

## Monolithic Integrated GaN Resonant Tunneling Diode Pair with Picosecond Switching Time for High-speed Multiple-valued Logic System

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**Abstract :** The explosive increasing needs of data processing and information storage strongly drive the advancement of the binary logic system to multiple-valued logic system. Inherent negative differential resistance characteristic, ultra-high-speed switching time, and robust anti-irradiation capability make III-nitride resonant tunneling diode one of the most promising candidates for multi-valued logic devices. Here we report the monolithic integration of GaN resonant tunneling diodes in series to realize multiple negative differential resistance regions, obtaining at least three stable operating states. A multiply-by-three circuit is achieved by this combination, increasing the frequency of the input triangular wave from  $f_0$  to  $3f_0$ . The resonant tunneling diodes are grown by plasma-assisted molecular beam epitaxy on free-standing c-plane GaN substrates, comprising double barriers and a single quantum well both at the atomic level. Device with a peak current density of  $183\text{kA/cm}^2$  in conjunction with a peak-to-valley current ratio (PVCR) of 2.07 is observed, which is the best result reported in nitride-based resonant tunneling diodes. Microwave oscillation event at room temperature was discovered with a fundamental frequency of 0.31GHz and an output power of  $5.37\mu\text{W}$ , verifying the high repeatability and robustness of our device. The switching behavior measurement was successfully carried out, featuring rise and fall times in the order of picoseconds, which can be used in high-speed digital circuits. Limited by the measuring equipment and the layer structure, the switching time can be further improved. In general, this article presents a novel nitride device with multiple negative differential regions driven by the resonant tunneling mechanism, which can be used in high-speed multiple value logic field with reduced circuit complexity, demonstrating a new solution of nitride devices to break through the limitations of binary logic.

**Keywords :** GaN resonant tunneling diode, negative differential resistance, multiple-valued logic system, switching time, peak-to-valley current ratio

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