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V. Drakinskiy[1a], P. Sobis[2], H. Zhao[1], T. Bryllert[1,3], and J. Stake[1]
[1]Terahertz and Millimetre Wave Laboratory, Department of Microtechnology and Nanoscience,
Chalmers University of Technology, SE-412 96 Gothenburg, Sweden
[2]Omnisys Instruments AB, SE-43132 V. Frölunda, Sweden
[3]Wasa Millimeter Wave AB, Gothenburg, Sweden
[a]vladimir.drakinskiy@chalmers.se

***Abstract*— We present the progress of the technological development of a full e-beam based monolithically integrated Schottky diode process applicable for sub-millimetre wave multipliers and mixers. Evaluation of the process has been done in a number of demonstrators showing state-of-the-art performance, including various multiplier circuits up to 200 GHz with a measured flange efficiency of above 35%, as well as heterodyne receiver front-end modules operating at 340 GHz and 557 GHz with a measured receiver DSB noise temperature of below 700 K and 1300 K respectively.**

Keywords— Schottky diodes, passive circuits, membrane, submillimeter wave mixers, multipliers

I. INTRODUCTION

There is a need for efficient and reliable heterodyne receivers operating in the sub-millimetre wave band above 300 GHz for future space science missions and earth observation instruments. The sub-millimetre wave regime allows the study of different meteorological phenomena such as water vapour, the ice and water content in clouds, and ice particle sizes and distribution, which are important parameters for the hydrological cycle of the climate system and the energy budget of the atmosphere.

Today Schottky diode mixers and multipliers are the key elements for millimetre and sub-millimetre wave room-temperature heterodyne receiver systems. At frequencies up to around 400 GHz discrete diode technology can be applied. The planar Schottky diode topology has proven reliable and is today used in most commercial mixer and multiplier circuits.

At higher frequencies (> 400 GHz) monolithic integration is needed due to better fabrication and alignment tolerances as well as to enable more advanced circuit integration. Moreover, the performance and functionality of discrete diode circuit designs, is limited by the shape and thickness of the supporting substrate. One of the solutions is the fabrication of monolithic integrated circuits (MICs) supported by a thin membrane. Numerous results based on this technique have been reported [1]. In this paper we present a full e-beam based Terahertz MIC GaAs Schottky membrane process enabling advanced circuit integration well up in the THz range.

II. DIODE FABRICATION

A. *Schottky diode mixer on membrane*

The Chalmers diode process is based on electron beam lithography, with a beam spot of less than 5 nm, allowing precise and repeatable anode and air bridge formation. Hence, this process module can also be utilized for submicron size anodes and terahertz monolithic integrated circuits (TMICs). Scanning Electron Microscope images of a mixer diode is shown in Figure 1.

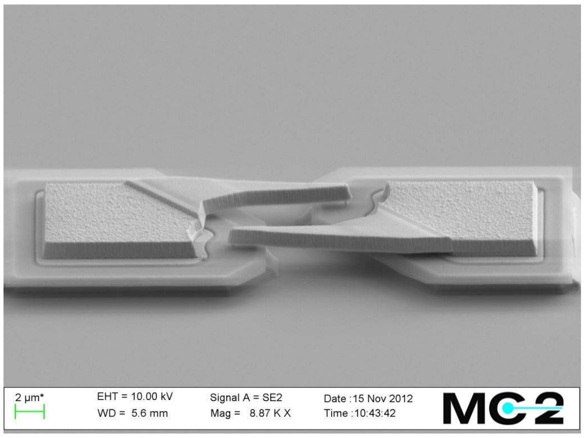

Figure 1. SEM image of an antiparallel diode with an anode area of 0.1 µm^2 designed for operating at 1.2 THz and fabricated at MC2 Chalmers.

For the diodes on membrane, the starting structure is a semi-insulating GaAs substrate supporting a 3 µm thick GaAs layer sandwiched in between two AlGaAs etch stop layers and a buffer and an active layers. The standard diode fabrication process is as follows:

- Deposition of a stress-balanced PECVD SiO_2 layer.
- Patterning of the ohmic contacts, wet etching through the SiO_2 layer and the active layer of GaAs and deposition of the ohmic contacts metallization with following lift off process.
- Annealing of the ohmic contacts.
- Patterning of the Schottky contacts, wet etching through the SiO_2 layer and deposition of the Schottky contacts metallization with following lift off process.
- Patterning of the air bridge and deposition of metallization with following lift off process.
- Isolation of the diode by wet etching.
- Patterning of the membrane shape, wet etching of 3 µm GaAs using a selective etchant, which stops etching on the bottom AlGaAs layer.
- Patterning of passive circuitry e.g. beamleads, waveguide probes and filter structures and deposition of metallization with following lift off process.

