# «Saint Petersburg OPEN 2018»

# BOOK of ABSTRACTS

## 5th International School and Conference on Optoelectronics, Photonics, Engineering and Nanostructures

April 2-5, 2018 • Saint Petersburg, Russia

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# Ti/4H-SiC Schottky diode breakdown voltage with different thickness of 4H-SiC epitaxial layer

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**Abstract.** Breakdown voltage for Ti/4H-SiC type Schottky diode with six guard rings have been calculated theoretically and by mean of numerical simulations. It is shown that the breakdown voltage can be increase at the minimum on 100 V in case when thickness of the *n*-type 4H-SiC epitaxial layer increase from 18 up to 22 μm. It is established that the breakdown voltage value for Ti/4H-SiC type Schottky diode with guard rings calculated by mean simulation in ATLAS program and theoretically have good approximation. Thus, above approach gives the possibility for projection of diode structure with different 4H-SiC epitaxial layer thickness with higher breakdown voltage value.

## 1. Introduction

The silicon carbide Schottky diodes are of special interest since these unipolar devices avoid reverse recovery effects of bipolar devices [1]. In particular, SiC Schottky diodes for power electronics in future must be produced by domestic company the ZAO «GRUPPA KREMNY EL» (Bryansk). It is obviously that for development of component base on the base of SiC studying and optimization of such important device as Schottky diode it is necessary. In our previous paper have been studied 4H-SiC type Schottky diodes with Ni and Ti Schottky anode contacts without guard rings [2–4] and 4H-SiC type MOS transistors [5]. Therefore in present work the main goal is investigation of thickness of the epitaxial layer (4H-SiC) effect on breakdown voltage 4H-SiC Schottky diode with Ti Schottky anode contact with guard rings for increasing of breakdown voltage value.

## 2. Materials and methods

Figure 1a shows the schematic silicone carbide Schottky diode structure for calculation. For calculation and numerical simulation were chosen the following the Schottky diode parameters: the concentration of donors (nitrogen) in the substrate equals $N^{+} = 10^{18}$ cm$^{-3}$, in the *n*-type epitaxial layer (nitrogen) equals $N^{-} = 3\times10^{15}$ cm$^{-3}$, in the guard rings (boron, depth of guard about 2 μm) regions $N_{p+} = 10^{18}$ cm$^{-3}$, anode material is Ti (titanium), the thickness of the epitaxial layer (4H-SiC) was chosen equals 18 μm, 20 μm and 22 μm, the radius of the structure equals *r*=140 μm.

## 3. Results and discussion

At first, on base of ionization integral Baliga's model [6] have been calculated theoretical value of breakdown voltage for different thickness of 4H-SiC epitaxial layer – 2.139 kV for 18 μm, 2.377 kV (20 μm) and 2.615 kV (22 μm). Afterward, with aim to compare theoretically calculated breakdown

voltage has been carried out numerical simulation on physical analytical model in ATLAS program that was described in detail in previous works [2-4], but in our case the incomplete impact ionization has been taking into account. As follows from Fig. 1b the breakdown voltage value $V_{\mathrm{ATLAS}}$ corresponds to 2.332 kV – for thickness of the 4H-SiC epitaxial layer equals 18 μm, 2.380 kV – for 20 μm, 2.412 kV – for 22 μm. It is established that in case when thickness of the 4H-SiC epitaxial layer

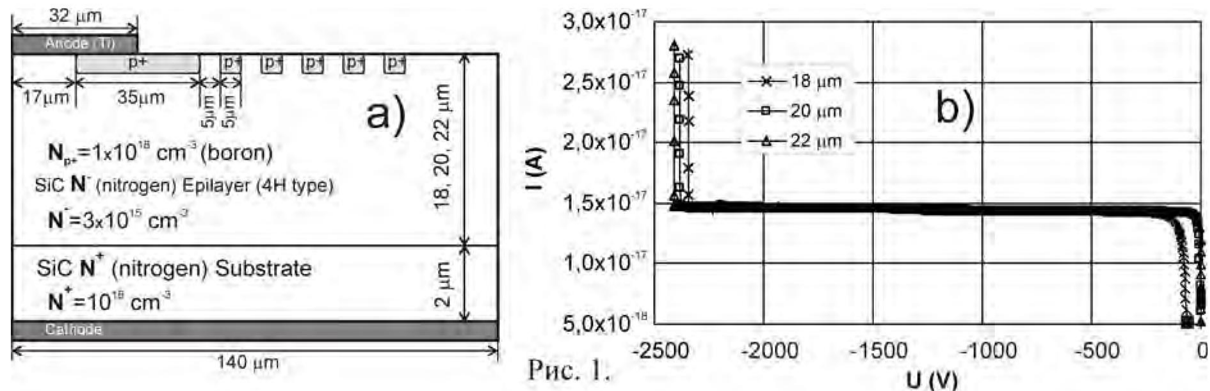


**Figure 1.** a) schematic silicone carbide Schottky diode structure in cylindrical coordinates for calculation; b) reverse *I-V* characteristics of Ti/4H-SiC Schottky diode calculated in ATLAS for various thickness of the epitaxial layer (4H-SiC) 18 μm, 20 μm and 22 μm.

increase from 18 up to 22 μm it lead to increase of breakdown voltage at the minimum on ~100-400 V in accordance with numerical calculation and theoretical calculation.

## 4. Conclusions.

Finally, investigation of thickness of the epitaxial layer (4H-SiC) effect on breakdown voltage Ti/4H-SiC Schottky diode with six guard rings for increasing of breakdown voltage value has been carried out theoretically and by mean of numerical simulation in ATLAS. For Ti/4H-SiC type Schottky diode with six guard rings it is established that in case when thickness of the 4H-SiC epitaxial layer increase from 18 up to 22 μm it lead to increase of breakdown voltage at the minimum on ~100 V.


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