Selective Au-AlGaN photodetectors for the 350 - 370 nm wavelength range

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Abstract. The selective Au-AlGaN-based Schottky barrier photodetectors operating in different UV ranges have been fabricated. The wide bandgap window effect and the over barrier emission are proposed as methods for control of the photosensitivity spectrum. Selective photodetectors were fabricated with the following parameters: a full width at half maximum of 5-6 nm with a maximum at 355 nm, 362 nm, 366 nm, and a sensitivity up to 140 mA / W.

1. Introduction
Devices based on photodetectors are widely used in virtually all areas of human activity [1], [2]. Recently, the need to create selective photodetectors, that can reliably provide radiation level control in a given wavelength range under conditions of high background illumination, has become more evident [3]. The use of optical filters to achieve high selectivity is often unacceptable due to their high cost and high degradability. Development of selective photodetectors for the ultraviolet region of the spectrum is especially important [4], [5]. Wide bandgap Aluminum Gallium Nitride (AlGaN) solid solutions, recognized as one of the most promising materials, can be used to achieve this goal. To successfully implement such detectors into production, it is necessary to develop a fabrication method that provides high parameters as well as low cost of the devices [6]. The abovementioned requirements can be met with structures based on the Schottky barrier [7]. Such structures can be used for designing high-performance UV photodetectors by means of comparatively simple and inexpensive methods [8].

2. Samples and experimental technique
The AlGaN epitaxial layers were grown by hydride vapour phase epitaxy (HVPE) technique [9], [10]. The top \textit{n}-doped AlGaN layer had a carrier concentration of $10^{17}$ cm\textsuperscript{-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 layer with Ti underlayer were used for forming Ohmic contacts [11], [12]. Prior to metal deposition the structures were cleaned with potassium hydroxide (KOH) during 2 min and washed with distilled water. To achieve good metal adhesion the structures were heated during deposition to a temperature of 300 °C. Photodetector 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
Using the wide bandgap window effect and the over barrier emission in Au-AlGaN structure, it is possible to fabricate a selective photodetector with a narrow range of photosensitivity. Selectivity was
achieved by using the wide bandgap window effect. Figure 1 shows the structure of the photodetector based on Au-AlGaN contact with a AlN content of 0.1. When the photodetector is illuminated from the metal side, two peaks are present in the photosensitivity spectrum, where the long-wavelength peak is caused by the over barrier emission. When increasing the energy of incident photons, interband transitions occur resulting in a short-wavelength peak at 346 nm. When the photodetector is illuminated from the side of the transparent sapphire substrate, light passes through the wide bandgap window, and in the spectral characteristics only the over barrier emission peak is observed. Thus, it is possible to fabricate a selective photodetector with the photosensitivity maximum at 355 nm.

![Figure 1](image)

**Figure 1.** a) Au-Al$_{0.1}$Ga$_{0.9}$N photodetector structure b) photosensitivity spectrum of:
1 - the top-illuminated photodetector, 2 - the back-illuminated photodetector.

Figure 2 shows processes that take place in the sample being illuminated from sides of metal layer and the substrate. When the sample is illuminated by monochromatic light with an energy $h\nu > q\phi_B$ from the side of metal contact, excited electrons in the metal layer have sufficient energy to overcome the barrier (Process 1 in Figure 2). If $h\nu > E_g$, and the metal film is thin enough, then the light passes through the metal layer, which results in electron-hole pairs generation in the semiconductor (Process 2 in Fig 2).

