Status and Progress of Schottky Technology Development for SWI and ISMAR

V. Drakinskiy[1*], P. Sobis[2], H. Zhao[1], A. Malko[1], T. Bryllert[1,3], and J. Stake[1]
[1]*Gigahertz Centre, Department of Microtechnology and Nanoscience (MC2), Chalmers University of Technology, Gothenburg, Sweden*
[2]*Omnisys Instruments AB, V. Frölunda, Sweden*
[3]*Wasa Millimeter Wave AB, Gothenburg, Sweden*
*Contact: vladimir.drakinskiy@chalmers.se, phone +46-31-7721848

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. The process has been employed in a number of demonstrators showing state-of-the-art performance.**

I. Introduction

There is a need for developing efficient and reliable heterodyne receivers operating in the sub-millimetre wave band above 500 GHz for future science missions and Earth observation instruments such as International SubMillimetre Airborne Radiometer (ISMAR) and the Submillimetre Wave Instrument (SWI)[1,2]. The sub-millimetre wave regime allows studying different meteorological phenomena such as water vapour, cloud ice water content, ice particle sizes and distribution, which are important parameters for the hydrological cycle of the climate system and the energy budget of the atmosphere. Similar data can be collected from the atmospheres of planets and moons.

ISMAR is an airborne platform dedicated for the demonstration and validation of microwave atmospheric sounding instruments in 200 GHz to 1000 GHz range and currently under development by the Met Office in UK.

SWI is a part of JUpiter ICy moons Explorer (JUICE) mission, which is the next large European science mission planned for launch in 2022 and arrival at Jupiter in 2030. This mission will tour the giant planet to explore its atmosphere, magnetosphere and tenuous set of rings and will characterise the icy moons Ganymede, Europa and Callisto mapping their surfaces, sounding their interiors and assessing their potential for hosting life, as the moons are thought to harbor vast amounts of water.

The operational frequency bands for science missions carrying planetary atmosphere characterisation instruments are moving towards up to several Terahertz (THz) [3,4]. While discrete GaAs Schottky diodes and hybrid circuits are adequate for frequencies up to 400 GHz, monolithic integration is necessary at higher frequencies 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. Monolithic integrated circuits (MICs), supported by a thin membrane, overcome restrictions imposed by the substrate thickness [5-7]. On the other hand, a drawback of GaAs Schottky based sub-systems is that they traditionally require relatively high local oscillator (LO) powers, in the order of ~mW, compared to SIS and HEB technologies, which operate at ~μW levels. The LO power requirements have to be considered when moving to higher frequencies ~1 THz. For applications with limited mass and power budget, applying biasing schemes or switching to low bandgap material systems e.g. InGaAs, becomes an interesting solution, as the required LO power can be reduced up to an order in magnitude. These options however come with the downside of increased mixer noise.

In the presentation we would like to show a current status of process development of THz MIC GaAs Schottky membrane mixers and multipliers and an alternative Schottky diode mixers based on InGaAs material.

II. Diode Fabrication

One of the process requirements for mixers operating at THz frequencies is anode's area, which becomes as small as 0.15 μm^2 or even smaller (Fig.1). 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.

A. GaAs Schottky diode mixers and multipliers on membrane

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 Chalmers THz MIC membrane Schottky process is described in [8,9]. For process of THz MIC a resist reflow is used to form a stream-line slope across the mesas followed by a metal deposition and lift-off. Scanning Electron Microscope (SEM) image of an integrated mixer diode is shown in Fig.2.

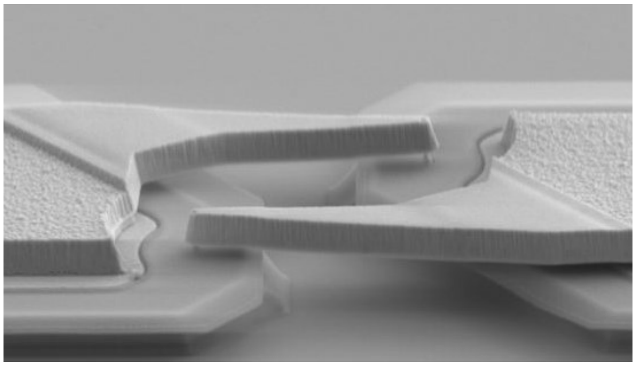

Figure. 1 SEM image of an antiparallel diode with an anode area of 0.1 μm^2 designed for operating at 1.2 THz and fabricated at MC2 Chalmers.

