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Features of the potential barrier and current flow in the narrow Schottky diodes

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ABSTRACT

This paper presents some specific characteristics of the potential barrier and the current flow in the narrow Au–nGaAs Schottky diodes (SDs), in which an additional electric field (AEF) directly measured by atomic-force microscopy.

Show that there existing a potential barrier in the narrow SD is formed by the superposition of the space charge field and the AEF in the near-contact area of the semiconductor. Dependence of the potential barrier height of the voltage narrow SD has about the same character in both forward and reverse directions.

Forward *I–V* characteristics narrow Au–nGaAs SD width of 1, 2 and 3 μm represented by straight lines in the semi-logarithmic scale in a wide current range of about nine order and ideality factor is close to unity. The reverse current of the same narrow SD in the initial reverse voltage is virtually absent and with increasing voltage increases linearly in the order of 3–5 in the semi-logarithmic scale.

The correlation between the numerical values of electrophysical parameters of the forward and reverse current–voltage characteristics of narrow SD was founded. Energy diagram of the narrow SD was created and its corresponding energy parameters were evaluated. It has been shown that the conductivity in the narrow Au–nGaAs SD qualitatively and quantitatively well described by energy model real metal–semiconductor contacts with AEF.

1. Introduction

With the development of microelectronics and nanotechnology on the characteristics of real metal–semiconductor contacts (MSCs) is given special attention. Extensive study of electronic processes

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in real MSC with limited uniform or non-uniform contact surface, shows that in near-contact area of the semiconductor, along with the main electric field, there is an additional electric field (AEF), resulting from the potential difference between the contact surface and the adjacent free surfaces of the metal and semiconductor [1]. It centers around a contact and penetrate into the peripheral region of the semiconductor. Many differences between the electrophysical parameters and characteristics of real and ideal MSC is well interpreted by means of energy models and current flow mechanism developed in [2] based on the superposition of AEF and the space charge field (SCF).

AEF real MSC was recently established with electrical and thermoelectric methods, and it has been measured directly by modern atomic-force microscopy (AFM) and studied in detail in [3–6]. In [3], investigated by AFM topography, phase contrast and the potential distribution on the free surface of the Au–nGaAs Schottky diode. Found that around a thin film metal contact in the region AEF formed a transition region (aureole) surface of GaAs, where the potential varies gradually between the values of the potentials of the metal contact and the free surface of a semiconductor.

The width of the aureole with increasing contact diameter of 5–50 μm increases from 2 to 20 μm and up to 500 μm – more about 30–35 μm. The potential of the aureole at a distance greater than 10 μm from the periphery of the contact changes more two times, and on the periphery of the contact with the width of less than 2 μm – more 10 times. In the case of Au–nGaAs Schottky diode with a mesa structure, the width of the aureole is reduced by more than two times [4]. The width of the aureole and the value of reduction potential are defined by the magnitude and sign in the space charge [5]. For Au–nGaAs SD the increase in diameter from 5 up to 500 μm leads to increase in potential and width of the aureole from 4 up to 26 μm and for Au–pGaAs SD to reduce of potential and increase in width of the aureole from 2 up to 4 μm.

Numerous features AEF depending on the configuration and size of the contact surface geometry, the nature and thickness of the metal film, the conductivity types and properties of the semiconductor surface, as predicted in [2], the experimentally established in AFM studies in the thesis [6], where the first direct measurements AEF SD based on GaAs. Specific features on the surface distribution of AEF SD: surface potential changes linearly in the aureole and sharply on the lateral boundary of the metal 1–2 μm in width and moderately on the metal surface.

Great interest was attracted to study the effect of AEF on the nature of current flow in the DS [4–11]. The AFM study of the current distribution on the surface of epitaxial n-GaAs revealed a significant effect of the distribution of the contact potential difference (CPD) on the periphery to current flow in them [4–6]. It was found that the current through peripheral region of contact began to pass at certain reverse bias. As reverse bias increased up to 5 V, the peripheral currents began to grow.

The brightness of the AFM images in the main area of the contact and the bright ring remains unchanged at the general background level. The width of the bright ring measured by AFM was less than 0.3 μm. It is interesting to note that the occurrence of the reverse current in the narrow peripheral region and the local microcontacts of SD on GaAs under certain applied voltages have been found in research with scanning electron microscopy also in the early studies [7,8].

In [9] studied mezacontacts Au–nGaAs Schottky diode with a diameter of 5–700 μm on the surface of the epitaxial layer nGaAs thickness of 0.6 μm. Significant dependence of the saturation current forward and reverse current–voltage characteristics of the SD in their diameter was determined in AEF measurements. The increase in contact diameter of 5–700 μm reduces the distinction of forward and reverse saturation currents from five orders of magnitude to zero.

In [10], the AEF has a influence on the photoelectric characteristics Au–nGaAs SD converter and significantly increases the efficiency of conversion of light energy into electrical energy. In a study of Au–nGaAs SD same area (7854 μm^2) circular with a diameter of 100 μm, and a rectangular shape with a width of 89, 40, 20, 10 and 5 μm found that the saturation current of the various forms of SD in the forward direction is almost the same value. Their inverse *I–V* characteristics in a semi-logarithmic scale are linear over a wide range of voltages and consist mainly of the peripheral currents with the same linear density (1×10^{-10} A/μm). Photocurrent narrow Au–nGaAs SD under AEF increases by three orders of magnitude.

In [11] it is shown that the electric influence between assembled in diode matrix SD with different diameters ($D = 3$, 5, 10, 15 and 30 μm) is manifested in the change of the surface potential and *I–V* characteristics. A sufficient condition is the existence of overlapping areas aureoles AEF. Difference