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Multiple Negative-Differential Resistance Regions Based on AlN/GaN Resonant Tunneling Structures by the Vertical Growth of Molecular Beam Epitaxy

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Abstract : Resonant tunneling diodes (RTDs) based on GaN have been extensively studied. However, no results of multiple logic states achieved by RTDs were reported by the methods of epitaxy in the GaN materials. In this paper, the multiple negative-differential resistance regions by combining two discrete double-barrier RTDs in series have been first demonstrated. Plasma-assisted molecular beam epitaxy (PA-MBE) was used to grow structures consisting of two vertical RTDs. The substrate was a GaN-on-sapphire template. Each resonant tunneling structure was composed of a double barrier of AlN and a single well of GaN with undoped 4-nm space layers of GaN on each side. The AlN barriers were 1.5 nm thick, and the GaN well was 2 nm thick. The resonant tunneling structures were separated from each other by 30-nm thick n+ GaN layers. The bottom and top layers of the structures, grown neighboring to the spacer layers that consist of 200-nm-thick n+ GaN. These devices with two tunneling structures exhibited uniform peaks and valleys current and also had two negative differential resistance NDR regions equally spaced in bias voltage. The current-voltage (I-V) characteristics of resonant tunneling structures with diameters of 1 and 2 μm were analyzed in this study. These structures exhibit three stable operating points, which are investigated in detail. This research demonstrates that using molecular beam epitaxy MBE to vertically grow multiple resonant tunneling structures is a promising method for achieving multiple negative differential resistance regions and stable logic states. These findings have significant implications for the development of digital circuits capable of multi-value logic, which can be achieved with a small number of devices.

Keywords : GaN, AlN, RTDs, MBE, logic state
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