Investigating the potential of SiGe Diode in BiCMOS 55nm for power detection and datacom applications at 300 GHz

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***Abstract*—This paper describes millimeter wave (mmW) on-wafer continues wave (CW) power detection using dedicated high frequency diode junction, integrated on SiGe BiCMOS 55 nm technology from STMicroelectronics. This extraction was performed for two test structures configurations in order to evaluate the potential of this diode junction for power detection as well as for sub-Terahertz Transmission Link on 220 to 320 GHz Frequency Range. The power detection is performed by biasing the diode on its forward regime. That allows to obtain a voltage responsivity (γ) for variable bias current increasing from 1 nA to 5 µA and exhibiting a corresponding γ decreasing from 3000 V/W to 500 V/W at 320 GHz.**

I. INTRODUCTION

THE wireless communication application growth with video and music streaming leads to data traffic increasing exponentially and tends to saturate the allocated frequency bandwidths. That requires higher data rate with up to 100 Gb/s by increasing operating frequency. Sub-THz communication represents a great opportunity in order to reach data rates higher than 10 Gb/s. However, Atmospheric attenuation of THz waves is utmost important and leads to transmission distance limitation. THz communication for medium distance have a window between 200 GHz and 320 GHz frequency range. Several links have already been demonstrated in this frequency range using photonics and electronics technologies [1], [2]. THz link has been reported at 300 GHz using photonics device on transmitter chain and III-V Schottky barrier diode (SBD) on receiver chain, by performing intensity modulation and direct detection [3]. Silicon devices development becomes competitive to III-V semiconductors featuring higher integration level for electronics [4] or photonics [5].

II. TEST STRUCTURES

Figure 1 shows the two diodes test structures configurations which have been characterized. The first structure is dedicated to continuous wave power detection composed of diode with one anode finger of 1 µm, on two-port configuration. The second structure is dedicated to modulated signal detection. Composed of a diode with one anode of 5 µm, on "T" configuration. Both configurations were characterized for CW on wafer power detection, for a first evaluation of their voltage responsivity on modulated signal configuration. Figure 2 shows the measured I-V characteristic of both diodes.

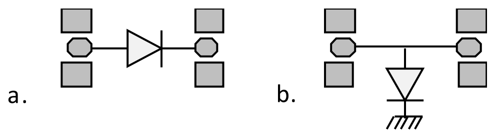

Fig. 1. Test structures configurations, a. L1N1 dedicated to CW power detection, b. L5N1 dedicated to modulated signal detection.

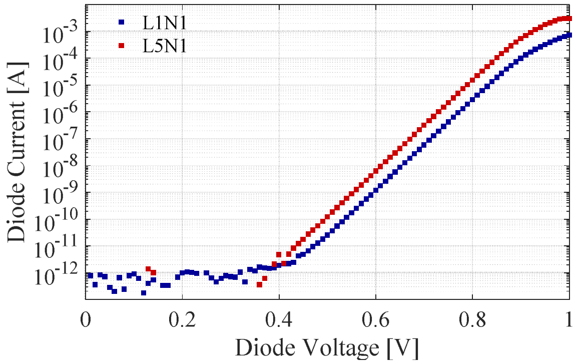

Fig. 2. Measured I-V characteristic of used diodes: one anode finger for 1 and 5 µm finger length.

III. SIGE PN JUNCTION DETECTION SENSITIVITY EXTRACTION

Figure 3 shows the block diagram of the setup used in order to perform on-wafer CW detection on test structure configuration a. The diode was biased on its forward regime through the integrated bias tee of RF probes. The current bias was applied and the corresponding DC voltage was measured. VNA extender was used as high frequency signal source on 220 GHz to 320 GHz frequency range providing available power around -30 dBm at contact pads plane. The 50 Ω mmW load connected after output RF probe helps to minimize any reflection at waveguide interface and stationary waves in the right probe.

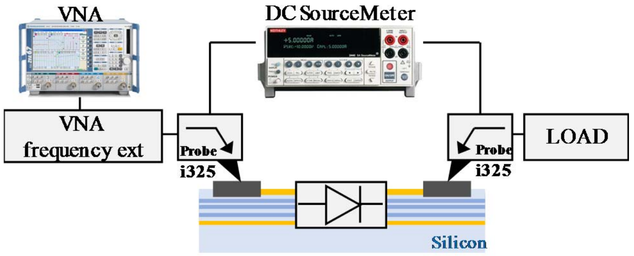

Fig. 3. Test bench block diagram to perform on wafer power detection on test structure configuration a.