![Figure 2](image)

**Figure 2.** Energy diagram of photoexcitation processes

The excitation of electrons in the metal layer with energy sufficient to overcome the potential barrier ($h\nu > q\phi_B$) is also possible when the sample is illuminated from the substrate side (Process 1 in Fig 2). However, when $h\nu > E_g$, the light is intensively absorbed on the back surface of the top semiconductor layer. Therefore, the probability for electron-hole pairs generated in this region to reach the metal-semiconductor interface is very small. The photosensitivity spectrum position along the wavelength axis can be controlled by varying the composition of the solid solution that forms a Schottky barrier.
with Au. For this purpose, a photodetector based on epitaxial layer AlGaN with an AlN content of 0.06 was fabricated (Fig. 3a). In this case, by illuminating the photodetector from the metal side, the over barrier emission can be recognized as an inflection in the long-wavelength region of the obtained spectrum. When this structure is illuminated from the substrate side, the top AlGaN layer with an AlN content of 0.06 acts as a wide bandgap window. Thus, it is possible to fabricate a selective high photosensitive photodetector with a peak sensitivity wavelength of 362 nm (Fig. 3b).

![Figure 3](image)

(a) Au-Al$_{0.06}$Ga$_{0.94}$N photodetector structure  
(b) photosensitivity spectrum of:  
1 - the top-illuminated photodetector, 2 - the back-illuminated photodetector.

It is possible to control the sensitivity in both short- and long-wavelength spectrum regions if an extra layer is used in the photodetector structure (Fig. 4a). In this case GaN layer, acting as a wide bandgap window, sets the short-wavelength boundary of the photosensitivity spectrum to 360 nm (Fig. 4b).

![Figure 4](image)

(a) Au-Al$_{0.1}$Ga$_{0.9}$N-GaN photodetector structure  
(b) photosensitivity spectrum of:  
1 - the top-illuminated photodetector, 2 - the back-illuminated photodetector.

The long-wavelength boundary is set by the potential barrier height of the Au-AlGaN contact with an AlN content of 0.06. Although the maximum photosensitivity value of the structure with an extra GaN layer is lower in relation to the structures considered above, this structure is designed to show how the effects of wide
bandgap window and over barrier emission when applied in combination can be used to control the photodetector sensitivity range. Thus, here we have demonstrated a wavelength selective Au-AlGaN photodetector with the possibility of setting its selectivity (see Table 1).

| Parameter                                      | Au-Al$_{0.06}$Ga$_{0.94}$N | Au-Al$_{0.1}$Ga$_{0.9}$N/ GaN | Au-Al$_{0.1}$Ga$_{0.9}$N |
|------------------------------------------------|-----------------------------|-------------------------------|---------------------------|
| $\lambda_{\text{max}}$ under illumination from the side of metal, nm | 355                         | 347 and 353                   | 346 and 353               |
| $\lambda_{\text{max}}$ under illumination from the side of substrate, nm | 362                         | 366                          | 355                       |
| FWHM under illumination from the side of metal, nm | 40                          | 30                           | 30                        |
| FWHM under illumination from the side of the substrate, nm | 5                           | 5                            | 6                         |
| The sensitivity range under illumination from the side of metal, nm | 200-380                     | 200-375                      | 200-375                   |
| The sensitivity range under illumination from the side of substrate, nm | 358-378                     | 361-375                      | 350-375                   |

Selective photodetectors were fabricated with the following parameters obtained: a full width at half maximum (FWHM) of 5-6 nm, photosensitivity in the range of 351 to 373 nm with a maximum at 355 nm, 362 nm, 366 nm, and a sensitivity up to 140 mA / W.

4. Conclusion

Selective photodetectors based on solid solution AlGaN have been fabricated. On the basis of the structure with the top epitaxial AlGaN layer (with an AlN content of 0.1) that forms a Schottky barrier with Au, a selective photodetector with a photosensitivity maximum at 355 nm and a FWHM of 6 nm has been fabricated. With the AlN content reduced to 0.06 the photosensitivity maximum shifted to 362 nm, whereas the FWHM decreased to 5 nm. By using an extra GaN layer, which acts as a wide bandgap window in the Au-Al$_{0.1}$Ga$_{0.9}$N structure, the sensitivity maximum was shifted to 366 nm. It has been shown how varying the solid solution composition, which acts as a wide bandgap window, can change the range of the photosensitivity in the short-wavelength region of the spectrum.

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