FABRICATION AND OPTIMISATION OF PLANAR SCHOTTKY DIODES

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Abstract

Aiming at a more reliable and cheaper fabrication the replacement of whisker contacted Schottky diodes for applications in the THz frequency range is an important topic of investigation. The recent status of planar Schottky diodes using the quasi-vertical approach is shown. Mixer diodes with anode diameters of 0.8 - 2 μm and cut-off frequencies up to 9 THz have been fabricated that offer characteristics comparable to whiskered diodes with the same diode parameters.

Introduction

GaAs Schottky barrier diodes are used as frequency multiplier in all-solid-state local oscillators and as mixer element in heterodyne receivers in the THz frequency range. Especially whisker-contacted Schottky diodes have been the preferred nonlinear element at frequencies above 300 GHz. The main limitation of whiskered diodes is that there is no integration possible. Therefore, the development of competitive planar Schottky barrier diodes has been put forward in the last decade. The first planar device that has shown that the replacement of whisker-contacted devices is possible, is the surface channel diode [1]. Another approach that has been proposed three years ago is the quasi-vertical Schottky diode [2]. This paper describes the technology developments that made available mixer diodes using the quasi-vertical approach. First results of planar varactor diodes are shown.

Diode Design

The main idea of the quasi-vertical approach is to transfer the optimum geometry of the substrateless whiskered Schottky diode to a planar device. The main features are shown in fig. 1

The benefits of the substrateless Schottky diodes are:

- Minimum series resistance
- Little affected by the skin effect
- Excellent power handling capabilities

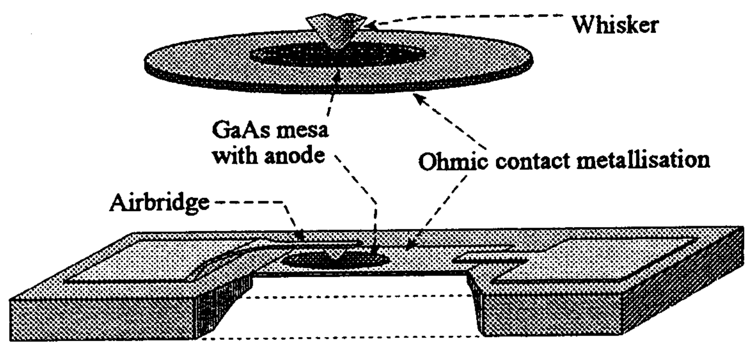

Fig. 1 Structure of the substrateless whiskered Schottky diode and quasi-vertical planar Schottky diode

These benefits are mainly caused by the reduction of the GaAs dimensions. Typical dimensions of whiskered diode chips have been drastically reduced. A reduction of the lateral dimension from 100-250 µm to 20-30 µm gives a reduction of the series resistance caused by the skin effect. The low thermal conductivity of GaAs leads to heating effects at high power levels. Therefore the reduction of the chip thickness from 70-80 µm to 2-3 µm leads to a significant improvement in the power handling capabilities. Additionally the contribution of the substrate to the series resistance is minimized. Fig. 2 gives a comparison of the series resistance of a substrateless diode and a planar surface channel diode for identical diode parameters [3,4].

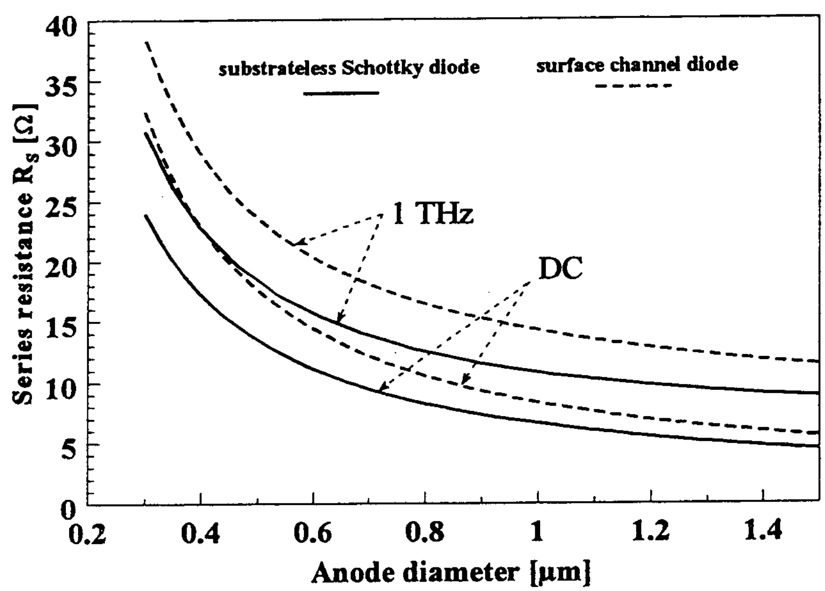

Fig. 2. Series resistance for different diode geometries

The difference in series resistance is about 20-30 %. The basic active region of the quasi vertical planar Schottky diodes is identical to the substrateless Schottky diode. Therefore, the above remain the same as for whiskered diode chips where many experiences are available.

In the design of planar devices reducing stray capacitances that limit the performance is important. Mainly two contributions to the parasitic capacitance have to be considered. The main contribution regards to the contact pads that typically cause a parasitic capacitance of 10 fF on GaAs substrate for planar devices. With respect to an integration using a proper design, this contribution vanishes. Therefore, the main contribution that has to be reduced is the parasitic capacitance of the airbridge. Using a finite-difference technique, we have investigated the influence of the airbridge parameters on the parasitic capacitance. We could achieve the most effective reduction in fabricating a high airbridge that is at least two microns higher than the diode mesa. Even with an airbridge width of 4 microns the contributions do not exceed 2 fF.

