Pt/GaAs side wall Schottky diode

Petr Macháč[1], Martin Žilka[1], Zdeněk Výborný[2]

[1]Institute of Chemical Technology, Department of Solid State Engineering, Technická 5, 166 28 Prague 6, Czech Republic, +420224355157
[2]Academy of Sciences, Institute of Physics, Cukrovarnická 10, 162 53 Prague 6, Czech Republic, +420220318413

Abstract — This contribution deals with the technological realization of a special GaAs Schottky diode, based on the side-by-side technique. This is a structure, where one of the dimensions of the Schottky contact is given by the thickness of the epitaxial layer on which the structure is fabricated. We reached the value of cut-off frequency 21 GHz; this is in discrepancy with the theoretically predicted parameters. The contribution describes the technological improvements, which should lead to increase limiting frequency through the changing the structure morphology.

I. Introduction

Recently there was published a procedure [1] for making the Schottky contacts of area less than 0,5 μm^2 using conventional optical lithography. Small area is reached by limiting of one dimension of the junction by thickness of the epitaxial layer. The resulting Schottky junction is normal to the substrate surface. Its area is limited by the lithography resolution in one direction only (generally in micrometers); the other direction is given by thickness of the epitaxial layer, which can reach 100 nm or less. This procedure was called the side-by-side technique. Author of the work predicts for this type of Schottky diode fabricated on GaAs cut-off frequency of generally THz, but the structure was not realized.

The first realization of a GaAs Schottky diode based on the side-by-side technique has been published in [2]. There was prepared a diode with stripe width of 20μm, on an epitaxial layer 820nm thick. The results assumed in the original work [1], however, were not reached. The principal problem occurring at the realization was high serial resistance of the diode, which was as high as 500Ω. A great deal of this value was caused by high contact resistance of the ohmic contact.

The aim of this presented work is to optimize the features of the GaAs Schottky diode based on the side-by-side technique mainly to reach higher cut-off frequency. We carried out better ohmic contacts and designed a new morphology of such contact. Moreover, more complex epitaxial structures were used. These design modifications were aimed to reduce the value of the serial resistance of the diode and to increase its cut-off frequency.

II. Experimental Details

The technological process of the diode preparation was similar to that described in [2]. To reduce contact resistivity of the ohmic contact, epitaxial structures as per Fig. 1 were used. Non-doped GaAs plates with orientation (100) were used as substrates. As a reference structure we used simple epitaxial layer of the n-GaAs type, with doping level of 1x10^{17} cm^{-3}. The heavily doped subcontact layer (doping level 1x10^{18} cm^{-3}) was used in the second structure, the third structure utilized a δ-doped layer with silicon, doping level 3x10^{12} cm^{-2}. The epitaxial layers were grown by metal-organic vapor phase epitaxy in the Institute of Physics, Academy of Science, Czech Republic.

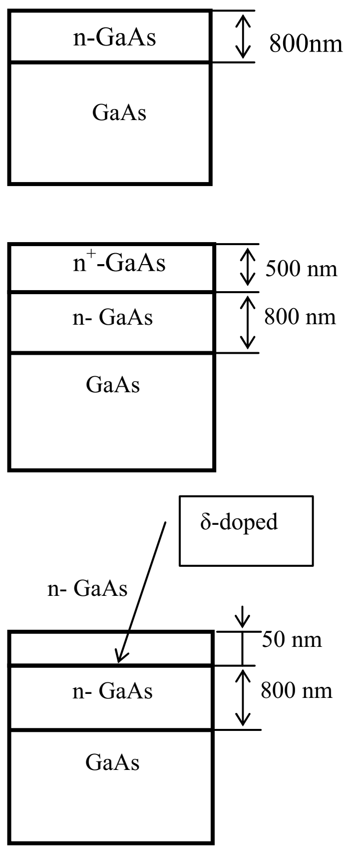

Fig. 1. Schematic outline of epitaxial structures.

Fig. 2. Ohmic contact layout.

The technological procedure was supplemented with one more lithographic step and consequential etching which removed the sub-contact layer except of the area

