Modeling of a heterojunction bipolar transistor based AlGaAs / GaAs

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Abstract

The simulation of the physical components semiconductor uses approximations varied depending on the type of devices to study and expected effects. Also, the systems obtained are rarely simple to solve. Numerically, the transportation problems are most difficult to discrete. It should also be noted that the problem is strongly nonlinear, coupling quantities very heterogeneous and are not at all in the same order of size. It should be noted moreover than the exploitation of the physical models can be conceived only if the computing times remain reasonable.

The physical model as simple implemented for HBT transistors is the model of drift diffusion. This model is given in the form of differential equations in partial derivatives, describing the physical behavior of charges and currents in each part of the device.

The objective of our work consists in studying the electronic properties of a heterojunction bipolar transistor based $Al_xGa_{1-x}As$ /GaAs, and the distribution of electric potential, of the field electric thus the concentration of the electrons and the holes.

Keywords: *HBT (heterojunction bipolar transistor), $Al_xGa_{1-x}As$ /GaAs, Modeling, drift diffusion.*

I. Introduction

The heterojunction bipolar transistor (TBH) GaAs/ AlxGa1-xAs, is formed mainly by a stacking of semiconductor materials, group III-V. It can respond to new needs in terms of digital information processing, telecommunications, optical and microwave circuits. It is a very powerful component which has its benefits on the one hand the use of GaAs material and also its bipolar structure. The material GaAs has a mobility electric five times higher than that of Si. And with this material, it is possible to easily hétérostructures. Using a wide-gap material to the emitter, the AlxGa1-xAs and a lower gap for the base, the GaAs [1].

The analysis of physical mechanisms that govern the behavior of heterojunction bipolar transistor has been the subject of many studies and simulation remains a crucial step for the control of its operations.

The simulation study of HBT transistor is conducted using a program written in MATLAB. The basic idea was the direct resolution of equations of semiconductors in steady (static) in a more or less simplified with a method of finite differences or finite elements.

The solution technique is based on the approach of D. L. Scharfetter and H. K. Gummell [2] where each equation is solved sequentially and has the advantage of reducing the memory, as opposed to the combined algorithm based on Newton-Raphson where two equations are solved as a single equation.

We introduce the first physical models adopted and then we will present the results

II. Formulation of the problem

The model of drift-diffusion model transport carriers as they drift under the influence of the electric field and diffusion of carriers due to their density gradient. This phenomenon is given by three coupled equations in the form of differential equations in partial derivatives, which are respectively the Poisson equation and continuity equation for electrons and holes.

The Poisson equation relates the density of potential electrostatic charges is given by equation (1).

$$div(\varepsilon \vec{grad}\,\psi) = -q(p - n + C) \qquad (1)$$

Where ε is the permittivity of semiconductor, ψ is the electrostatic potential, q is the electronic charge elementary, n and p represent the density of electrons and holes and C is the number of ionized impurities. The equations that describe the continuous flow of carriers are expressed by equations (2).

$$\begin{cases} \dfrac{\partial n}{\partial t} = \dfrac{1}{q} div\left(\vec{J}_n\right) + G_n - R_n \\ \dfrac{\partial p}{\partial t} = \dfrac{1}{q} div\left(\vec{J}_p\right) + G_p - R_p \end{cases} \quad (2)$$

Where $G-R$ is the rate of generation-recombination of free carriers, n and p are concentrations of electrons and holes, $\vec{J}_n$ and $\vec{J}_p$ are the current densities respectively electrons and holes are expressed by equations (3).

$$\begin{cases} \vec{J}_n = qn\mu_n \vec{E} + qD_n \vec{\nabla}_n \\ \vec{J}_p = qn\mu_p \vec{E} - qD_p \vec{\nabla}_p \end{cases} \quad (3)$$

With μ_n and μ_p the mobility of carriers and D_n and D_p the diffusion coefficients, connected by the equation of Einstein.

The boundary conditions associated with the previous equations are Dirichlet types.

$$\begin{cases} n\left(\vec{n},0\right) = n_0 \\ p\left(\vec{n},0\right) = p_0 \\ \psi\left(\vec{n},0\right) = \psi_0 \end{cases} \quad (4)$$

With p_0, n_0: the initial concentrations of holes and electrons respectively.

ψ_0 : the sum of the potential and the potential heat applied to the ohmic contacts,

$\vec{n}$: the direction x, y.

