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Spectral photosensitivity of the *m-n*^{0}*-n* structure on the basis of epitaxial layers

D.M. Yodgorova, A.V. Karimov, F.A. Giyasova, R.A. Saidova, A.A. Yakubov
Physical-Technical Institute of the Scientific Association "Physics-Sun",
Academy of Sciences of the Republic of Uzbekistan, 2B, Mavlyanov str., 700084 Tashkent, Uzbekistan
Phone: +998-71-1331271, fax: +998-71-1354291, e-mail: karimov@uzsci.net

Abstract. The results of studies of the spectral characteristics of the m-n^0-n-structure with a base area on the basis of thin epitaxial specified undoped GaInAs and oxygen-doped AlGaAs layers are presented. It is experimentally revealed that own defects and oxygen impurities introduced into the thin active n-area, whose thickness is about the diffusion length, promote the greater photoresponse in the impurity spectral band (1.2 and 1.55 μm). At the same time, impurities present in GaInAs at the background level can be excited, although ineffectively, from the quasineutral part of the active region depleted by the blocking voltage.

Keywords: spectral characteristics, epitaxial layer, photocurrent, photodiode, active region, impurity.

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1. Introduction

Development of both the global system of communication with transmission of optical signals and wireless computer nets induces new requirements to extend functional resources and to raise photosensitivity and reliability. In this aspect, the intense constructive and technological researches are performed with the purpose of increasing the detector diode limiting sensitivity and decreasing the conversion losses [1, 2]. Schottky junction structures with a thin active region (~ 1 μm) are created on the basis of epitaxial layers of binary GaAs and InP generated on a highly doped base. This allows increasing the limiting sensitivity and the frequency range of photodiodes [3, 4]. Another issue is to obtain a sufficient photosensitivity in a specified spectral range by applying a complex system of solid solutions with predetermined properties and guaranteed proportions.

In this work, we present the results of studies of the spectral characteristics of the m-n^0-n structure with a base area produced on the basis of thin epitaxial specified undoped GaInAs and oxygen-doped AlGaAs layers grown on the highly doped n$^+$GaAs base.

2. Experimental specimens and methods of research

Epitaxial layers such as $Al_{0.2}Ga_{0.8}As$ and $Ga_{0.95}In_{0.05}As$ have been grown by the method of liquid epitaxy of Ga: GaAs:Al(In) = 1850:150:11(16) solution-melt, so that the layers proportion was specified during the process. The layers proportion was also determined on the basis of the spectral characteristics of the triple solid solution and the behavior of its forbidden gap [5]. The growth of epitaxial layers has been accomplished using a complex system of liquid epitaxy [6] which allows one to grow not only similar layers but also various heteroepitaxial ones. By growing the epitaxial layers, we used oxygen-doped nGaAs with $4\cdot10^{15}$-cm^{-3} carrier density as a source and a polycrystalline source with $7\cdot10^{15}$-cm^{-3} carrier density for epitaxial layers of nGaInAs. In both cases, the thickness of epitaxial layers amounted to 1.5–2 μm. On the basis of the grown heteroepitaxial nAlGaAs-n$^+$GaAs and nGaInAs-n$^+$GaAs layers, we produced photodiode m-n^0-n$^+$-structures. On the layer side, the translucent rectifying contacts (60–70 Å) of Ag have been formed by vacuum deposition, and the rear side of the n$^+$GaAs layer has been provided with ohmic contacts of Sn+In structures whose area amounts to 15-17 mm². The potential barrier height of Ag-n^{0}AlGaAs is 0.52 eV, and the conversion height of Ag-n^{0}GaInAs is 0.89 eV. The forbidden gap of n^0$Al_{0.2}Ga_{0.8}As$:O layer is ~ 1.67 eV, and that of $Ga_{0.95}In_{0.05}As$ ~ 1.32 eV. These parameters have been determined with the purpose to reveal the influence of oxygen and intrinsic defects of indium (aluminum) layers [7] on the spectral characteristics of the structure with metal-semiconductor barrier. On the basis of the fabricated structures, the spectral and current characteristics have been researched.

3. Experimental results and their discussion

As shown in Fig. 1, the spectral characteristics of m-n^0-n$^+$-structures cover various optical ranges according to the proportion of the base region. In case of n^{0}AlGaAs (curve 1), the photosensitive region begins from λ = 0.5 μm and continues up to 2 μm. The peak photosensitivity is in compliance with intrinsic absorption. In the region of near 1.5 μm, it is formed by photocarriers excited from levels of the oxygen impurity loaded into the heterolayer of AlGaAs.

