Influence of the composition of the GaAsP solid solution on the Ag-GaAsP barrier height

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Abstract. The height of the potential barrier for the Ag-GaAsP has been measured experimentally. The dependence of the Schottky barrier height of the Ag-GaAsP structure on the composition of the solid solution is correlated with the dependence of the bandgap GaAsP on its composition. We calculate the equation describing the dependence of the height of the Ag-GaAsP Schottky barrier on the composition of GaAsP for indirect and direct-gap solid solutions.

1. Introduction

GaAsP solid solutions are widely used in modern optoelectronics when creating devices for the visible, ultraviolet and infrared ranges of the spectrum [1, 2]. One of the most important applications of such materials is the realization of photodetectors with improved noise characteristics. Changing the composition of the solid solution GaAsP allows to create photodetectors with a given position of the long-wave boundary of photosensitivity. Using Schottky barriers on the basis of silver in these detectors allows for achieving the sensitivity and selectivity and improving their other characteristics while lowering manufacturing costs. The potential barrier between the metal and the semiconductor has the most important influence on the properties of such structures, therefore the study of factors that affect the height of the barrier Ag-GaAsP is topical.

2. Samples and experimental technique

The structures on the basis of gallium arsenide phosphide solid solutions have been investigated. Sulfur doped $n$-GaAsP epitaxial layers with a free carrier concentration of $(0.5…5) \times 10^{16} \text{ cm}^{-3}$ were grown by vapour phase epitaxy. Schottky barriers were formed by vacuum thermal evaporation of silver on the semiconductor surface preliminarily cleaned in tetrachloromethane environment. The ohmic contacts were formed by Au deposition in accordance with the standard technique [3, 4]. To study the effect of composition of solid solution on the height of Schottky barrier formed by the contact Ag-GaAsP, a series of samples with different composition of the solid solution had been created.

3. Experimental results and discussions

The height of the barrier metal-semiconductor can be calculated by the formula $q\varphi_B = q(\varphi_m - \chi)$, where $q\varphi_B$ is the height of the potential barrier metal-semiconductor, $\chi$ – the electron affinity of the semiconductor, $\varphi_m$ - the electron work function from metal. However, it is known that the real height of the Schottky barrier depends on many other factors, primarily on the surface state of the
semiconductor. In addition, the solid solutions of GaAsP may be both a direct-gaps and indirect-gaps, which leads to different influences of the over-barrier transferring of charge carriers in structures of metal-solid solution GaAsP.

The investigated samples were subjected to various chemical pretreatment of the semiconductor surface before spraying of metallic Ag contact. To determine the height of the potential barrier of the metal-semiconductor we used two methods: the photoelectric method and the current-voltage characteristics. Spectra of the photosensitivity of samples are presented in figure 1.

![Figure 1](image)

**Figure 1.** The dependence of the photosensitivity on the wavelength for samples with different composition of GaAsP.

As shown in figure 1, photodiodes on the basis of GaAsP with a composition approaching pure gallium arsenide have a more smooth decline in photosensitivity in the area of long wavelengths, which is caused by indirect-gap of semiconductor. On the basis of obtained spectral characteristics, the dependencies of the root of photocurrent on the energy are built, by which the height of the potential barrier metal-semiconductor was determined by the photoelectric method. To determine the height of the barrier by the current-voltage characteristics, the forward part of current-voltage characteristics has been approximated in accordance with the formula $J = J_S \exp \left[ \frac{qU}{nkT} \right]$, and the coefficient of non-ideality $n$ and saturation current $J_S$ have been determined. Then, according to the formula $\varphi_B = (kT / q) \ln[A^{**}T^2 / J_S]$, the barrier height has been calculated, where $A^{**}$ is the effective Richardson constant. The coefficient of non-ideality $n$ shows the deviation of the slope angle of the graph from the ideal exponential function, and it is an indicator of sample quality. For good structures it did not exceed 1.1. Based on the analysis of obtained values of the potential barrier height, we plotted the dependence of the height of the Schottky potential barrier on the composition of solid solution GaAsP (figure 2).

It can be seen that two dependencies had appeared: the first characterizes the samples with a clean surface (1 in figure 2), this dependence of the Schottky barrier’s height in the structure of the Ag-
GaAsP on solid solution's composition correlates with the dependence of the band gap GaAsP on its composition (figure 3).

![Figure 2](image)

**Figure 2.** The dependence of the barrier height on the GaAsP solid solution’s composition: 1 – clean surface, 2 – for large number of surface states.

The second kind of dependence is primarily determined by a large number of surface states, samples of this type were processed in various chemical reagents (2 in figure 2).

![Figure 3](image)

**Figure 3.** The dependence of the band gap of GaAsP on the solid solution's composition: $E_gX$ – bandgap at X point; $E_g\Gamma$ – bandgap at $\Gamma$ point.

As a result, the dependencies of the Ag-GaAsP potential barrier's height on the composition of GaAsP have been approximated for direct-gap and indirect-gap GaAsP. The height of the potential Schottky barrier in the structure of Ag-GaAsP obeys the following dependencies on the solid solution's composition.
composition: \( q \varphi_B [\text{eV}] = 1.96x^2 + 0.24x + 0.88 \), at \( x \leq 0.46 \); \( q \varphi_B [\text{eV}] = 0.30x^2 - 0.17x + 1.42 \), at \( x \geq 0.46 \), with an error of 0.1, where \( x \) is a mole fraction of GaP in the solid solution GaAsP.

4. Conclusion
In the process of investigation of Ag-GaAsP samples with different rates of GaP, the measurements of their spectra of photosensitivity were carried out. The changing of the position of the long-wave border while increasing the content GaP in the solid solution GaAsP was demonstrated. On the basis of obtained spectral characteristics, the height of the potential Ag-GaAsP barriers for different compositions of the solid solution had been determined. In addition, the height of the metal - semiconductor barrier has been calculated by the current - voltage characteristics. Using the obtained data, the dependence of the Ag-GaAsP potential barrier's height on the composition of the solid solution was plotted.

The height of the potential Schottky barrier in the structure of Ag-GaAsP obeys the following dependencies on the solid solution's composition:

\[ q \varphi_B [\text{eV}] = 1.96x^2 + 0.24x + 0.88 \], at \( x \leq 0.46 \)
\[ q \varphi_B [\text{eV}] = 0.30x^2 - 0.17x + 1.42 \], at \( x \geq 0.46 \),
with an error of 0.1, where \( x \) is a mole fraction of GaP in the solid solution GaAsP.

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