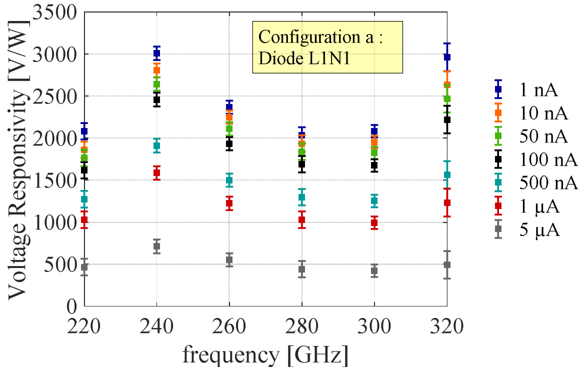

Fig. 4. Configuration a. Extracted voltage responsivity on 220 to 320 GHz frequency range for a variable bias current from 1 nA to 5 µA and -30 dBm of input power

In the case of biased detection operation, the diode is controlled with its DC current. The corresponding voltage value (V_{OFF}) when the source is OFF, is not equal to zero. Hence, when the source is switched in its ON state, the corresponding voltage value is shifted to (V_{ON}). Thus, the ratio between the delta voltage (V_{ON}–V_{OFF}) and the injected power of millimeter-wave signal corresponds to the sensitivity of the detector (γ). Figure 4 shows the extracted voltage responsivity of test structure a. The sensitivity of detector was extracted on 220 GHz to 320 GHz frequency range for variable bias current increasing from 1 nA to 5 µA and exhibiting a corresponding voltage responsivity decreasing from 3000 V/W to 500 V/W at 320 GHz. This unmatched detector is highly sensitive to source impedance. In addition, on the used setup for the on-wafer power detection, the sensitivity extraction depends on the presented impedance of the RF probes to the device and induce ripples on extracted values function of frequency. The main limitation on used measurement methodology comes from the measurement accuracy of voltage response. For bias power detection, a few mV of delta voltage is measured using 2 V voltage range measurement of the DC Source/meter, inducing an uncertainty of +/- 200 µV on the measurement values for (V_{ON}) and (V_{OFF}). The uncertainty was accounted for γ extraction. This limitation becomes more important for very low power detection.

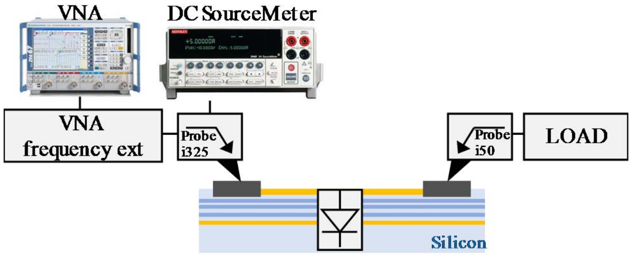

Fig. 5. Test bench block diagram to perform on wafer power detection on test structure configuration b.

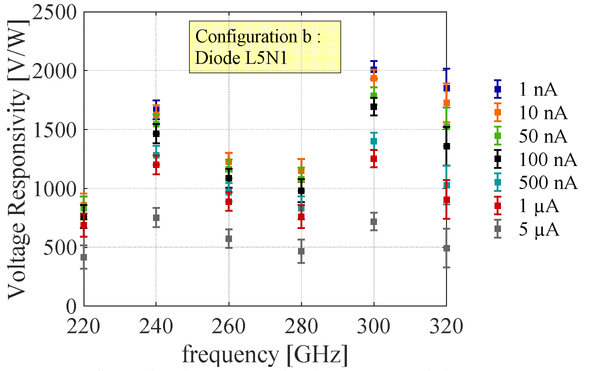

Fig. 6. Configuration b. Extracted voltage responsivity on 220 to 320 GHz frequency range for a variable bias current from 1 nA to 5 µA and -30 dBm of input power

The test structure a. induces the measurement of the voltage response between the two-bias tee (Input and Output). In case of modulated signal detection, the limitation is directly related to bias tee cut off frequency (DC path). Thus, the configuration b allows the device polarization through the bias tee and the measurement of demodulated signal at a lower frequency through the output RF probe (in coaxial configuration). Figure 5 shows the block diagram of the setup used in order to perform on-wafer CW power detection on configuration b, based on the constraints of modulated signal detection. The RF signal on 220 to 320 GHz frequency range is provided to the device as for the configuration a. However, in this case, the diode was biased on its forward regime through the integrated bias tee of input RF probe, and 50 GHz RF probe was used on the right side. In order to reproduce the influence of impedance presented on the right side, like on configuration of a modulated signal detection.

Figure 6 shows the extracted voltage responsivity of configuration b. The extracted response keeps the same variation function of bias polarization as the configuration a. As for configuration a, the detector sensitivity was extracted on 220 GHz to 320 GHz frequency range for variable bias current increasing from 1 nA to 5 µA and exhibit a corresponding voltage responsivity decreasing from 2000 V/W to 700 V/W at 300 GHz. The test structures availability induces the use of two different diodes size, leading to un-comparable response.

IV. CONCLUSION

The described detector based on diode junction in a BiCMOS 55 nm technology from STMicroelectronics exhibits interesting features for Sub-Terahertz detection power detection as well as towards future receivers for data links in the 300 GHz band. The monitoring of bias current allows competitive and wide range γ value. Next step will be to use synchronous detection (lock-in amplifier) to increase accuracy for lower power signal detection and evaluate the potential of these structures for modulated signal detection.

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