Interband Tunneling Diodes for High Performance Electronics and Millimeter Wave Detection

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InAs/AlSb/GaSb interband tunneling diodes offer unique characteristics for applications requiring high performance, low power operation. Specifically, these devices have excellent high frequency properties (speed indices < 1 ps), low operating voltages (typically 0.1-0.5 V), and low parasitic resistances (excellent ohmic contacts and low access resistances). We have recently developed specific InAs/AlSb/GaSb device structures for two unique applications: low power digital integrated circuits and direct millimeter wave detection.

For low power digital circuits, we have integrated resonant interband tunneling diodes (GaSb quantum well, AlSb barriers, InAs(n) electrodes) with high performance InP-based high electron mobility transistors (HEMTs) to demonstrate a delay flip-flop using the monostable/bistable logic element (MOBILE) architecture. The resonant interband tunneling diode (RITD) and HEMT were integrated monolithically using a stacked layer structure and selective etch processes. Power dissipation less than 2.8mW/gate was measured for the flip-flop using relatively large device geometries (~75 μm^2 RITDs and 50μm-wide HEMTs). A high effective voltage gain (over 380) was realized from the circuit due to the inherent bistability in the MOBILE circuit.

For millimeter wave detection at W-band (94 GHz) and above, we have developed an InAs(n)/AlSb/AlGaSb/GaSb(p) single barrier, interband tunneling diode (essentially a heterostructure Esaki diode). The broken-gap band offset between InAs and GaSb, where the conduction band minimum of InAs lies energetically below the valence band maximum of GaSb, creates a natural asymmetry in the current flow with bias direction. The resulting curvature in the I(V) characteristic is ideal for zero bias direct detection, or mixing with low local oscillator power. S–parameter and voltage sensitivity measurements from 1 to 110 GHz show that the diodes exhibit high sensitivity square law direct detection with zero bias. Projected responsivity from a diode placed in a well-matched measurement circuit at 94GHz is on the order of 10,000μV/μW.