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DEVICE-PROCESS SIMULATION OF SILICON DIODE STRUCTURES BY VARIOUS PARAMETERS OF EPITAXIAL FILM

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INTRODUCTION

At present various diodes types [1] are widely used as in the capacity of discrete devices so in the capacity of different integrated circuit components. The new semiconductor devices design requires device-process simulation of such ones very often because the simulation allows to reduce costs on experimental samples making. The device construction and its technological fabrication process are unknown very often and it's necessary to realize device-process simulation for specific manufacturing environment. Therefore the simulation of semiconductor devices [2] including diodes is the important stage in its production process.

The aim of this work was the simulation of the silicon diode structure with area of 4 μm x 1 μm = 4 μm^2 at its formation in next epitaxial film types: 1) 17.0SEPh2.0; 2) 25.0SEPh6.0; 3) 25.0SEPh20.0. The simulation of diode technological fabrication process and the electric characteristics was performed with the help of the software package of the company Synopsys [3] which is the instrument for such aims.

SELECTION AND SIMULATION OF THE PROCESS CHART FOR DIODE FORMATION

The short technological fabrication process of simulated diode includes next operations:

1. Selection of substrate type: 100SESb0,01 (silicon doped antimony Sb of the electron type conductivity with the diameter D = 100 mm and resistivity of ρv= 0,01 Ohm·cm).
2. Formation of epitaxial films of next types: 17.0SEPh2.0; 25.0SEPh6.0 and 25.0SEPh 20.0.
3. Pyrogenic oxidation with oxide thickness d=700 nm.
4. Etching-out of windows in deposited oxide. The window diameter is 180 μm.
5. The prior oxidation with oxide thickness d=150 nm.
6. The ion-implantation doping by boron.

7. The up-diffusion of boron and oxidation with oxide thickness d=600 nm.
8. Etching-out of windows in oxide. The window diameter is 150 µm.
9. The annealing at the temperature of 850 Celsius degrees during 30 minutes in O2.
10. The ion-implantation doping by boron.
11. The substrate thinning up to 180 µm.
12. The metal deposition for formation of contacts to the p-type areas.

The calculation values of diode structure design parameters are presented in the Table 1 and on the Fig 1.

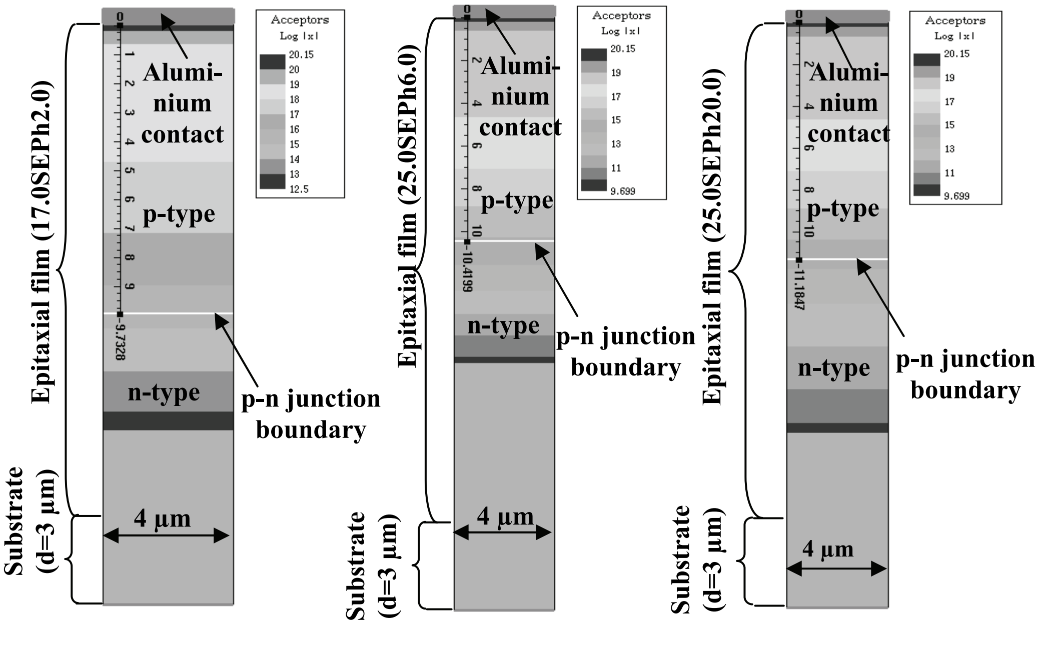

Fig. 1. The part of diode structures maked in the next epitaxial film types: 17.0SEPh2.0 (a); 25.0 SEPh 6.0 (b) and 25.0SEPh20.0 (c)

The diode structure maked in epitaxial film type of 17.0SEPh2.0 is shown on the Fig. 1, (a); that maked in epitaxial film type of 25.0SEPh6.0 is presented on the Fig. 1, (b); the structure formed in epitaxial film type of 25.0SEPh20.0 is shown on the Fig. 1, (c). The width of above-mentioned structures is 4 µm for acceleration modeling process. The junction depth Xj of the structure shown on the Fig. 1, (a) is 9.76 µm and its p-region sheet resistance Rs is 42.7 Ω/sq, the residual oxide thickness Dres is 419 nm; the Xj of the structure shown on the Fig. 1, (b) is 10.44 µm and its Rs is 42.4 Ω/sq, the Dres is 419 nm; the Xj of the structure presented on the Fig. 1, (c) is 11.24 µm and its Rs is 44.2 Ω/sq, the Dres is 419 nm (see Table 1).

