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Activationless electron and hole recombination rate in semimetallic single and double quantum wells

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In recent years, a tremendous amount of experimental and theoretical investigation has been done on intraband and interband transition diodes such as InAs/GaSb/InAs due to the possible device applications of these structures in optoelectronic devices of the future [1]. In this paper, we propose a theory for the electron-hole recombination and generation processes in these transition diodes in which a third particle is not involved. This type of recombination can occur in semimetallic quantum wells and heterostructures made from InAs and GaSb. The conduction band of an InAs semiconductor lies beneath the valence band of a GaSb semiconductor, and the separation between the conduction band and valence band is approximately 150 meV. This negative, or crossed-gap configuration of these quantum wells leads to a charge transfer between the semiconductor InAs and semiconductor GaSb generating intrinsic carriers, both electrons and holes, on either side of the interface. These quantum wells behave like semimetallic materials and they are called semimetallic quantum wells. Due to the overlapping conduction and valence band, there are activationless generation and recombination processes which do not require an extra excitation particle such as a phonon or photon. Therefore, we call these processes **acivationless recombination processes.** As we know that in direct semiconductors, an electron and a hole recombine via emitting a photon. This process is called **direct recombination**. But in case of indirect semiconductors, the conservation of the momentum cannot be satisfied in the electron-hole recombination. Generally in these semiconductors, electrons and holes recombine through recombination centers because they can take up any momentum difference between the electrons and holes. In this recombination process, the energy of the electron is usually lost to phonons. This process is called **indirect recombination process**. We have developed a theory for the conductance due the generation and recombination processes in semimetallic n-type and p-type single quantum wells (SQW) and double quantum wells (DQW). To calculate the generation and recombination rates we used an $8 \times 8 \mathbf{k}\cdot\mathbf{p}$ matrix Hamiltonian. In this model, the effect of nonparabolicity and anisotropy are included. Using the transfered matrix method we have derived the expression of the tunneling coefficient and from the tunneling coefficient, the activationless recombination rate is obtained. Numerical calculations are performed for n- and p-type single and double quantum wells made from InAs and GaSb. We have considered the symmetric and asymmetric double quantum wells. We found that when we introduce the asymmetry due to different quantum well thicknesses or an external potential, the recombination rate decreases due to scattering for both n-type and p- type quantum wells. We also found that as the energies of the electrons and holes increase the recombination rates also increase for both types of SQWs.

References

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