- Thinning down the sample from the backside to the AlGaAs layer which is then etched away to release the devices.

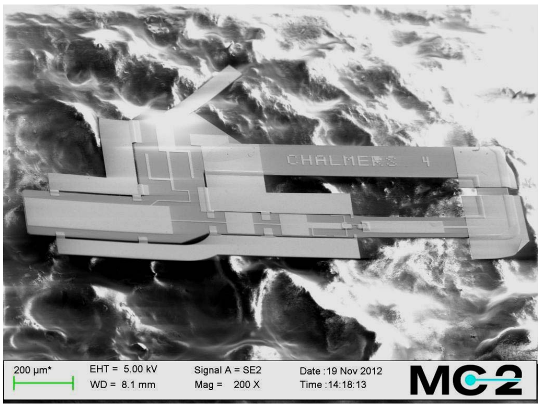

Figure 2. SEM image of a released monolithically integrated Schottky membrane mixer designed for operating at 557 GHz and fabricated at MC2 Chalmers.

In Figure 2, a 557 GHz membrane mixer MIC developed under the TeraComp FP7 EU project is shown. With this particular mixer design an optimum receiver noise level of less then 1300 K DSB including all losses has been reached with several assembled mixer modules, using an external IF LNA with a T_{min} of 30 K. The result by itself is a redefinition of state of the art performance for room temperature receivers at these frequencies, but also an important indication for the device quality of our process [2].

B. Schottky doublers on membrane

The device technology described above can also be used for GaAs Schottky multipliers. Results for our narrowband GaAs Schottky varactor multipliers show a very good agreement between model simulations and measurements indicating good process control.

In Figure 3 a Schottky membrane doubler mounted in a waveguide block module is shown. The design is optimized for a high efficiency and low input power. The measurements show state-of-the-art results that are presented in Figure 4.

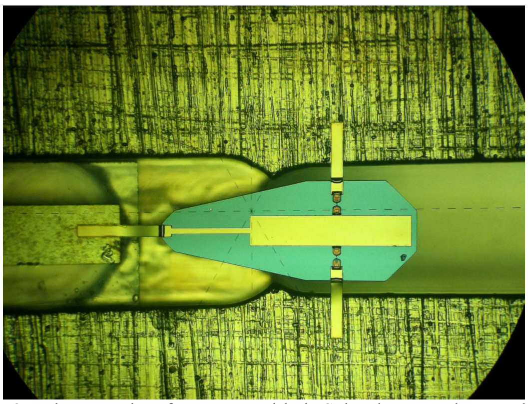

Figure 3. Photograph of an assembled Schottky membrane doubler, designed for an operating output frequency of 170 GHz and fabricated at MC2 Chalmers.

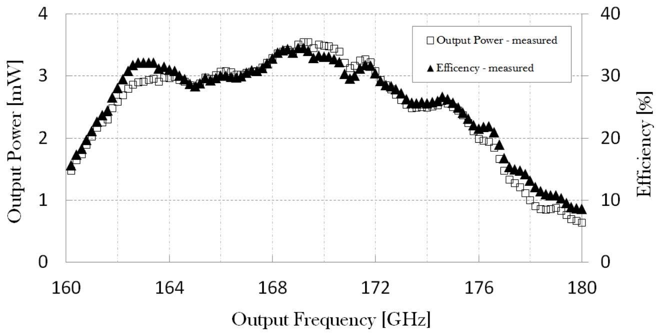

Figure 4. Measured results for a low power 170 GHz high efficiency Schottky membrane doubler, with a measured bandwidth of nearly 10% and with a 3.5 mW of output power running at 35% efficiency.

Figure 5 shows the measured results for a broad band Schottky doubler, which covers a full waveguide band with more than 10% conversion efficiency and good return-loss.

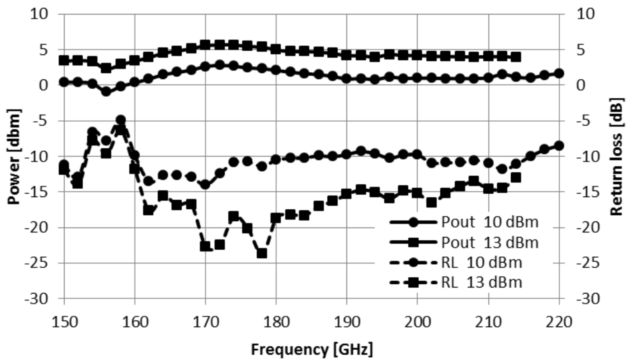

Figure 5. Measured results for a broadband Schottky membrane doubler covering a full waveguide band.

III. Conclusions

The fabrication process of monolithically integrated Schottky diode mixers and multipliers for THz applications has been developed. The agreement between the results and simulations indicates good control and stability of the process.

Acknowledgment

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