Conception and Fabrication of GaAs Schottky diodes for Mixers

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Abstract—**We report on the design and fabrication of Schottky diodes for millimeter and submillimeter wave mixers. The process for anti-parallel pairs of diodes with submicronic anode areas on 10/50µm thick GaAs substrates is presented and these diodes will be used in 183GHz and 330GHz mixer blocks.**
I(V) measurements have been performed and values of the ideality factor and the reverse saturation current have been determined.

Index Terms—**GaAs Schottky diodes, Air-bridges, Millimeter and submillimeter waves mixers**

I. INTRODUCTION

Millimeter and submillimeter heterodyne observations will improve our understanding of the universe, the solar system and the Earth atmosphere. Schottky diodes are strategical components that can be used to build THz sources or mixers working at room temperature. A GaAs Schottky diode is one of the key elements for multipliers and mixers at THz frequencies since the diode can be extremely fast by reducing its size and also very efficient thanks to the low forward voltage drop[1].

II. FABRICATION TECHNOLOGY

The fabrication process presented below is based on electron beam lithography and conventional epitaxial layer designs. The starting material is a semi-insulating 500µm GaAs substrate with epitaxial layers grown by Metal-Organic Chemical Vapor Deposition (MOCVD) or Molecular Beam Epitaxy (MBE).

The layer structure consists of a first 400nm of AlGaAs etch-stop layer and a first GaAs 40µm membrane followed by a second 400nm of AlGaAs etch-stop layer and a second GaAs thick membrane.
The active parts of the substrates are as followed, 40nm AlGaAs etch-stop layer, an 800nm heavily doped $5x10^{18}$ cm^{-3} n^{+} GaAs layer and a 100nm n type GaAs layer doped $1x10^{17}cm^{-3}$.

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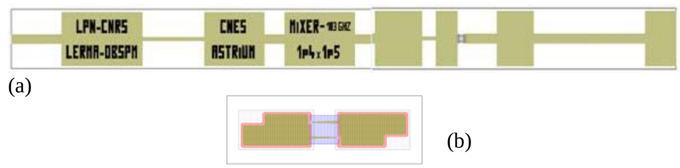
A. Device Processing

Two different structures for mixers, a 183GHz MMIC mixer (Fig 1-a) and a 330GHz circuit mixer (Fig 1-b) have been designed via CAD systems and fabricated using e-beam lithography.



(a) (b)

Fig 1: CAD captures of 183GHz MMIC mixer (a) and 330GHz circuit mixer (b).

A selective AlGaAs/GaAs wet etching is used to define the device mesas, the etch rate slows down sufficiently when the etch-stop layer is reached.
For the ohmic contacts, the n+ GaAs layer is recessed, Ni/Ge/Au metal films are successively evaporated and a rapid thermal annealing is performed.

For the air-bridges and Schottky anodes/connection pads, the process is as followed. Firstly, a square of resist is exposed and reflowed to form the support for the air-bridges.
The anodes are then fabricated using two layers of resists and the required profile is obtained by the combination of resist layer thicknesses, sensitivities and exposure doses.
Finally, Ti/Au metal film is evaporated to make the Schottky contacts and connection pads.

The diodes are then passivated using Si_3N_4 deposited by PECVD (Plasma Enhanced Chemical Vapor Deposition). To allow circuit integration, circuits are separated by a deep dry etching using ICP (Inductive Coupled Plasma) - RIE: 10µm etching for the 330GHz circuit and 50µm etching for the 183GHz MMIC.

Finally, the wafer is then mounted topside-down onto a carrier wafer by using wax. The semi-insulating GaAs substrate is thinned to the desired thickness (10µm or 50µm) using the same process as in [2].

Some scanning electron microscopy (SEM) pictures of the circuit and the diodes are shown in Fig 2 and Fig 3.

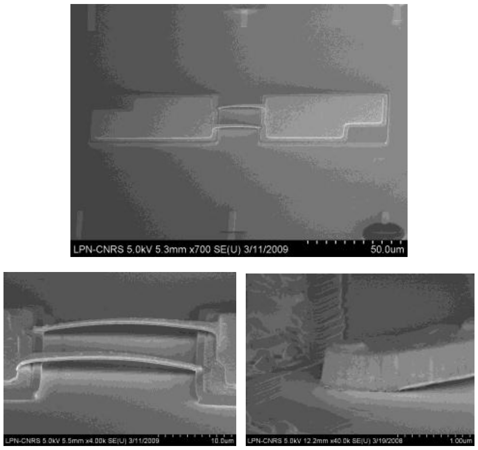


Fig 2: SEM pictures of the 330GHz circuit mixer

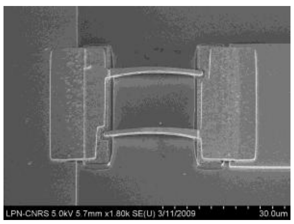


Fig 3: Close-up of the anti-parallel pair of Schottky anodes and air-bridges of the 183GHz MMIC mixer.

B. Devices DC Characteristics

Table 1 represents diode parameters fabricated at the LPN. All the diodes have the same finger length of 20µm. Electrical characteristics for each diode are deduced by standard I(V) measurements and reported in Table 2.

TABLE 1: FABRICATED DIODES PARAMETERS

Circuit Name	Diode #	Anode dimensions [µm x µm]
183 GHz	117M5	1.4 x 1.5
183 GHz	117M7	1.4 x 1.5
330GHz	117M8	0.8 x 1
330GHz	117M9	0.8 x 1
Best 1.10^{17}	117B2	5 x 7

TABLE 2: MEASURED DC PARAMETERS

Diode #	Ideality Factor n	Saturation current Is [A]	Series Resistance Rs [Ω]
117M5	1.165	6.56×10^{-14}	8.6
	1.178	1.39×10^{-13}	8.6
117M7	1.148	2.25×10^{-13}	5.71
	1.171	8.18×10^{-14}	7.11
117M8	1.097	3.51×10^{-14}	9.22
	1.125	3.91×10^{-14}	11.92
117M9	1.11	6.13×10^{-14}	10.47
	1.116	6.54×10^{-14}	11
117B2	1.08	2.53×10^{-11}	5.8

III. CIRCUIT INTEGRATION

183GHz MMIC Mixer: The completed testing structure consists of the circuit on a 50µm thick GaAs membrane, directly integrated onto the testing block pictured in Fig 4-a.

330GHz Mixer: The pair of anti parallel diodes, on a 10µm thick GaAs membrane is transferred topside down onto a 50µm thick quartz filter circuit substrate using epoxy [3]. A second quartz circuit completes the testing structures and the subharmonically 330GHz pumped mixer block is shown in Fig 4-b.

RF measurements will be performed at the Observatoire de Paris.

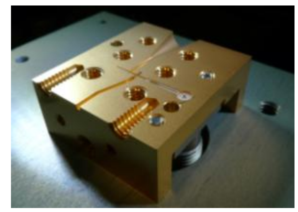

(a)

(b)

Fig 4: 183 GHz mixer bloc (a) and 330GHz mixer (b) bloc.

IV. CONCLUSION

Schottky diodes for mixers have been fabricated and their electrical parameters have been characterized. Since all fabrication steps are performed using e-beam lithography, our process allows further shrinking of the anode surface for higher frequencies mixers and multipliers.

RF Tests are in progress and results will be presented soon.

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