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Record Peak Current Density in AlN/GaN Double-Barrier Resonant Tunneling Diodes on Free-Standing Gan Substrates by Modulating Barrier Thickness

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Abstract : Leveraging plasma-assisted molecular beam epitaxy (PA-MBE) on c-plane free-standing GaN substrates, this work demonstrates high-performance AlN/GaN double-barrier resonant tunneling diodes (RTDs) featuring stable and repeatable negative differential resistance (NDR) characteristics at room temperature. By scaling down the barrier thickness of AlN and the lateral mesa size of collector, a record peak current density of 1551 kA/cm2 is achieved, accompanied by a peak-to-valley current ratio (PVCR) of 1.24. This can be attributed to the reduced resonant tunneling time under thinner AlN barrier and the suppressed external incoherent valley current by reducing the dislocation number contained in the RTD device with the smaller size of collector. Statistical analysis of the NDR performance of RTD devices with different AlN barrier thicknesses reveals that, as the AlN barrier thickness decreases from 1.5 nm to 1.25 nm, the average peak current density increases from 145.7 kA/cm2 to 1215.1 kA/cm2, while the average PVCR decreases from 1.45 to 1.1, and the peak voltage drops from 6.89 V to 5.49 V. The peak current density obtained in this work represents the highest value reported for nitride-based RTDs to date, while maintaining a high PVCR value simultaneously. This illustrates that an ultra-scaled RTD based on a vertical quantum-well structure and lateral collector size is a valuable approach for the development of nitride-based RTDs with excellent NDR characteristics, revealing their great potential applications in high-frequency oscillation sources and high-speed switch circuits.

Keywords : GaN resonant tunneling diode, peak current density, peak-to-valley current ratio, negative differential resistance
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