IEEE MICROWAVE AND GUIDED WAVE LETTERS, VOL. 3, NO. 6, JUNE 1993

Composite Anode Contact for Planar Transferred Electron Devices

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***Abstract*—In order to prevent the anode contact of transferred electron devices (TED's) from burning out, a Schottky contact is frequently used. Unfortunately this approach gives rise to a decrease in efficiency due to the built-in voltage of the Schottky contact. A possibility to avoid this decrease is to use a composite contact. By combining a short stripe of a Schottky metal with an ohmic contact, the loss of dc power dissipated in the Schottky anode contact is eliminated thereby maintaining to some extent the depletion layer necessary for preventing the formation of a stationary high field domain at the anode contact. With this approach, a 30% increase in efficiency of a CW operated field effect controlled transferred electron device (FECTED) oscillator at a frequency of 35 GHz has been obtained. The achieved efficiency of 3.8% is, to our knowledge, the highest efficiency obtained with a planar TEO at 35 GHz.**

I. Introduction

An attractive candidate for building a monolithic millimeter-wave oscillator is the so called field-effect controlled transferred electron device (FECTED) [1]. It is a planar device with an injection limiting cathode contact that makes it extremely useful for very high frequency operation as it is not subject to the usual transit-time limitation as conventional TED's and FET's are. As a consequence of this, it is not necessary to fabricate gates with dimensions in the submicrometer range. Another advantage is that the frequency of oscillation can be tuned over a wide range by simply varying the dc voltage applied to the gate.

One very severe problem of conventional TED's is the very high electric field forming at the ohmic anode contact. The reason for this stationary high field layer is the "diffusion instability" caused by electrons diffusing from the highly n-doped contact layer to the weakly n-doped drift region [2]. This negative space charge causes "humps" of the electric field as illustrated in Fig. 1. If a voltage is applied to the n+ regions of the device, the field at the cathode side of the device is weakened, whereas at the anode side the field is increased. Thus, the maximum value of the electric field appears at the ohmic anode contact. This field is further enhanced by travelling domains moving into the anode contact. There, they get stuck thereby further increasing the electric field. This can easily cause breakdown and destruction of the device.

One frequently used method for suppressing the excessive field is the replacement of the ohmic contact by a Schottky contact at the anode side of the drift region. The depletion region occurring underneath the metal contact causes a positive space charge to form thereby counteracting the negative space charge. The corresponding electric field is shown in Fig. 2. Using this technique, the field at both the cathode and the anode contacts is lowered thereby preventing breakdown to occur. However, the built-in voltage at the Schottky anode contact occurs which adds up to the dc-power dissipation of the device. In order to enhance the oscillator efficiency, this voltage drop should be avoided.

If a FECTED is operated correctly no travelling domains

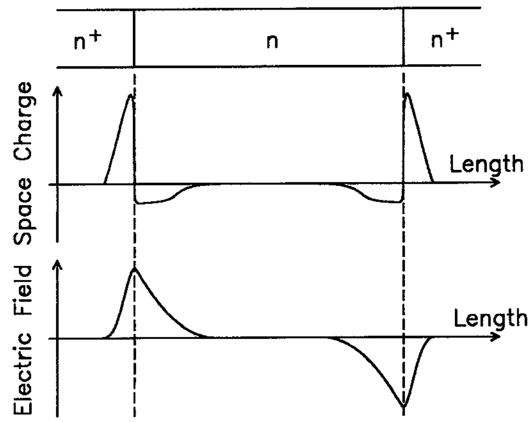

Fig. 1. Curves of space charge and electric field without external biasing as valid for a transferred electron device with ohmic cathode and ohmic anode contact.

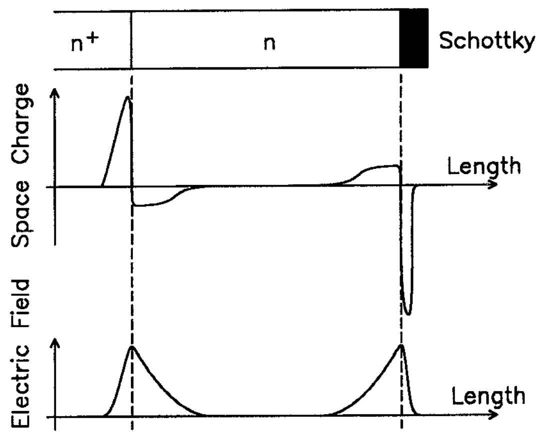

Fig. 2. Curves of space charge and electric field without external biasing as valid for a transferred electron device with ohmic cathode and Schottky anode contact.

