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Integrated Schottky Technology for Supra-THz Applications

Vladimir Drakinskiy[1], Divya Jayasankar[1], Peter Sobis[1,2], and Jan Stake[1]

***Abstract*—This paper presents the technological development of e-beam lithography based monolithically integrated supra-THz Schottky diode process at the Chalmers University of Technology. Schottky diodes with sub-micron contact area integrated with mixer circuits were realised on an ultra-thin 2-μm GaAs substrate. The fabrication process, challenges and the yield of planar integrated mixer circuits are presented.**

***Index Terms*—Schottky diodes, GaAs, Mixers, Terahertz electronics**

I. Introduction

Schottky diodes are employed as primary detecting element as well as in the local oscillator chain for frequency stabilisation of quantum-cascade lasers (QCLs) [1]. They operate in wide intermediate frequency and ambient temperature, which is crucial for long lifetime space/air-borne missions to study Earth and other planetary atmospheres. Detection of molecular lines such as OI and OH at terahertz (THz) frequencies is essential. Our group has demonstrated successful frequency stabilisation of quantum-cascade lasers (QCLs) at 3.5 THz, and 4.7 THz using a Schottky-based harmonic mixer [2]. This paper reports the development of integrated sub-micron Schottky diode circuits on ultra-thin GaAs substrate.

II. Fabrication process

The realisation of terahertz integrated circuits demands the alignment of patterns with high accuracy and precision in the order of sub-microns. Hence, we have developed a fabrication process entirely based on electron-beam lithography. The GaAs wafer consists of a 50-nm-thick n-doped epi-layer with a doping concentration of $6 \times 10^{17}\,\mathrm{cm}^{-3}$. Followed by a 500-nm-thick, heavily doped n^{++} buffer layer with a doping concentration of $5 \times 10^{18}\,\mathrm{cm}^{-3}$. The wafer consists of two (Al,Ga)As etch stop layers as given in [3].

The detailed fabrication process is as follows, to protect the active layer, SiO_2 was deposited using PECVD. Later, the ohmic (Pd/Ge/Au/Pd/Au) and anode (Ti/Pt/Au) contacts were formed and followed by the formation of the mesa by etching both epi- and buffer layer. High anisotropy of the dry etching process compared to wet etching allows vertical sidewalls and minimises the risk of over-etching under the resist mask. In the next step, air bridge contacts and mixer circuit elements such as hammer-head filter were formed [4]. Finally, to provide mechanical support and heat transfer, 1-μm gold beamleads are formed. Fig. 1a shows the scanned electron micrograph (SEM) of the fabricated single-ended planar Schottky diode fundamental mixer circuit with sub-μm anode contact area on a 2-μm GaAs substrate.

III. Yield analysis

Before releasing the circuits, on-wafer dc tests were carried out using Kelvin probes in dark conditions. Fig. 1b shows the scatter plot of extracted diode parameters: series resistance (R_s) and ideality factor (η) consisting of about 30 integrated mixer circuits with three different contact areas. The mean and standard deviation of R_s and η are summarised below in Table. I. We believe the variation in diode parameters is caused due to a small deviation in Schottky contact areas.

[1]Chalmers University of Technology, SE-412 96 Gothenburg, Sweden.
[2]Low Noise Factory AB, SE-412 63 Gothenburg, Sweden.

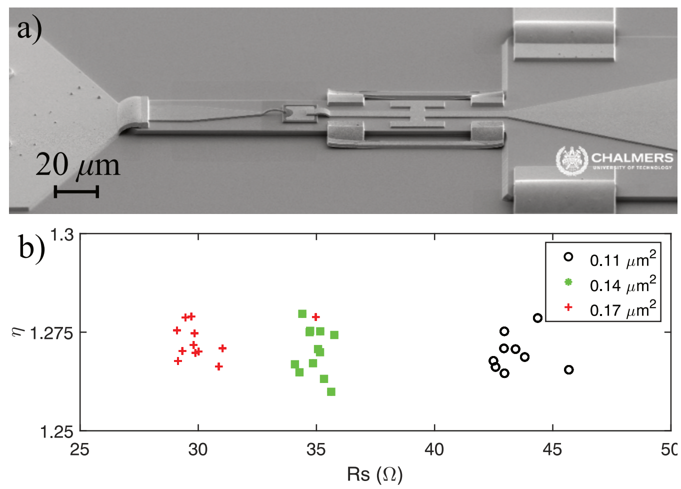

Fig. 1. Supra-THz Schottky mixers. a) SEM of the integrated 3.5-THz fundamental mixer circuit realised on a 2-μm GaAs substrate. b) Extracted R_s and η for three Schottky diode contacts (0.11, 0.14, and 0.17 μm^2).

TABLE I
Extracted dc-parameters of integrated 3.5-THz fundamental mixer circuits

Area (μm^2)	Series resistance (Ω)		Ideality factor (η)	
	Mean	Std.Dev	Mean	Std.Dev
0.11	44	2.7	1.27	6.0×10^{-3}
0.14	35	0.5	1.27	5.9×10^{-3}
0.17	30	1.6	1.27	4.4×10^{-3}

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