BAND OFFSETS AND CURRENT TRANSPORT IN GaN BASED HBTs

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Abstract

In recent years heterostructure systems based on group III-nitride compounds and alloys have emerged as some of the most promising compounds for optical device applications. A particular system that has been the subject of considerable attention are those of AlGaN/GaN and InGaN/GaN heterostructures because of their interesting physical properties as well as their technological importance. Control of band offsets may lead to a new degree of freedom in the design of heterojunction devices and permit independent optimization of carrier injection, carrier confinement and ionization thresholds in high speed electronic and optoelectronic devices [1]. In this work we present a theoretical investigation of the electronic properties of ideal AlGaN/GaN and InGaN/GaN heterostructures. The calculations are based on an extended form of universal tight-binding method [2]. The nonorthogonal sp^3 set of orbitals of adjacent atoms and spin-orbit coupling are used to describe the valence band energies and screens them by the optical dielectric constants of the bulk GaN, AlN, and InN as well as AlGaN and InGaN ternary alloys. The interacting matrix element required for the model is obtained by fitting existing band structures for bulk materials [3].

It is found that with the Hartree-Fock tight-binding parameters [4] and the evaluated matrix element the model compare very well with experiment [5] for the band offsets between AlN,GaN, and InN semiconductors. Then using the recently proposed extended drift-diffusion model [4] the effects of band offsets on the current transport and gain and 1/F noise performance of AlGaN/GaN and InGaN/GaN HBTs were investigated as a function of forward bias, temperature, and alloy composition. It is found that the heteroemitter junction resistance to the diffusing minority electrons across the AlGaN/GaN heteroemitter space charge region is much stronger at small forward biases as compared with that to the recombined electrons and holes, leading to a higher recombination current and 1/F noise due to recombination process at small biases. The proposed model should be useful in understanding the temperature, pressure, strain, and

alloy composition effects on the current transport and quantum 1/F noise in GaN based heterojunction bipolar transistors.

References

[1] H. Morkoç, H.Ünlü, and G. Ji, *Principles and Technology of MODFETs*, Vols. 1,2, John Wiley (1991).

[2] H. Ünlü, Extended tight binding and thermochemical modeling of III-Nitride heterostructures at any temperature and pressure, *Phys. Stat. Sol. (b) 216*, pp 107-111, (1999).

[3] D. J. Chadi, Phys. Rev. **B 16**, pp 790-796 (1977).

[4] W. A. Harrison, *Electronic Structure and the Properties of Solids*, Freeman, San Francisco, 1980.

[5] H. Morkoç, F. Handani, and A. Salvador, in *Semiconductors and Semimetals*, **Vol. 50**, Chapter 8, pp 193-257, Academic (1998).

[6] H. Ünlü, Current Transport and 1/F Noise in Heterojunction Bipolar Transistors, *Proc. of 15th Int. Conf. on Noise in Physical Systems and 1/F Fluctuations*, pp 295-299 (1999).