Modeling Transport of III-V Nitride-based Quantum Wires

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The III–V compounds are being increasingly used in integrated optoelectronics [1], passive filter devices [2], distributed feed- back lasers and Bragg reflectors [3]. Attempts have been made to design and develop electronic, optoelectronic, and sensor devices, such as metal oxide-nanowire transistors, light emitting diodes, waveguides, and biochemical sensors that are highly miniaturized and possess excellent performance characteristics. The III–V compounds are also suitable for the development of modulation-doped field-effect transistors.

The Einstein relation for the diffusity–mobility ratio (DMR) of the carriers in materials is known to be very useful since the diffusion constant (a quantity very important for device analysis but whose exact experimental determination is rather difficult) can be obtained from this ratio by knowing the experimental values of the mobility. In addition, it is more accurate than any of the individual relations for the diffusivity or the mobility, which are two widely used quantities in carrier transport of semiconductor devices.

The conventional form for this DMR, for example, for electrons, is (kT/q), where k is the Boltzmann's constant, T is the absolute temperature, and q is the electronic charge. In this conventional form, it appears that the DMR increases linearly with T and is independent of the carrier concentration. This relation holds only under the condition of carrier nondegeneracy, although its validity has been erroneously suggested for degenerate materials [4]. The performance of the electron devices at the device terminals and the speed of operation of modern switching transistors are significantly influenced by the degree of carrier degeneracy present in these devices [5], and the simplest way of analyzing them under degenerate condition is to use the appropriate Einstein relation to express the performance of the devices at the device's terminals and the switching speed in terms of the carrier concentration [5].

Our objective in this investigation is to present a general DMR for semiconductor III-V nitride-based nanowires (Fig. 1) taking the appropriate carrier degeneracy, doping, band structure and terminal biases into account. One sample result for the DMR versus carrier concentration is shown in Fig 2. Theoretical details and a range of calculated results will be presented and discussed.

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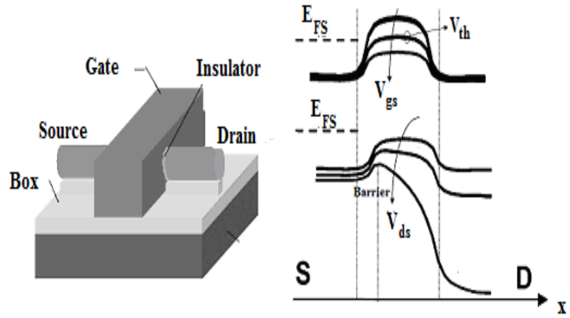

Fig. 1 3D quantum wire structures considered in this work, and band structure at different biases

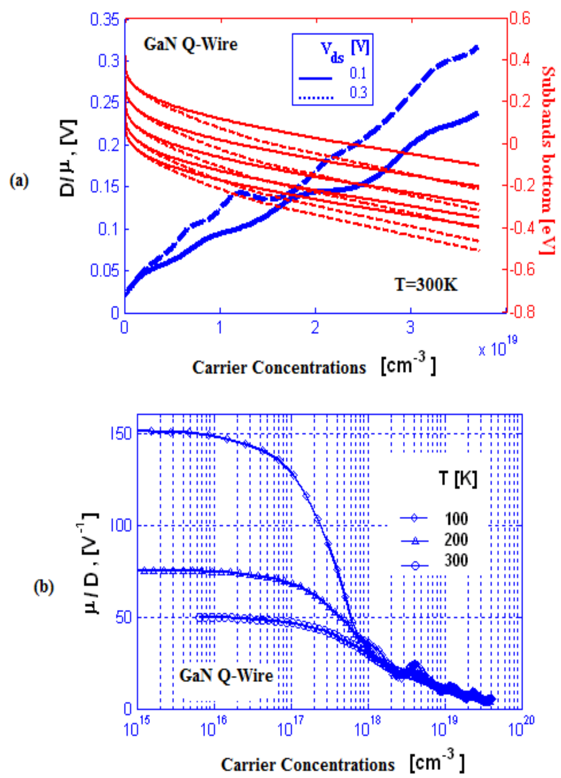

Fig. 2 (a) Represents DMR vs. carrier concentrations at room temperature. (b) Represents MDR vs. carrier concentrations at V_{ds}=*0.1V* and different temperature values

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