In the case of the epitaxial n^{0}GaInAs layer as a base area, the photosensitivity is surveyed within the intrinsic absorbing region in the narrow spectral range 0.9–0.94 μm (see Fig. 2, curve 1). At the same time, the low photoresponse in the short-wave part of the spectrum is caused by defects of the indium isovalent impurity appeared as recombination centers of the barrier region.

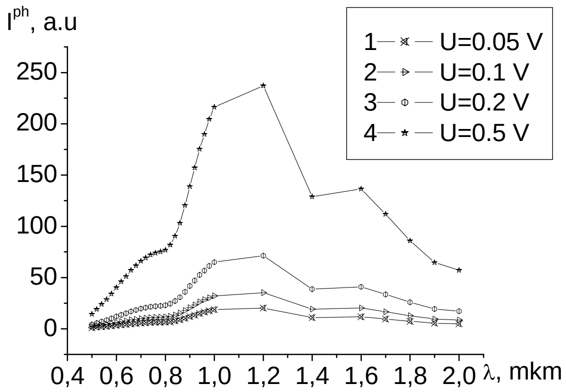

Fig. 1. Spectral characteristics of the m-n^0-n$^+$ structure with (–)Ag-n^{0}AlGaAs-n$^+$GaAs-(In+Sn)(+).

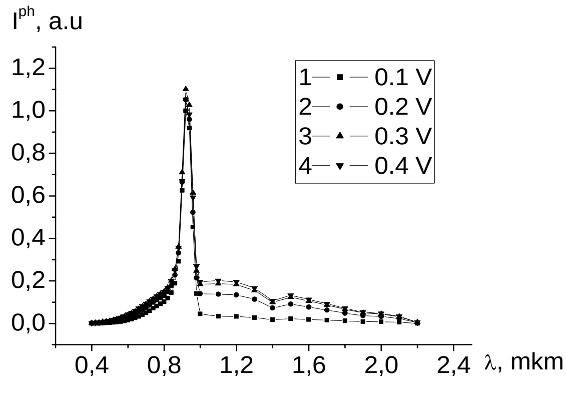

Fig. 2. Spectral characteristics of the m-n^0-n$^+$ structure with (–)Ag-n^{0}GaInAs-n$^+$GaAs-(In+Sn)(+).

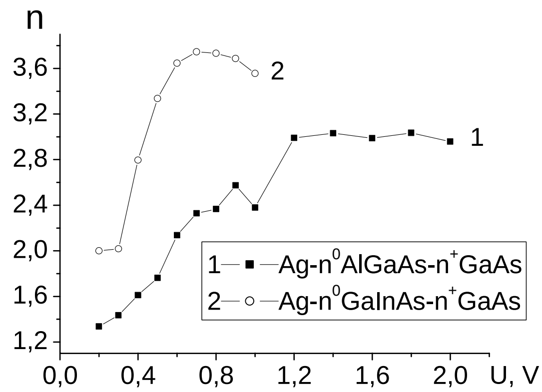

Fig. 3. Dependence of dark current exponents on the blocking voltage.

As the electric field intensity increases, the photoresponse of the Ag-n^{0}AlGaAs-n$^+$GaAs structure will grow within the whole spectral range (Fig. 1, curves 3 and 4), but to a greater extent within the long-wave region, particularly in the impurity band (1.55 μm). In the Ag-n^{0}GaInAs-n$^+$GaAs structure, the photoresponse marginally rises in the long-wave region of the spectrum due to the presence of uncontrolled impurities. The reduction of the photoresponse growth with increase in the voltage can be related to the increase of the tunneling current via the barrier, which is confirmed by a sharp increase of the exponent of the dark current dependence on the voltage U, $I \sim \exp(qU/nkT)$ (Fig. 3, curve 2).

In the field of an intensity of 0–0.5 V, the input resistance of the m-n^0-n$^+$ structure remains at the level of 1–10 GOhm with a capacity of 5–7 pF that testifies to high-frequency properties of the structures under study.

4. Conclusion

Thus, the performed researches show that oxygen impurities providing deep lying levels and introduced as a doping impurity into the thin active region (whose thickness is about the diffusion length) of the structure with the metal-semiconductor barrier promote obtaining a greater photocurrent in the impurity area of the spectrum as compared with that in the area of intrinsic absorption. Moreover, the impurities comparable with the background are slightly excited from the quasineutral part of the active region depleted by a blocking voltage, rather than directly from the surface.

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