

Effect of aluminum mole fraction on the hamiltonian of GaN/AlGaN quantum dot laser diode

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ABSTRACT

Analysis of the electron and hole transport in the quantum dot laser diode has been carried out in this paper. The electron and hole quantum dot potential has been deduced using the transfer matrix method and an iterative method have been utilized for computation of Eigen energy. The Hamiltonian is very useful to approximate the extent of the wave function within the quantum dot. The overall Hamiltonian for the quantum dot has been obtained and the normalized Eigen frequency has been deduced in the paper which is very essential for the analysis of the radiated spectra within the quantum dot region.

Key words: Aluminum mole fraction, Hamiltonian, quantum dot laser diode.

INTRODUCTION

Contemporary electronics and optoelectronics is entirely based on the advanced semiconductor technology¹. III-V wide-band gap compound semiconductor proved to be very promising and very efficiently applicable for blue-ultraviolet light-emitting devices². The quantum dot Semiconductor laser diode has wide range of spectrum due to tailoring of band parameters. The quantum dot due to low threshold current provides efficient laser diodes. The paper reveals the dependence of Eigen frequency on Aluminum mole fraction and the interaction coulomb potential V_e and V_h . The mathematical approach is discussed in detail in section II includes the transfer matrix method for the determining the Eigen energy and the results are discussed in section III.

Mathematical analysis

The Hamiltonian, which we use for the description of potential energy, related quantum dot is

$$H = h(r, p) + C,$$

where, C is the Coulomb interaction potential and h the single-particle Hamiltonian.

The dielectric constant k and effective mass m are material parameters, E is the eigen energy which has been deduced by using Transfer Matrix Method (TMM), $V_e(r)$ and $V_h(r)$ are quantum dot potentials for electron and hole respectively. The iterative method has been used to determine the eigen energy and the inter coulomb potentials V_e and V_h ,

$$V_e(r) = V_c - V_e e^{-(x_e^2 + y_e^2)/\alpha_e^2} e^{-z_e^2/\beta_e^2} \quad \dots(1)$$

$$V_h(r) = V_v - V_h e^{-(x_h^2 + y_h^2)/\alpha_h^2} e^{-z_h^2/\beta_h^2} \quad \dots(2)$$

RESULTS AND DISCUSSION

The quantum dot laser diode is having a lower threshold current and better efficiency than the heterostructure laser diode. The following figure reveals the electron and hole transport in the quantum dot laser diode. In fig. 1 the dependence of quantum dot potential of electron and hole on Aluminum mole fraction has been observed to be changing in a non-linear manner. The quantum dot potential for electron increases with the increase of Aluminum mole fraction as the conduction band offset increases. While, the quantum dot potential for the hole is found to be decreasing non linearly

with the increase in the aluminum mole fraction, this is basically due to increase in the barrier potential develop at the interface of the quantum dot and the cladding region.

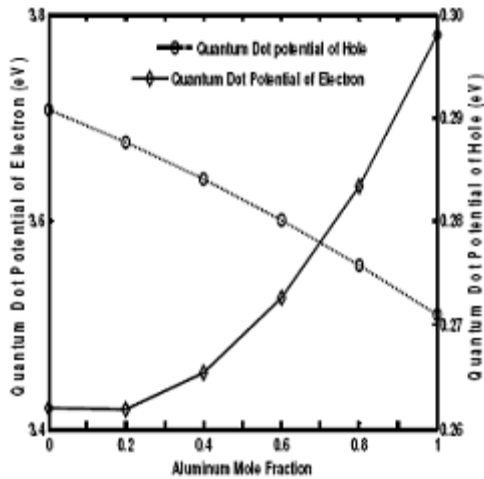


Fig. 1: Aluminum mole fraction dependence of quantum dot potential

linearly with the increase in the Aluminum mole fraction. The normalized frequency reveals the viability of the radiating spectra when the electron and hole are recombining in the quantum dot region. Thus it is obvious that with the increase of barrier height potential the tunneling will be hard and hence, the recombination will be hard to occur due to

Fig. 2 explores the normalized Eigen frequency variation with respect to Aluminum mole fraction since value of ϵ is constant. The normalized Eigen frequency observed to be decreasing non-

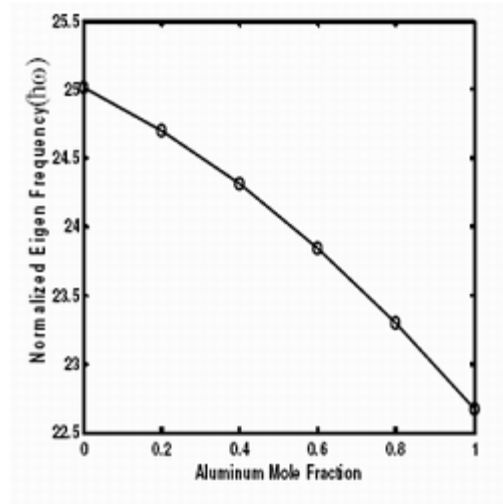


Fig. 2: Normalized eigen frequency variation with aluminum mole fraction

transport of electrons from the barrier region, which results in the lower photon radiation in the quantum dot. Therefore, the normalized frequency of the radiating photon emission is observed to be decreasing with the increase of the aluminum mole fraction.

REFERENCES

1. C Skierbiszewski¹, P Perlin, I Grzegory, Z R Wasilewski, M Siekacz, A Feduniewicz, P Wisniewski, J Borysiuk, P Prystawko, G Kamler, T Suski and S Porowski, *Semiconductor Science and Technology*, **20**: 809, (2005)
2. J. Piprek and S. Nakamura, *IEE Proc-Optoelectron.* **149**(4): 145 (2002)