}$Ga$_{0.9}$N, also caused to shifting the maximum sensitivity. The maximum of spectral characteristics of selective photodiode was at 366 nm. It has been shown that changing the composition of the solid solution, which performing the role of the wide window, change the range of the photosensitivity in the shortwave region of the spectrum.

Acknowledgment

The work was supported by the Ministry of Education of the Russian Federation in the framework of the project of the state task in the field of scientific activity, project number 16.1307.2014K.

References

[1] Kung P, Yasan A, McClintock R, Darvish S R, Mi K, Razeghi M Future of Al$_x$Ga$_{1-x}$N materials and device technology for ultraviolet photodetectors, Proc. SPIE, vol. 4650, p. 199-206, 2002.
[2] Helava H I, Menkovich E A, Kurin S Yu, Antipov A A, Roenkov A D, Barash I S, Tarasov S A, Shmidt N M, Makarov Yu N, Lamkin I A UV LEDs for high-current operation Journal of Physics: Conference Series vol. 461, p. 012028, 2013.
[3] Lamkin I, Tarasov S Ultraviolet photodiodes based on AlGaN solid solutions Journal of Physics: Conference Series vol. 461, p. 012025, 2013.
[4] Ulmer M, Razeghi M, Bigan E, Ultra-Violet Detectors for Astrophysics, Present and Future, Proc. SPIE. vol. 2397, p. 210-216, 1995.
[5] Petrov A A, Tarasov S A, Lamkin I A, Menkovich E A, Solomonov A V, Kurin S Yu Research of the solar-blind and visible-blind photodetectors, based on the AlGaN solid solutions Journal of Physics: Conference Series. vol. 572, p. 012063, 2014.
[6] Menkovich E A, Tarasov S A, Lamkin I A Luminescence of nanostructures based on semiconductor nitrides Functional Materials vol. 19, № 2, p. 233, 2012.
[7] Kurin S, Antipov A, Barash I, Roenkov A, Usikov A, Helava H, Ratnikov V, Shmidt N, Sakharov A, Tarasov S, Menkovich E, Lamkin I, Papchenko B, Makarov Y Characterization of HVPE-grown UV LED heterostructures Physica status solidi (C) №3, p. 813–816, 2014
[8] Rumyantsev S I, Pala N, Shur M S, Gaska R, Levenshstein M E Low-frequency noise in Al$_{0.1}$Ga$_{0.9}$N-based Schottky barrier photodetectors Applied Physics Letters vol. 79, (6), p. 866-858, 2001.
[9] Barash I, Roenkov A, Kurin S, Antipov A, Helava H, Tarasov S, Menkovich E, Lamkin I, Makarov Yu. CHVPE growth of AlGaN-based UV LEDs Physica Status Solidi (C) Current Topics in Solid State Physics vol. 10, № 3, p. 289-293, 2013.
[10] Lamkin I A, Tarasov S A, Petrov A A, Menkovich E A, Solomonov A V, Kurin S Yu Investigation into the processes of atom redistribution encountered during of the formation of metal layers on the surface of aluminum gallium nitride Journal of Physics: Conference Series vol. 572, p. 012062, 2014.