Optimization of GaAsSb/InAlAs/InGaAs tunnel diodes for millimeter-wave detection

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Abstract—**We evaluated optimal voltage sensitivity (S_V) and noise equivalent power (NEP) of GaAsSb/InAlAs/InGaAs tunnel diode detectors in 220-330 GHz band at room temperature. The NEP values have strong dependence on the diode mesa size. With increasing the device area from 0.8×0.8μm^2 to 1.4×1.4μm^2, the estimated minimum NEP improved from 200pW/Hz$^{1/2}$ to 80pW/Hz$^{1/2}$.**

I. INTRODUCTION

Non-linear properties of current-voltage characteristics in GaAsSb/InAlAs/InGaAs tunnel diodes provide a mechanism for square-law detection in the millimeter-wave range [1-3]. Recently we reported on the room-temperature voltage sensitivitiy S_V of the devices exceeding 1000V/W in 220-330GHz band [3]. Despite high S_V values, the noise equivalent power (NEP) was limited to about 300pW/Hz$^{1/2}$ by the thermal noise in the junction resistance R_J of the diodes.

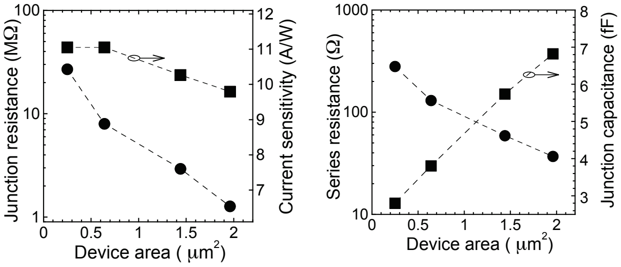

Fig. 1. Measured current sensitivity $S_C=1/2(\partial^2I/\partial V^2)/(\partial I/\partial V)$, junction resistance $R_J= (\partial I/\partial V)^{-1}$, series resistance R_S and junction capacitance C_J of GaAsSb/InAlAs/InGaAs tunnel diodes at zero-bias.

To optimize the detector performance we evaluated dependences of the Sv and NEP on the diode mesa size.

II. RESULTS

Impedance-matched S_V and NEP have been calculated by using the small-signal model of the device. Parameters of the model were extracted from on-wafer measurements of the reflection coefficient $\Gamma=S_{11}$ of the device samples in 220-330GHz band. The measurement set-up, equivalent device model and de-embeddeing of the diode's characteristics have been described in Ref. [3]. Dependences of the series resistance R_S, junction capacitance C_J, junction resistance $R_J= (\partial I/\partial V)^{-1}$, and current sensitivity $S_C=1/2(\partial^2I/\partial V^2)/(\partial I/\partial V)$ on the device area are presented in Fig.1. The calculated S_V and NEP of the devices are shown in Fig.2 and Fig.3.

The estimated NEP values demonstrate strong dependence on the size of device area. The minimum NEP improved to 80pW/Hz$^{1/2}$ in 1.4×1.4μm^2 device due to a reduction of the R_S and R_J accompanied by a moderate increase in C_J.

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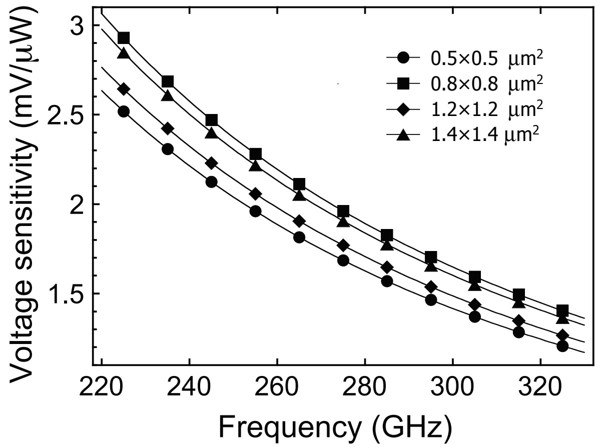

Fig. 2. Estimated impedance-matched voltage sensitivity S_V for the device samples with different area sizes. Simulated values were calculated from $S_V=S_{C0}R_J/(1+R_S/R_J+R_SR_J(2\pi fC_J)^2)$ using the device parameters extracted from the on-wafer measurements of the reflection coefficient $\Gamma=S_{11}$ [3].

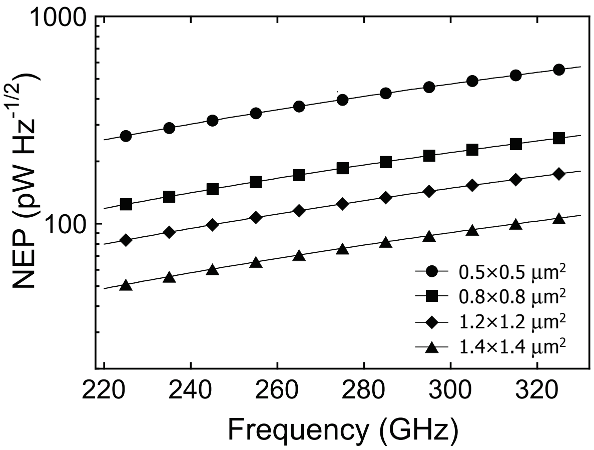

Fig. 3. Estimated NEP for the device samples with different area sizes. The values were calculated using the device parameters extracted from the on-wafer measurements of the reflection coefficient $\Gamma=S_{11}$ and the current-voltage characteristics.