Table 1

The calculated residual oxide thickness Dres, p-n-junction depth Xj and sheet resistance Rs values received after the diodes p-type region up-diffusion for three types of epitaxial film

	The residual oxide thickness, Dres, nm	The sheet resistance, Rs, Ω/sq	The p-n-junction depth, Xj, μm
The type values[1)] / The epitaxial film type	450	40	9,5
17.0SEPh2.0	419	42,7	9,76
25.0SEPh6.0	419	42,4	10,44
25.0SEPh20.0	419	44,2	11,24

[1)] The type values are presented for epitaxial film type 25,0SEPh6,0.

THE SIMULATION OF DIODE STRUCTURE ELECTRICAL PERFORMANCES

The diode electrical characteristics simulation results are presented in the Table 2. The calculation value of direct voltage drop is 0.86 V for diode maked in epitaxial film type of 17.0SEPh2.0, is 0.88 V for diode maked in epitaxial film type of 25.0SEPh6.0 and is 0.88 V for diode maked in epitaxial film type of 25.0SEPh20.0 (see Table 2).

The breakdown voltage values of simulated diode in epitaxial film type of 17.0SEPh2.0 is 124 V, in epitaxial film type of 25.0SEPh6.0 is 270 V and in epitaxial film type of 25.0SEPh20.0 is 266 V (see Table 2).

The simulated diode structure include the total epitaxial film thickness which growed on the substrate with thickness of 3 μm (instead of substrate thickness of 180 μm received after its thinning).

Table 2

The calculated values of direct voltage drop Uth at diode current 100 мA and breakdown voltage Ubr at diode current 10 μA recieved with using epitaxial film three types

The epitaxial Film type	Direct voltage drop, Uth, V	Breakdown voltage, Ubr, V
17.0SEP2.0	0.86	124
25.0 SEP 6.0	0.88	270
25.0 SEP 20.0	0.88	266

Such limitations are conditioned by maximal mesh nodes quantity which allowable in the 2-D process simulation program TSuprem4 and by computation time. The maximum allowed quantity of nodes in TSuprem4 is 40000. The substrate with thickness of d = 180 μm and resistivity of ρ_v= 0,01 Ohm·cm contribution into total impedance of p-region/epilayer/substrate structure is 1 Ohm. The direct voltage drop on such resistance is 0.1 V at current of 100 mA.

The calculated values of the direct voltage drop on diodes were defined at current $2,264\times10^{-5}$ A because structure with area of 4 μm ×1 μm=4 μm^2 was simulated. The p-n-junction active region radius of diode as an device is 75 μm then diode active structure total area is $\pi\cdot(75)^2\approx$ 17671,5 (μm^2). The current value of $2,264\times10^{-5}$ A through device with area 4 μm^2 corresponds to one of 100 mA through device with area 17671,5 μm^2 at forward bias of diode p-n-junction. The current value of $2,264\times10^{-9}$ A through device with area 4 μm^2 corresponds to one of 10 μA through device with area 17671,5 μm^2 at reverse bias of diode p-n-junction.

Diode structure design parameters and electrical ones values received as a results of modeling are well matched with the experimental data.

CONCLUSION

The results of simulation of diode technological fabrication process and its electric characteristics for the cases of using next epitaxial film types: 1) 17.0SEPh2.0; 2) 25.0SEPh6.0; 3) 25.0SEPh20.0 are presented in this article. The calculation values of diode structure design parameters, threshold and breakdown characteristics and respective voltage values were received for three epitaxial film types. The calculated results are well matched with the experimental data.

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CW EPR STUDY OF NATURAL MONGOLIAN COALS

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CONTINUOUS WAVE ELECTRON PARAMAGNETIC RESONANCE (CW EPR) METHOD.

The cw EPR spectra were obtained in the solid state at room temperature (300 K) in glass tubes in a presence of air (I) and in a flow of nitrogen gas (II). The samples were in size of greater than 5 mm and weighted nearly 30 mg. Sample mass is measured on the Mettler Toledo AE 260 micro balance and size on SMZ-140 series Stereomicroscope with magnification range ×40. A Bruker Elexsys II E500 X-Band spectrometer was used operating at a frequency of 9.8 GHz, with a 100 KHz modulation frequency, 0.01-0.1 mT modulation amplitude and ≤ 200 mW microwave power (200 mW at 0 dB attenuation). The spectrometer was equipped with a super high Q-factor resonator (ER 4122 SHQE) which has a cylindrical shape TE_{011} cavity. Modulation amplitude and time constant of EPR regis-