I.1. Physical parameters

The study model of semiconductor devices is enabling us to describe the internal movement of the charges, according to a precise geometry and building technology based on doping. It is enough to model the physical parameters that are included in the simulation. The variation band gap ΔEg with temperature is given by the model Varsheni [3].The mass effective depends on the energy gap [4]. Mobility μn and μp are simulated using the model of Caughey and Thomas [5] which reflects the influence of ionized impurities at 300 K. This is the recombinant Schockley-Read-Hall and Auger recombination [6]. The doping profile C for this device is obtained by ion implantation.

II. Results and interpretations

The system of equations (1) and (2) is solved using the method of finite differences in two dimensions, which remains a flexible and general technique for analyzing various geometrical configurations and electrical transistor HBT. Thus the MATLAB software is designed to characterize the transistor HBT identifying potential spatial distributions of electric field and concentrations of electrons and holes. The simulation program developed was applied to a transistor based HBT AlGaAs / GaAs. Figure 1 shows the two dimensional structure used for the presentation of results.

Figure 2 shows the distribution of potential at all points of mesh. It is observed that the potential is high in the collector because of the opposite polarization in the base-collector junction.

Figure 3 shows the electric field along the structure It is observed that the potential figure (2) is almost uniform in all points of the base, therefore the magnetic field is almost zero it extends from the emitter side.

Figures 4 and **5** respectively changes in density of electrons and holes in the structure of HBT from the transmitter to the collector. We can see that the density of holes in the emitter and collector is significantly lower than that of electrons in the base against the density of holes in the base is more important than that of electrons in the emitter and collector. This is due to the higher potential barrier seen by holes heterojunction the base-emitter.

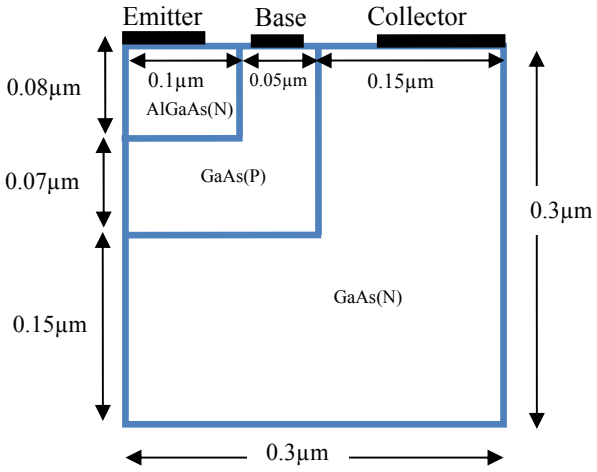

Figure 1: Structure of two-dimensional TBH studied.