Fabrication Technology

The main disadvantage of the quasi vertical planar Schottky diode was the lack of a suitable, mature fabrication technology. Especially technologies for a proper structurisation of small contacts from the backside of the wafer were not available. In addition existing airbridge technologies had to be modified with respect to small airbridge dimensions and airbridge height of at least four microns. Using a new two-stage spray etching technique, we have overcome the structurisation problem (fig. 3). Fig. 4 shows that we have established an airbridge technology according to the requirements.

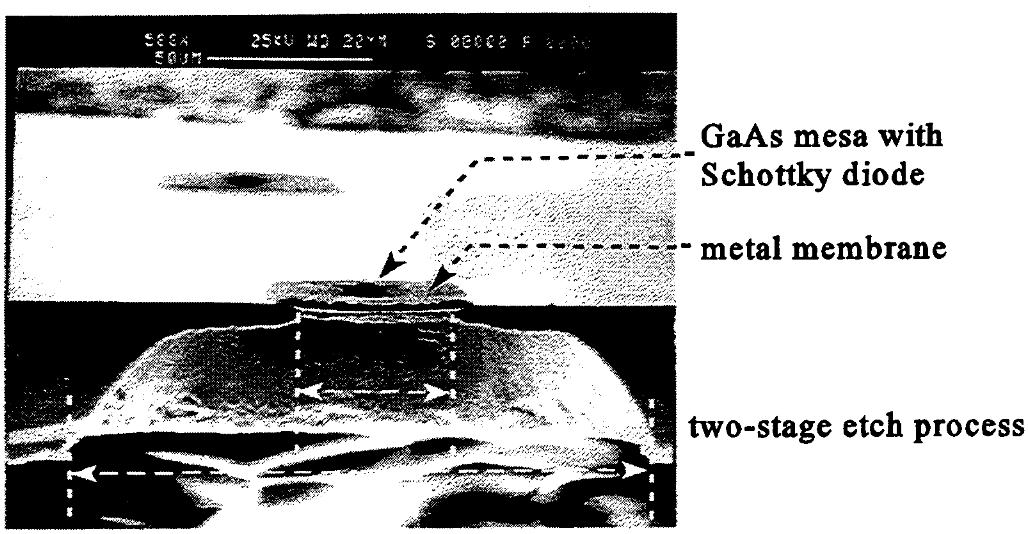

Fig. 3 Two-stage etching technique for contact structurisation

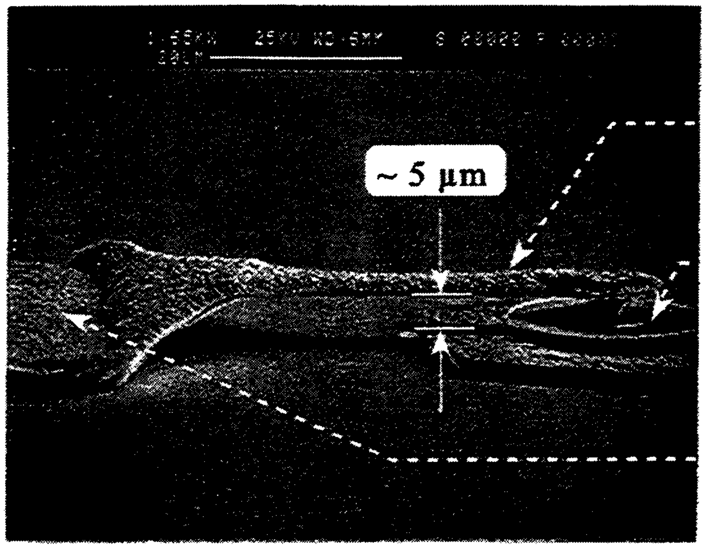

Fig. 4 SEM-picture of quasi vertical diode

Results

The characteristic parameters of different planar mixer diodes are given in the table below. There is no remarkable difference between these diodes and substrateless whisker diodes with the same diode parameters.

	DAP0308	DAP0312	DAP0320
n_{epi} [cm^{-3}]	$3 \cdot 10^{17}$	$3 \cdot 10^{17}$	$3 \cdot 10^{17}$
d_{epi} [nm]	70	100	100
d_a [µm]	8	12	2
R_S [Ω]	15-20	9.2	5
C_{jo} [fF]	1.1	2.2	5.8
η	1.13	1.1	1.08
V_{br} [V]	5-5.8	5-5.8	4.9-5.1
f_c [THz]	9	7.9	5.5

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The parasitic capacitance of single devices is 9-10 fF. This is mainly due to the contribution of the contact pads (>8fF). First varactors with a low series resistance, zero-bias junction capacitances in the range between 10fF and 20 fF and a capacitance variation of $C_{jo}/C_{min} > 2.4$ have been fabricated. Using substrateless whiskered diodes capacitance modulations of >3 are possible. This indicates that there is a further improvement possible.

Conclusion

The technology for quasi-vertical planar Schottky diodes has been established. Several improvements in the technology made available planar quasi-vertical mixer diodes with anode diameters of 0.8µm, 1.2 µm and 2 µm and corresponding cut-off frequencies up to 9 THz. The characteristics are comparable to whiskered diodes with the same diode parameters.

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