

# Solving Differential's Equation of Carrier Load on Semiconductor

Morteza Amirabadi, Vahid Fayaz, Fereshteh Felegary, Hossien Hossienkhani

**Abstract**—The most suitable Semiconductor detector, Cadmium Zinc Telluride, has unique properties because of high Atomic number and wide Band Gap. It has been tried in this project with different processes such as Lead, Diffusion, Produce and Recombination, effect of Trapping and injection carrier of CdZnTe, to get hole and then present a complete answer of it. Then we should investigate the movement of carrier (Electron – Hole) by using above answer.

**Keywords**—Semiconductor detector, Trapping, Recombination, Diffusion

## I. INTRODUCTION

A revolution has been occurred in electronic industry by discovering Semiconductor and Transistor inventing. Studying in Semiconductor field begins in 19<sup>th</sup> century which its properties have been investigated up to now [3]. At the beginning to build detectors, Germanium and Silicon have been used. Both of them have a good load transport, especially Germanium which has an extra power of energy separation. But its disadvantage is that Silicon has a low Atomic number so it has a few Cross section and Germanium [1], on the other hand has a small Band Gap that its application in low temperature is possible because of thermal noises decreasing. The most suitable Semiconductor detector which has been noticed recently is CdZnTe detector which has unique properties because of high Atomic number and low Band Gap and it can also be active in room temperature [2].

## II. DIFFERENTIAL EQUATION IN SEMICONDUCTOR

In this article we will investigate some works like: the Lead that related to the electric field, Gradient, Produce and Recombination, the effect of Trapping [5]. We can name obtained equation, Differential equation on Semiconductor in detector [6]. In the condition of imbalance when the movement of load, Gradient Density, Produce and Recombination and Trapping occurred, the whole of load is changing. At first we will notice electrons as load carrier.

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Just as when some loads come into element or produce in it, some of them come out or destroy in Trapping. By considering permanent Load, Load appear minus loss of it is equal to load changing.

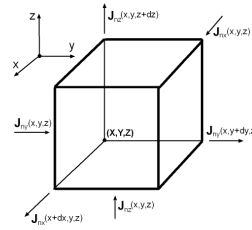


Fig. 1 element of flux

$J_n(x, y, z)$  is Electron Flow. We have:

$$J_{nx}(x+dx, y, z) = J_{nx}(x, y, z) + \frac{\partial J_{nx}}{\partial x} dx$$

So the whole free Electron Load is:

$$\frac{\partial Q_n}{\partial t} = -\nabla \cdot J_n dV + qG_n dV - qG_R dV - qG_m dV$$

Flow equation is:

$$\frac{\partial n_n}{\partial t} = -\frac{\nabla \cdot J_n}{q} + G_n - G_R - G_m$$

We put Flow equation, Recombination equation and Trapping the carrier in above equation:

$$\frac{\partial n_p}{\partial t} = n_p \mu_n \frac{\partial \mathcal{E}}{\partial y} + \mu_n \mathcal{E} \frac{\partial n_p}{\partial y} + D_n \frac{\partial^2 n_p}{\partial y^2} + G_n - \frac{n_p - n_{po}}{\tau_n} - \frac{n_p - n_{po}}{\tau_m}$$

$$\frac{\partial p_n}{\partial t} = p_n \mu_p \frac{\partial \mathcal{E}}{\partial y} - \mu_p \mathcal{E} \frac{\partial p_n}{\partial y} + D_p \frac{\partial^2 p_n}{\partial y^2} + G_p - \frac{p_n - p_{po}}{\tau_p} - \frac{p_n - p_{po}}{\tau_{ip}}$$

## III. SOLVING CARRIER DIFFERENTIAL EQUATION ON SEMICONDUCTOR IN TOTAL

For solving Differential equation, we put

$$G_p = \delta(t)\delta(y - y_0)$$

It means producing Hole Electron in the moment of  $t=0$  in the location of  $y_0$ . So we have:

$$\frac{\partial P_n}{\partial t} = \mu_p \mathcal{E} \frac{\partial P_n}{\partial y} + D_p \frac{\partial^2 P_n}{\partial y^2} - \left( \frac{\tau_{ip} + \tau_p}{\tau_{ip} \tau_p} \right) (P_n - P_{no})$$

Suppose that  $p(y, t)$  is an integral of two independent changeable:

$$P_n(y,t) = Y(y)T(t)$$

That if we place it in main equation , the answer is :

$$P_n(y,t) = \int_{-\infty}^{+\infty} C(w)e^{-iwy} e^{-\left(D_p w^2 + i\mu_p \mathcal{E}w + \frac{1}{\tau_{eff}}\right)t} dw$$

And:

$$C(w) = \frac{1}{2\pi} \int_{-\infty}^{+\infty} F(y)e^{iwy} dy$$

Finally , with integral on W , the total answer is :

$$P_n(y,t) - P_{no} = \frac{C}{\sqrt{4\pi D_p t}} \text{EXP} \left[ \frac{-(y - y_0 + \mu_p \mathcal{E}t)^2}{4D_p t} - \left( \frac{\tau_{ie} + \tau_e}{\tau_e \tau_{ie}} \right) t \right]$$

We can write the similar answer for Electron Density in Semiconductor ( n ) like below :

$$n_n(y,t) - n_{no} = \frac{C}{\sqrt{4\pi D_n t}} \text{EXP} \left[ \frac{-(y - y_0 - \mu_n \mathcal{E}t)^2}{4D_n t} - \left( \frac{\tau_{ie} + \tau_e}{\tau_e \tau_{ie}} \right) t \right]$$

