Material Science Research India Vol. **5**(1), 203-204 (2008)

Hole-phonon scattering mechanism in III-V semiconductor multiple quantum wells

SMRUTI MOTARWAR, KANCHAN TALELE, E.P. SAMUEL and D.S. PATIL

Department of Electronics, North Maharashtra University, Jalgaon (India)

(Received & Accepted: January 10, 2008)

ABSTRACT

Analysis of carrier transport while moving through GaN multiple quantum well has been carried out through phonon scattering using Fermi Golden rule. Hole capture in a Gallium Nitride quantum wells has been carried out with hole-optical phonon scattering mechanism using semi-classical approach. Our analysis show that the hole capture time vary as a function of the excess energy, quantum well width, barrier width and aluminum (Al) mole fraction in the barrier layer. Strong dependence of hole capture time on mole fraction x in the barrier layer of $Al_xGa_{1-x}N$ has been attributed to the variation of energy and barrier height. The form factor varies in an oscillatory manner with the change in energy.

Key words: Carrier transport, phonon scattering and Fermi Golden rule.

INTRODUCTION

Quantum Well (QW) lasers are expected to exhibit superior lasing properties such as lower threshold current density, higher differential gain as compared to heterostructure laser diodes. The interaction between carriers confined within the well region and surface states can be controlled by the variation of the quantum well width, the thickness of the top barrier layer and the potential depth. Calculating the carrier capture time by the quantum well involves the computation of the probability per unit time that a carrier in some initial state in quantum well heterostructure emits a longitudinal optical (LO) phonon, and ends up in some final state within the quantum well as dictated by energy and momentum conservation conditions. Further the capture time of the electron and the hole in the quantum well shows great significance in the lasing action and needs the attention for the improvement of the laser diode efficiency and to lower the threshold current[1]. Hence, it was thought that it is necessary to put emphasis on theoretical studies concerning the process of carrier capture within quantum well, which have been performed using different models, e.g. emission of optical phonons or carrier-carrier scattering in a layered system[2].

Mathematical approach

The solutions of time independent Schrödinger equation (1) and its general solution obtained by imposing the boundary conditions for the barrier and the well regions are given in equation (2). The A and B are the arbitrary constants deduced by intimidating the boundary conditions and applying the normalizations of the wave function.

$$\frac{d^2\psi(x)}{dx^2} = \frac{2m^*}{h^2}(E-V)\psi(x) \qquad \text{...1)}$$

$$\begin{aligned}
\psi(z) &= \mathrm{B}\exp(kbz), && z \le -w/2 \\
\psi(z) &= \mathrm{A}\cos(k_w z), && -w/2 \le z \le w/2 \\
\psi(z) &= b\exp(-kbz), && w/2 \le z
\end{aligned} \qquad \text{...(2)}$$

As we had mentioned earlier the capture process is much obscure which enforced us to necessitate the classical model approach to be used along with the quantum model approach to realize the comprehensive hole capture phenomena in shallow quantum well. The capture time of the hole for the GaN quantum well has been determined. The form factor Gif has been deduced from the following expression in (3).

$$Gif = \int \psi^{*}_{f} e^{-ik_z Z} \psi_i dz \qquad ...(3)$$

RESULTS AND DISCUSSION

Fig. 1 reveals that with the increase in the laser excess energy the hole capture time is decreased linearly which consequently infers that the transition of the electron from the barrier to well region is improved with the increase in laser excess energy. This is mainly due to the increase in the kinetic energy of the electron present in a barrier region, which gains the excess amount of energy and enables them to cross over the barrier region.

The fig. 2 shows form factor Gif variation with the energy and wave vector. The large energy attributes the broadening and slight shift of the band in short wavelength as it is explored in fig. 2.

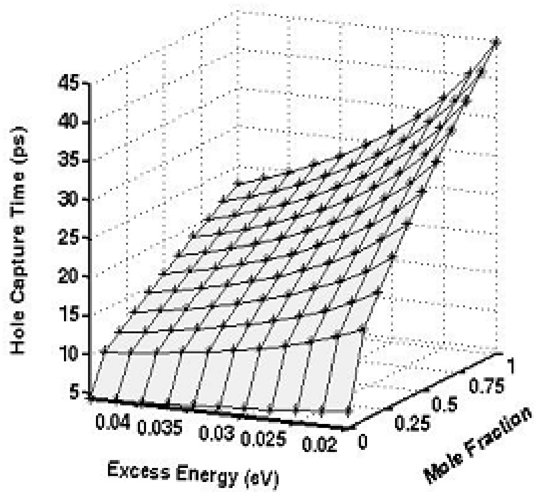

Fig. 1: Dependence of hole capture time on excess energy and mole fraction

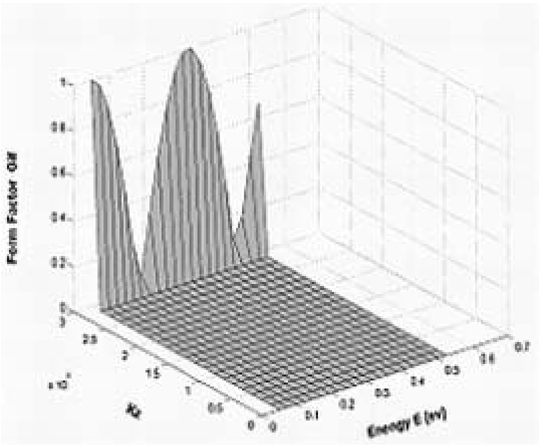

Fig. 2: Form factor dependence on wave vector and energy

REFERENCES

1. Larol Kalna and Martin Mosko, *Physical Review B*, **54**: 17730-17737 (1996).

2. B. K. Ridley, *Phys. Rev.* B**49**: 17-253 (1994).