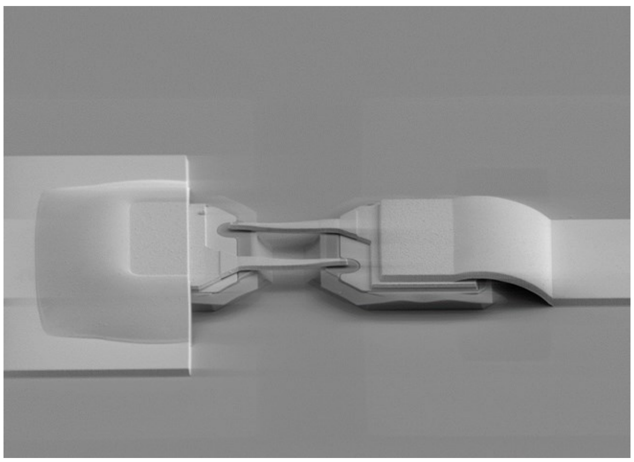

Figure. 2 SEM image of the monolithic integrated antiparallel diodes fabricated at the MC2 process laboratory at Chalmers.

B. InGaAs Schottky diode mixers

Process for InGaAs Schottky diode is quite similar to that for GaAs Schottky diode, except for that the mesa etching and e-beam dose are carefully optimized for the different materials.

III. Conclusions

A full e-beam integrated Schottky diode membrane process dedicated for THz operation, has been developed at Chalmers University of Technology. The process is currently supporting several THz science projects, e.g. the development of 874 GHz front-end receivers for ISMAR instrument, and SWI 600/1200 GHz broadband spectrometer front-ends for JUICE mission, as well as the development of THz harmonic mixers for QCL phase locking applications up to 4.7 THz [10].

Acknowledgment

This work was carried out in the GigaHertz Centre, in a joint research project financed by the Swedish Governmental Agency of Innovation Systems (VINNOVA), Chalmers University of Technology, Omnisys Instruments AB, Wasa Millimeter Wave AB, Low-Noise Factory AB, and SP Technical Research Institute of Sweden.

References

[1] http://www.metoffice.gov.uk/research/foundation/observational-studies/microwave

[2] http://sci.esa.int/juice/

[3] E. Schlecht, J.V. Siles, C, Lee, R. Lin, B. Thomas, G. Chattopadhyay, I. Mehdi, "Schottky Diode Based 1.2 THz Receivers Operating at Room-Temperature and Below for Planetary Atmospheric Sounding," *Terahertz Science and Technology, IEEE Transactions on* , vol.PP, no.99, pp.661,669.

[4] S.A. Retzloff, A. Young, J. Hesler, "A 1.46 THz Schottky receiver at cryogenic temperatures," 39:th Int. Conf. on *Infrared, Millimetre, and THz waves, IRMMW 2014*.

[5] P.H. Siegel, R.P. Smith, S. Martin, and M. Gaidis, "2.5 THz GaAs monolithic membrane-diode mixer," IEEE Trans. Microw. Theory Tech., vol.47, no. 5, pp. 596-604, May 1999.

[6] P.J. Sobis, V. Drakinskiy, A. Emrich, H. Zhao, T. Bryllert, A-Y. Tang, J. Hanning, J. Stake, "300 GHz to 1.2 THz GaAs Schottky membrane TMIC's for next generation space missions," *24th International Symposium on SpaceTerahertz Techniques, ISSTT 2013*.

[7] P. Neumaier, H. Richter, J. Stake, H. Zhao, A.-Y. Tang, V. Drakinskiy, P. Sobis, A. Emrich, A. Hülsmann, T. Johansen, T. Bryllert, J. Hanning, V. Krozer, and H.-W. Hübers, "Molecular Spectroscopy With a Compact 557-GHz Heterodyne Receiver," *IEEE Transactions on Terahertz Science and Technology*, vol. 4, 2014.

[8] H. Zhao, V. Drakinskiy, P. Sobis, J. Hanning, T. Bryllert, A.-Y. Tang, and J. Stake, "Development of a 557 GHz GaAs monolitic membrane-diode mixer", 24th International Conference on Indium Phosphide and Related Materials, Audust 2012.

[9] V. Drakinskiy, P. Sobis, H. Zhao, T. Bryllert, and J. Stake, " Terahertz GaAs Schottky diode mixer and multiplier MICs based on e-beam technology," , *25th International Conference on Indium Phosphide and Related Materials,* Kobe, Japan, 2013.

[10] B.T. Bulcha, J.L. Hesler, N.S. Barker, "Development of THz Harmonic Mixer for QCL Phase Locking Application," 39:th Int. Conf. on *Infrared, Millimetre, and THz waves, IRMMW 2014*.