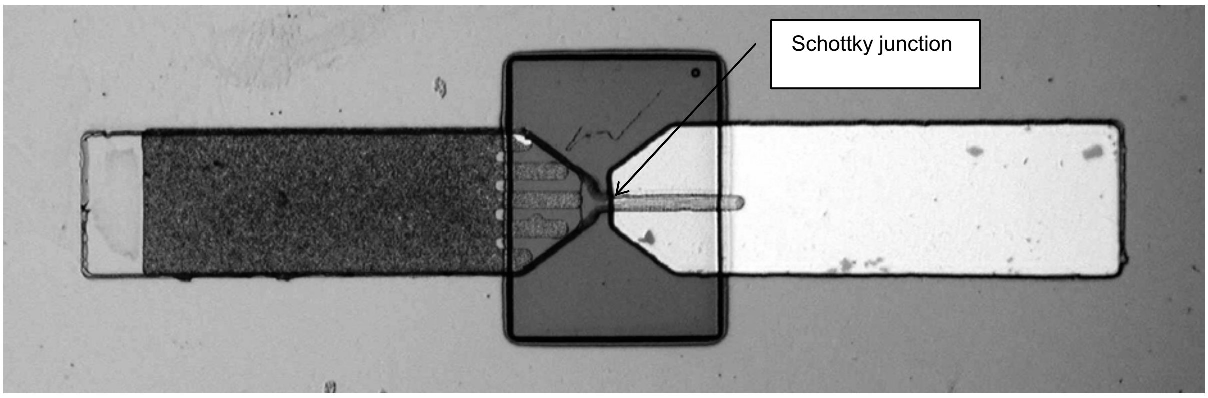

Fig. 3. Microphotography of the Schottky diode prepared by the side-by-side technique.

of the ohmic contact. Schematic illustration of the ohmic contact layout is shown at Fig. 2. The designed form of the metallization was targeted to increase the length of the contact edge, which adjoins the Schottky contact and thus to reduce the contact resistance. A microphotography of the Schottky diode structure is shown in Fig. 3. The structure has 10 μm width of the stripe, the arrow shows the position of the Schottky junction. The left contact pad is the ohmic contact and the right is the Schottky metal. The Schottky junction is covered by the polyimide passivation layer.

As a basic parameter, upon which the high-frequency features of the diodes were considered, the rectification capability was chosen; that was measured on a measuring set at the Department of Electromagnetic Field, Czech Technical University, Prague. The diode was connected as a parallel rectifier and the measured value was the dependence of the DC voltage component U_{ss} on the frequency of the input signal of 1 mW power. Prior to measuring, the diode chips were fixed to the micro strip lines 0.615 mm wide, fabricated on the corundum plate of 25x25 mm dimensions. The technology of surface mounting was used here.

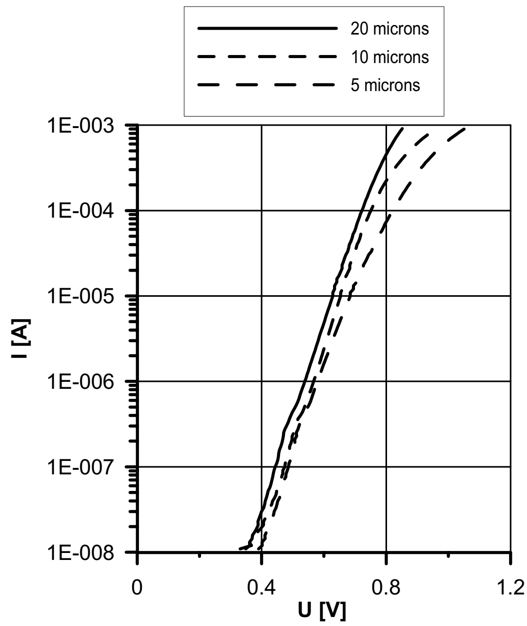

Fig. 4. Forward I-V characteristic of prepared Schottky diodes.

III. Results and discussion

The metallization of the Ge/Pd-type ohmic contact was used for the Schottky diode. We prepared a number of contact structures, aiming to optimize the layer thickness and the composition of the metallization. Thin titanium sub-contact layer was used for elimination of natural oxides from the GaAs surface and the contact structure was completed by the Au/Ti covering layer [3]. The most suitable parameters were reached for the metallization Au(40nm)/Ti(50nm)/Ge(80nm)/Pd(40nm)/Ti(0,5nm), whose contact resistivity was 4.9×10^{-6} Ωcm^2 (this value was reached on the GaAs epitaxial layer with doping level 7×10^{17} cm^{-3}).

The Pt Schottky contacts of the following parameters were prepared: n=1.07, $I_o=3.9\times10^{-14}$ A, $\phi_B=0.977$ eV. These Schottky contacts were prepared on the epitaxial layer with doping level 4×10^{16} cm^{-3}, the junction area 200x200 μm.

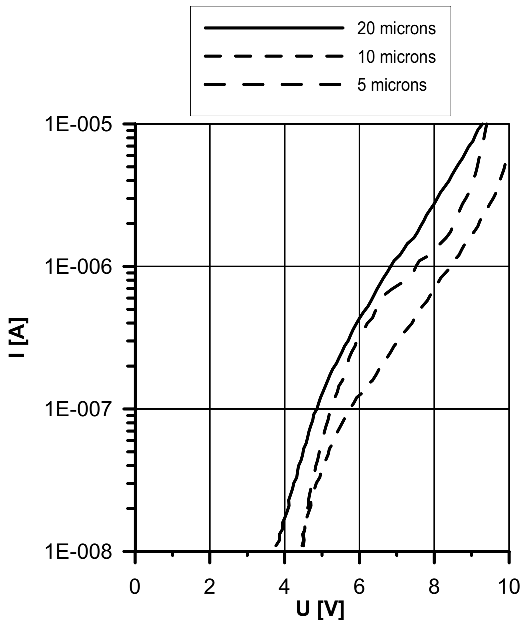

Fig. 5. Reversed I-V characteristic of the diodes.

