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Resonant Tunnelling Diode Output Characteristics Dependence on Structural Parameters: Simulations Based on Non-Equilibrium Green Functions

Authors : Saif Alomari

Abstract : The paper aims at giving physical and mathematical descriptions of how the structural parameters of a resonant tunnelling diode (RTD) affect its output characteristics. Specifically, the value of the peak voltage, peak current, peak to valley current ratio (PVCR), and the difference between peak and valley voltages and currents ΔV and ΔI. A simulation-based approach using the Non-Equilibrium Green Function (NEGF) formalism based on the Silvaco ATLAS simulator is employed to conduct a series of designed experiments. These experiments show how the doping concentration in the emitter and collector layers, their thicknesses, and the width of the barriers and the quantum well influence the above-mentioned output characteristics. Each of these parameters was systematically changed while holding others fixed in each set of experiments. Factorial experiments are outside the scope of this work and will be investigated in future. The physics involved in the operation of the device is thoroughly explained and mathematical models based on curve fitting and underlaying physical principles are deduced. The models can be used to design devices with predictable output characteristics. These models were found absent in the literature that the author acanned. Results show that the doping concentration in each region has an effect on the value of the peak voltage. It is found that increasing the carrier concentration in the collector region shifts the peak to lower values, whereas increasing it in the emitter shifts the peak to higher values. In the collector's case, the shift is either controlled by the built-in potential resulting from the concentration gradient or the conductivity enhancement in the collector. The shift to higher voltages is found to be also related to the location of the Fermi-level. The thicknesses of these layers play a role in the location of the peak as well. It was found that increasing the thickness of each region shifts the peak to higher values until a specific characteristic length, afterwards the peak becomes independent of the thickness. Finally, it is shown that the thickness of the barriers can be optimized for a particular well width to produce the highest PVCR or the highest ΔV and ΔI. The location of the peak voltage is important in optoelectronic applications of RTDs where the operating point of the device is usually the peak voltage point. Furthermore, the PVCR, ΔV, and ΔI are of great importance for building RTD-based oscillators as they affect the frequency response and output power of the oscillator.

Keywords : peak to valley ratio, peak voltage shift, resonant tunneling diodes, structural parameters
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