Fabrication of GaAs Schottky Nano-diodes with T-Anodes for Submillimeter Wave Mixers

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

***Index Terms* – Nano Schottky diodes, GaAs substrates, T-Anodes, Air-bridges, Submillimeter wavelengths, Frequency mixer**

I. Introduction

Millimeter and submillimeter heterodyne observations at THz frequencies will improve our understanding of the universe and the submillimeter-wave spectrum band 300GHz-400GHz continues to be of much interest for the exploration of the earth's and planets' atmospheres. A GaAs Schottky diode is one of the key elements for multipliers and mixers at these frequencies since the diode can be extremely fast by reducing its size and also very efficient thanks to the low forward voltage drop [1].

A. Fabrication technology

The fabrication process presented below makes use of the electron beam lithography and conventional epitaxial layer designs. The starting material is a semi-insulating 500µm thick GaAs substrate with epitaxial layers grown by Molecular Beam Epitaxy (MBE).

The layer structure consists of a 50nm $Al_{0,8}Ga_{0,2}As$ etch-stop layer, an 800nm heavily doped $5x10^{18}$ cm^{-3} n^{+} GaAs layer and a 100nm thick n type GaAs layer doped $1\text{-}5x10^{17}cm^{-3}$.

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B. Device Processing

A selective AlGaAs/GaAs wet etching is used to define the device mesas (a), the etch rate slows down sufficiently when the etch-stop layer is reached.
The ohmic contacts are first recessed into the n+ GaAs layer, Ni/Ge/Au/Ni/Au metal films are successively evaporated and a rapid thermal annealing is performed (a).
An air-bridge process is used to define the T-anodes and the connection pads at the same step. A first square of resist is exposed and reflowed to form the support for the air-bridges.

The T-anodes are fabricated using multi layer of resists and the required profile is obtained by the combination of resist layer thicknesses, sensitivities and exposure dose.
A Ti/Au Schottky and connection pads metal film is evaporated (b).

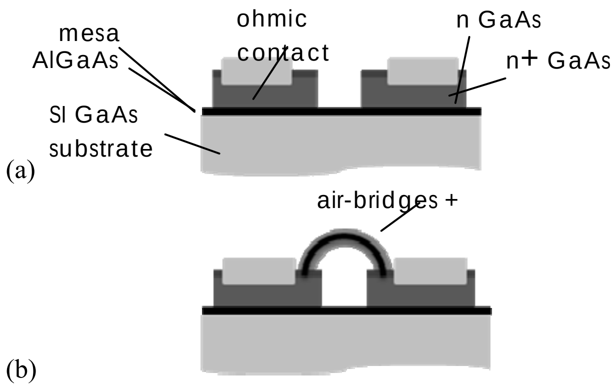

Fig.1 Fabrication process. (a) Ohmic and mesas definition. (b) T-anodes / air-bridge Schottky and connection pads deposition followed by passivation.

The diodes are finally passivated using Si_3N_4 deposited by Plasma Enhanced Chemical Vapor Deposition (PECVD). To allow a circuit integration, each circuit is separated from the others by a deep dry etching with an Inductive Coupled Plasma (ICP).

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 (12-10µm) using the process exposed in [2].

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

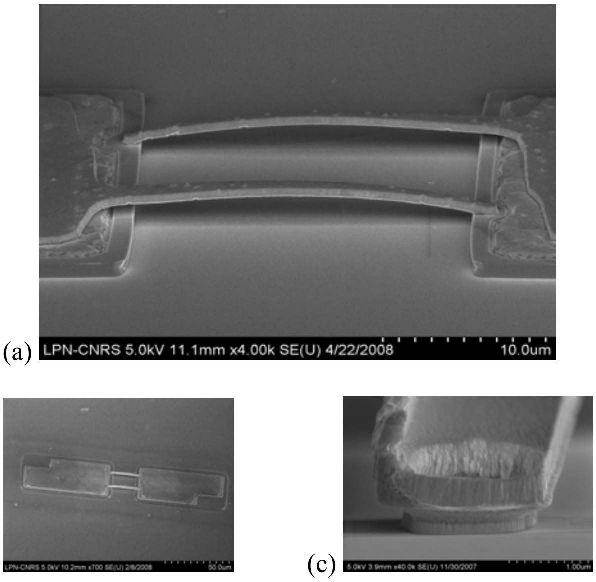

Fig.2 SEM pictures before passivation. (a) Air-bridges and the pair of anodes. (b) The 330GHz circuit. (c) Close-up of the T-Anode.

C. DEVICE DC CHARACTERISTICS

Table I represents diode parameters fabricated at the LPN in term of doping density and anode area. 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 II.

Diode	Doping (cm^{-3})	Anode Area (μm^2)
A-517-Sok	$5x10^{17}$	0.8
B-217-Sok	$2x10^{17}$	0.8
C-117-Sok	$1x10^{17}$	0.8
D-117-Ssup	$1x10^{17}$	1
E-217-Ssup	$2x10^{17}$	1

Table I. Fabricated diodes parameters.

Diode Pair	n	R_s (Ω)	I_s (A)
A	1.41	11	$1.6x10^{-13}$
B	1.20	11	$1.3x10^{-14}$
	1.24	12	$1.2x10^{-14}$
C	1.19	9	$6.8x10^{-16}$
	1.25	8	$2x10^{-15}$
D	1.28	13	$5.3x10^{-15}$
E	1.25	16	$8.3x10^{-15}$

Table II. Measured DC parameters for pairs of anti-parallel diodes.

It should be pointed that the process has not been fully optimized yet, and it is expected that the diode performances will be improved in the future.

D. Circuit Integration

The completed testing structure consists of a pair of antiparallel diodes transfered topside down onto a 50µm thick quartz filter circuit substrate using epoxy, a second quartz circuit and a subharmonically pumped mixer block at 330GHz [3]. RF measurements will be performed at the Observatoire de Paris.

CONCLUSION

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

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