The examples of measured forward current-voltage (I-V) characteristics of Schottky diodes are shown at Fig. 4. The picture depicts the influence of stripe width on the course of I-V characteristic. The increasing of the strip width produces the decreasing of the serial resistance.

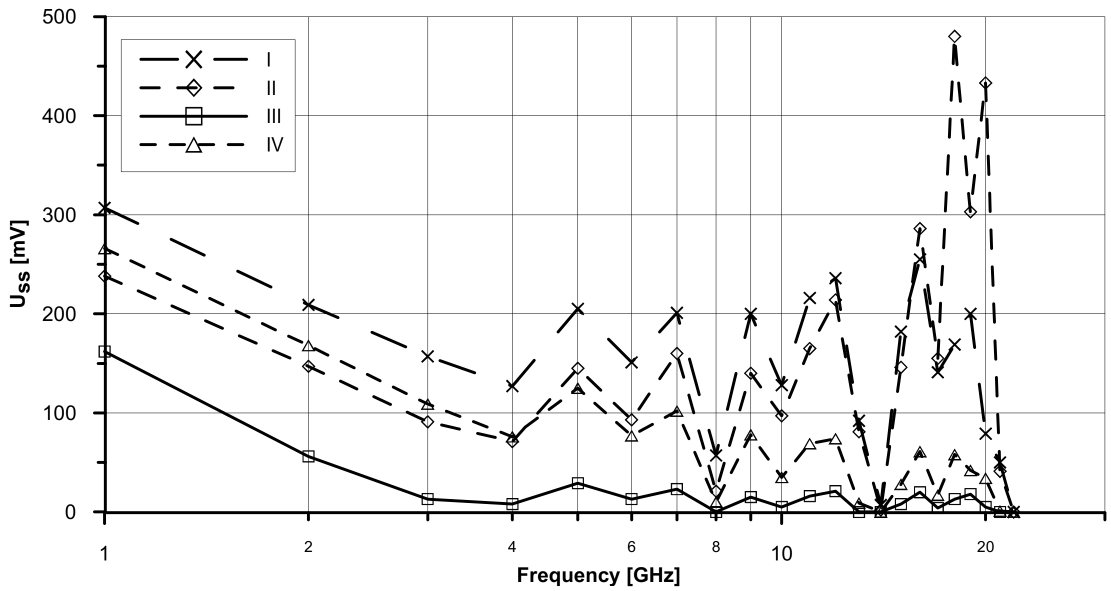

Fig. 6. Rectification capability of prepared diodes, I – the structure with δ-doped layer, 20 μm stripe; II – the structure with the subcontact layer, 20 μm stripe; III – the reference structure, 20 μm stripe; IV - the structure with δ-doped layer, 10 μm stripe.

The best diodes show the serial resistance in the range from 100 to 200 Ω. Fig. 5 shows reverse I-V characteristic of the diodes. The cut-off voltage exceeded 6 V (current of 1μA).

Fig. 6 shows the rectifying capability of several prepared diodes (I – the structure with δ-doped layer, 20 μm stripe; II – the structure with the subcontact layer, 20 μm stripe; III – the reference structure, 20 μm stripe; IV - the structure with δ-doped layer, 10 μm stripe). Reached limiting frequencies were 21 GHz in the case of the first two diodes. The reference diode produces very small output rectified voltage and the diode with 10 μm stripe shows permanent decay of the voltage. Steps in the characteristics are produced bad impedance matching and by a parasitic lead inductance.

VI. Conclusion

This contribution deals with the technological realization of a special GaAs Schottky diode, based on the side-by-side technique. We reached the value of cut-off frequency 21 GHz. Nevertheless, this result is far from the value earlier estimated by the author of the original work [1], where the side-by-side technique was suggested. We increased the cut-off frequency by 7 GHz using of new ohmic contact structure and more complicated epitaxial structures in comparison with our previous results [2], but the serial resistance is still high and other parasitic effects play a role. Further improvements could be reached by changing the structure morphology. Now we are preparing following modifications:

- elimination of the narrow stripe,
- expanding of the subcontact layer right to the Schottky contact,
- reducing of the Schottky junction dimensions.

We made the rough estimate of the cut-off frequency and we hope 200 GHz can be expected.

Acknowledgement

This work was supported by the Czech Ministry of Education, research project No. MSM-223100002.

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