Multiphysic FEMLAB modelling to evaluate mid-infrared photonic detector performances

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MULTIPHYSIC FEMLAB MODELLING TO EVALUATE MIDINFRARED PHOTONIC DETECTOR PERFORMANCES.

Introduction :

Infrared photo detectors operating in the mid infrared region find application in pollution monitoring, high speed infrared imaging systems and free space telecommunications. Currently the dominant infrared detector technology are based on HgCdTe or InSb photovoltaic devices. Because of their narrow band gap these devices show at room temperature (RT) high dark reverse current and small R0.A product, which significantly restrict the getting of high ambient performances.
To reduce the darkness current and increase R0.A product, we suggested studying structures with large band gap energy.
The objective of the photo detector structures modelling presented in this paper is double. It allows first to simulate and to estimate the theoretical performances of previously introduced large band gap components. As such we shall calculate, the product R0.A and the quantum efficiency to end in the specific detectivity D*. It is also a support to help in the understanding and in the interpretation of the made photo detectors characterizations.

Modelling equations:

This modelling is based on the coupled resolution of the Poisson equation (1), the equations of continuity for electrons and holes, respectively equations (2) and (3) and the equations of continuity under illumination, equations (4) and (5). Where the three dependent variables are Ψ the electrostatic potential, n and p respectively electron and hole concentrations.

$$-\nabla\cdot(\varepsilon\cdot\nabla\Psi)=q\cdot(p-n+N) \qquad (1)$$

$$-\nabla\cdot J_n=-q\cdot R_{SRH} \qquad (2)$$

$$-\nabla\cdot J_p=q\cdot R_{SRH} \qquad (3)$$

With q elementary charge, N represent fixed charges associated to the acceptors and donors ionised.

$$\frac{\partial n}{\partial t}=Gop(z)-\frac{\Delta n}{\tau_n}+\frac{1}{q}\cdot\nabla J_n \qquad (4)$$

$$\frac{\partial p}{\partial t}=Gop(z)-\frac{\Delta p}{\tau_p}-\frac{1}{q}\cdot\nabla J_p \qquad (5)$$

Modelised structures and results :

The model describes previously was applied to two kinds of structures, we present on the figure (1) these two structures as well as the meshing used for FEMLAB modelling. Equations (1) (2) (3) (4) (5) were solved for each structure area assuming the continuity of electric potential and electric field at all interior boundaries between each structure layer. For boundaries far from the component active zones, the normal electric field component and the carrier densities are all take as zero equals. At the electric contacts (boundaries in touch with metal), electric potential were considerate as fixed and we assume an infinite recombination velocity on these surfaces.
For all the solve wee also suppose that the steady state is reached what suppress any temporal dependence in the equation (4) and (5).
This modelling was done with a multiphysic parametric [(1)] non-linear resolving using electrostatic and diffusion FEMLAB modules.

As regards this work, we have limited studies to the influence of the active zone width and doping level on the component response. Thanks to this modelling, for both types structures, we have shown a great influence of the active zone doping level on the component detectivity, we have noted in particular an increase of R0.A product with active zone doping, what was not has waited *a priori*.
Concerning structures with superlattice active zones, for a given doping and conduction parameters, the modelling allowed us to put in evidence an optimal thickness for which the detectivity is maximal. This result has shown a relation between carrier diffusion lengths and active zone width.
We could easily from this first one model intend to study the photo detector characteristics according to other geometrical parameters such as for example the components size or contact widths. We will also intend to study in near future, the influence of surface states effects on components answer by modification of external boundary conditions in modelling.

References

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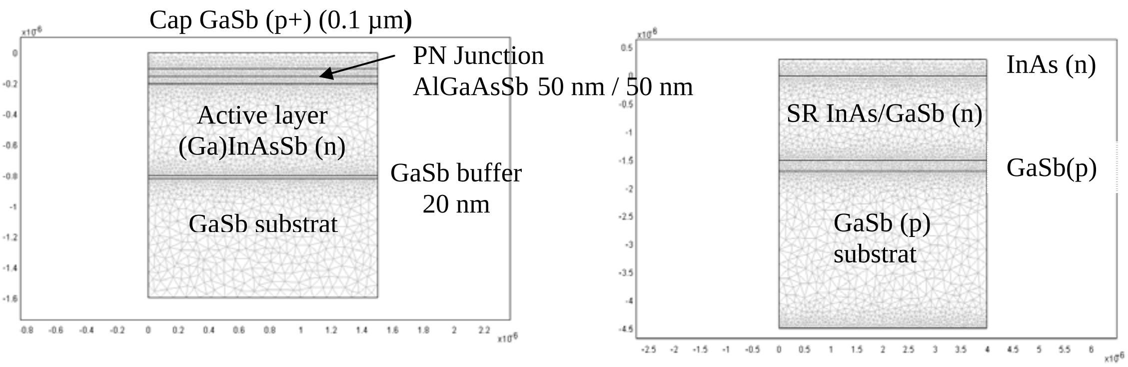

Figure 1(a) : (Ga)InAsSb active layer diode.

Figure 1(b) : InAs/GaSb superlattices active zone diode.

Figure 1 : Modelised diodes.