

ABSTRACT

Graphene-based transistors are being explored extensively, and are now considered as a promising candidate for post-silicon electronics. Due to its high carrier mobility, high saturation velocity, high current densities and single atomic thickness, graphene field-effect transistor (G-FET) can be scaled to shorter channel lengths without encountering the adverse short channel effects that restrict the performance of existing devices. However, the absence of the energy gap in graphene sheet is proved to be a major limitation for FETs, as it causes poor ON/OFF current ratio for digital electronics and poor intrinsic gain for analog electronics. Many approaches, like lateral carrier constriction in nanoribbons (GNRs), vertical inversion symmetry breaking in bilayer graphene (BLG), and the combination of both in bilayer graphene nanoribbons (BLGNRs), have been suggested to open up an energy gap into the graphene.

The main objective of this work is to develop a quantum transport model for graphene-based field-effect transistors. For accurate analysis, quantum simulations are performed by solving ballistic non-equilibrium Green's function formalism (NEGF) self-consistently with 2-D Poisson's equation. Initially, a 1-D real-space transport model with analytically defined transverse modes is developed, and it can be easily extended to simulations of graphene, nanoribbons (BLGNRs), bilayer graphene (BLG), and bilayer graphene nanoribbons (BLGNRs) FETs. This 1-D transport assumption allows accurate results in a reasonable amount of time, which is essential for any quantum simulation.

A study on various forms of graphene-based field effect transistors is carried out to find their suitability for digital and/or analog/RF applications. Firstly, a study on graphene tunnel field-effect transistor (T-GFET) is carried out and it was found more suitable over G-FET for analog/RF applications. Further, two different FET structures are examined for BLG NR. A dual gate structure with chemically abrupt doped junctions is explored for digital applications, whereas a dual gate structure with electrostatically doped by back gate is investigated for analog/RF applications. Finally, a BLG NR-TFET is explored for both low voltage digital and high-frequency RF applications. The device analysis has been carried out with respect to the oxide thickness, gate underlap, gate overlap, doping, device width, etc., to further improve the transistor performance. In summary, in this thesis, a 1-D quantum transport model was developed for graphene-based FETs, and three specific graphene-based devices such as T-GFET, BLG NR-FET, and BLG NR-TFET were explored.