Zero bias GaAsSb/InAlAs/InGaAs tunnel diodes for MMW-THz detection

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Heterostructure tunnel diodes based on III-V compound semiconductors are the promising detector technology for MMW-THz systems. These devices demonstrate fast response, high cutoff frequencies due to small device capacitances, good sensitivity and feasibility of the monolithic integration with other semiconductor components and integrated circuits. This presentation describes on-wafer characterization of GaAsSb/InAlAs/InGaAs tunnel diodes for direct detection in 220-330GHz band.

Schematic structure of the device is shown in Fig.1. The non-linear characteristics of the detector result from the quantum-mechanical tunneling in the staggered band gap heterostructure of the device. Variable resistance of the diode produces the square-law rectification of the input signal power. Voltage sensitivity of more than 1000V/W was measured over 220-330GHz at room temperature (Fig.2). The inherent cutoff frequency of the 0.8 µm × 0.8 µm mesa diode was \( f_C = (2\pi R_S C_J)^{-1} \approx 322 \text{ GHz} \).

The devices demonstrated enhanced temperature stability of the characteristics compared to the zero-bias Schottky barrier diodes. The estimated variations of the zero-bias sensitivity at temperatures from 17K to 300K were less than 2dB.

Fig. 1. Schematic cross-section of the completed tunnel diode detector after device processing (dimensions are not to scale).

Fig. 2. Measured voltage sensitivity of 0.8µm×0.8 µm mesa diode and the theoretical values \( S_V = S_C 0 / R_S (2\pi f C_J)^2 \) corresponding to the lossless impedance match at the detector’s input (solid line). Insert shows the equivalent circuit model of the device consisted of the non-linear junction resistance \( R_J \), the parallel junction capacitance \( C_J \), and the series resistance \( R_S \). \( S_C 0 \) is the low-level current sensitivity at zero bias. The parameters of the model were extracted from the measurements and were equal to \( S_C 0 = 11 \text{A/W}, R_S = 130 \Omega \) and \( C_J = 3.8 \text{ fF} \).