So the Density when (n) is defined the Electron Hole number :

$$P_n(y,t) - P_{no} = \frac{N}{\sqrt{4\pi D_p t}} \text{EXP} \left[ \frac{-(y - y_0 + \mu_p \mathcal{E}t)^2}{4D_p t} - \left( \frac{\tau_{ip} + \tau_p}{\tau_p \tau_{ip}} \right) t \right]$$

$$n_n(y,t) - n_{no} = \frac{N}{\sqrt{4\pi D_n t}} \text{EXP} \left[ \frac{-(y - y_0 - \mu_n \mathcal{E}t)^2}{4D_n t} - \left( \frac{\tau_{in} + \tau_n}{\tau_n \tau_{in}} \right) t \right]$$

The shapes below show the carrier in two ways of existence and non-existence of field.

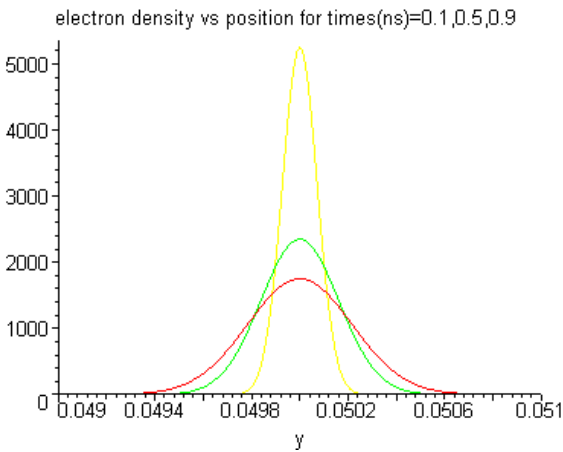


Fig. 2 Electron density vs position for different time

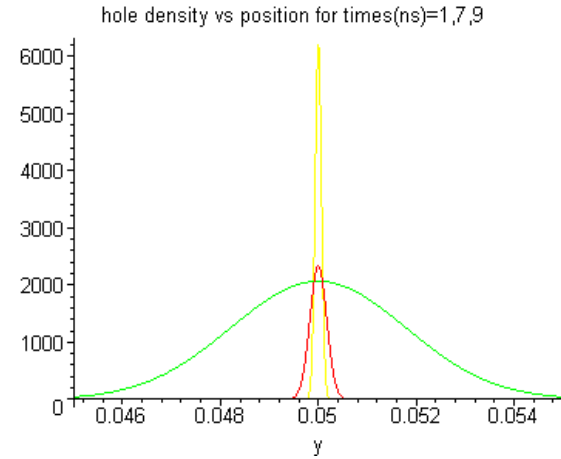


Fig. 3 Hole density vs position for different time

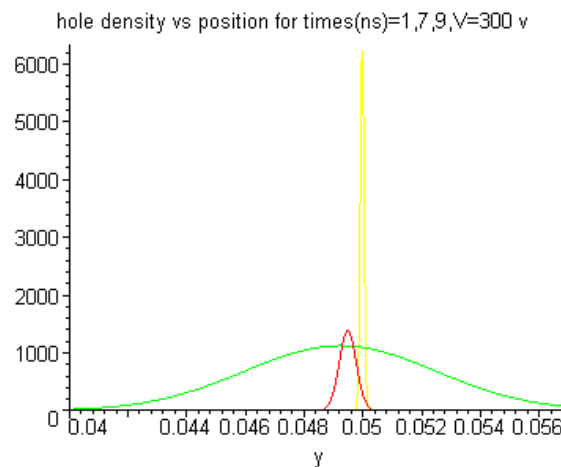


Fig. 4 Hole density vs position for different time with voltage 300 V

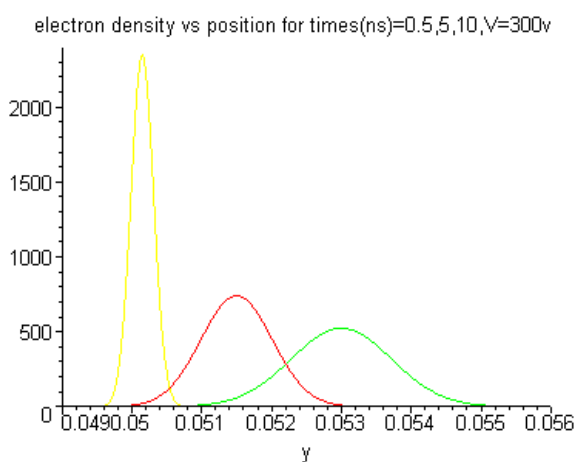


Fig. 5 Electron density vs position for different time with voltage 300 v

## IV. CONCLUSION

The above shapes show the carrier in both ways of the effect of Electronic field and without the effect of it . The noticeable point is that : the area under curve after time of (t) is not equal , because after producing carriers , with their movement into Cathode and Anode they will change into Recombination , then because the time of Recombination and Trapping is not equal for carriers , so at the desire time the number of them is not equal it will happen in the time of  $t=0$  when their numbers are equal . Another noticeable point is the high speed of Electrons in the portion of Holes. For this reason these Electrons will have less change into Recombination and Trapping. So the height of received Pals in Anode is more than Cathode. Because of high speed of Electrons, it should be used high sensitiveness detector. But if we use Pals Cathode, we can use a detector with a low sensitiveness.

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