Manuscript received February 10, 1993. This work was supported by the Austrian Fonds zur Förderung der wissenschaftlichen Forschung.

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IEEE Log Number 9209408.

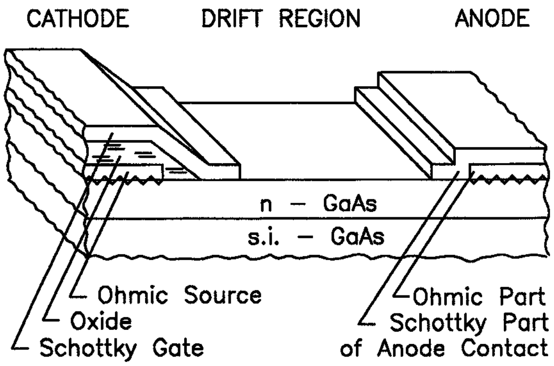

Fig. 3. Schematic cross section of a field effect controlled transferred electron device with an injection limiting cathode contact (left) and a composite anode contact (right). The gate electrode is used for adjusting electron-injection only and is connected to ground RF-wise.

exist due to the injection-limiting effect of the negatively biased gate contact. Consequently, a breakdown at the anode contact cannot occur. However, if the gate line is disconnected erroneously travelling Gunn domains may form which in turn can lead to the destruction of the device.

II. Design

Fig. 3 shows a cross sectional view of a FECTED with the proposed composite contact. On the left hand side of the device the injection-limiting cathode contact consisting of an ohmic source contact and a Schottky gate contact is depicted. The proposed anode contact is shown on the right-hand side. It consists of an ordinary ohmic contact and an overlapping Schottky contact which extends into the drift region of the device. The length of the overlapping Schottky region is about 0.5 μm. If a travelling domain reaches the anode the electrons are drained into the depletion layer underneath the Schottky contact.

III. Device Fabrication

For this investigation, we have chosen the same structure of the FECTED as used previously [3] with the exception of the anode contact. The circuitry has already been published in [4]. The ohmic contacts consist of 16.5 nm Ge / 33 nm Au / 16.5 nm Ge / 33 nm Au / 33 nm Ni / 33 nm Au and are annealed for 2 minutes at 450°C. The Schottky metallization contains 7 nm Cr and 120 nm Au. The spacing between the edge of the Schottky contact and the edge of the ohmic contact turned out to be not critical, although a long Schottky region adds dc-power loss.

IV. Experimental Results

Typical results obtained with oscillators with and without the proposed composite anode contact structure are shown in Table I. The predicted enhancement in efficiency has been proved by the shown experimental results. The dc-power calculated by multiplying the voltage drop across the Schottky diode times the supply current can thus be eliminated by the introduction of the additional ohmic stripe. This new design has no impact on the RF-performance since the microwave signal passes the depletion region of the Schottky-diode without being affected.

TABLE I
Bias Conditions and CW-Performance of FECTED-Oscillator-MMIC's With (A) and Without (B) the Proposed Composite Anode Contact

	(A)	(B)	
Bias Voltage	5.3	6	V
Bias Current	71.3	83	mA
RF-Power	14.3	14.8	mW
Efficiency	3.8	3.0	%

The bias conditions have been set for optimum output power, the frequency of operation has been 35.0 GHz.

V. Conclusion

We have shown that the efficiency of a FECTED-oscillator can be enhanced by the incorporation of an ohmic stripe into the Schottky anode contact without deteriorating the RF-performance. Using this approach, an efficiency of 3.8% and an output power of 14 mW have been obtained in CW-operation at 35 GHz. The measurements carried out on these devices have revealed the best efficiency figures ever obtained with planar transferred electron oscillators.

Acknowledgment

The authors would like to thank J. Katzenmayer, G. Hinterberger, and G. Hofmann for fabricating and testing the devices.

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