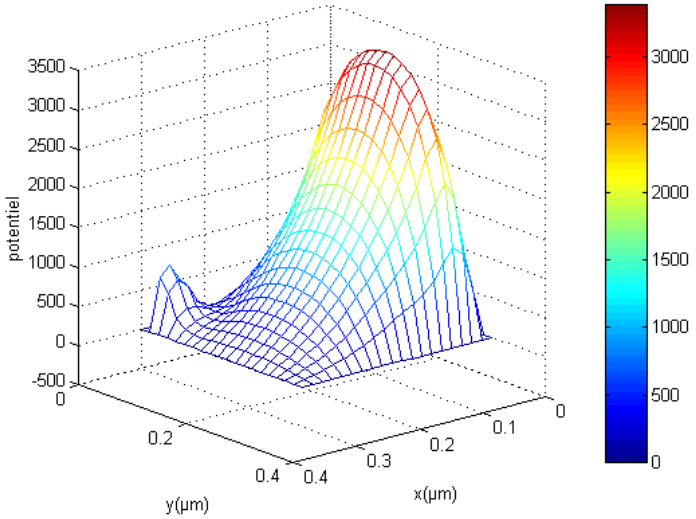

Figure 2: The potential distribution through the HBT based Al0.3Ga0.7As/GaAs

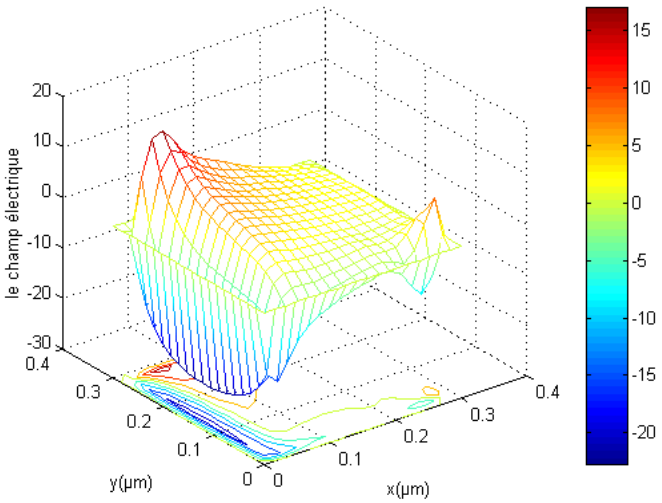

Figure 3: The distribution of the electric field through HBT based Al0.3Ga0.7As/GaAs

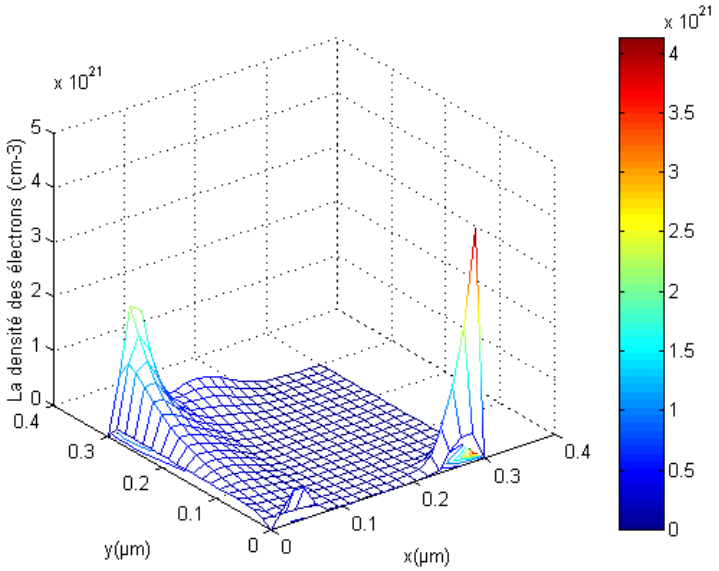

Figure 4: The concentration of electrons through HBT based Al0.3Ga0.7As/GaAs.

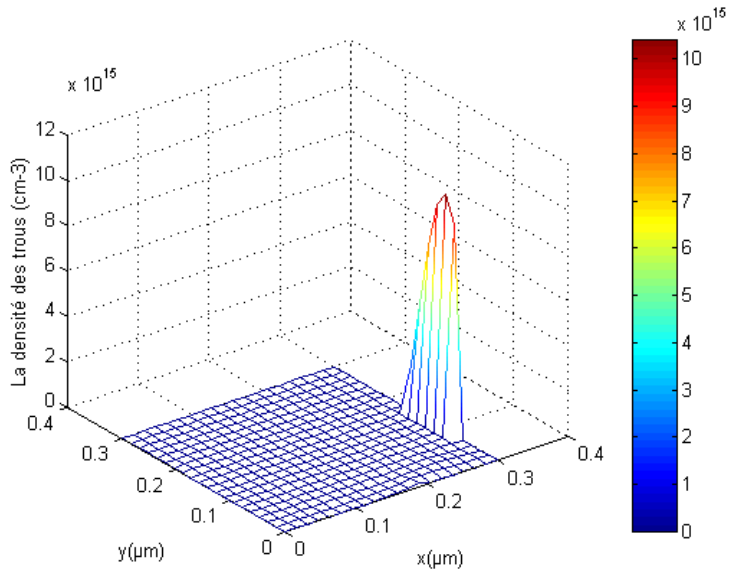

Figure5: The concentration of hole through HBT based Al0.3Ga0.7As/GaAs

III. Conclusion

In this work, we discredited physical equations used in the model of drift-diffusion by the method of finite differences and solving a coupled system is based on the algorithm Scharfetter and Gummel.

Through the simulation program developed in MATLAB environment, we have been to simulate the heterojunction bipolar transistor HBT based AlGaAs / GaAs in determining the spatial distribution of potential, electric field and the concentration of electrons and holes.

This work has enabled us to make a point of the simulation of semiconductor devices with the model of drift-diffusion.

IV. References

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