Investigation On Ion Implantation Models Impact On I-V Curve And Thin Film Solar Cell Efficiency

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Abstract: - Solar cell simulation could be useful for time saving and cost consumption. Different models usually used for implantation process that could affect on the final results. Impact of Dual Pearson, Gaussian and Monte Carlo implantation models are investigated by SILVACO software for a typical thin film solar cell and it is found although there are differences between the p-n junction depths and net doping profiles but there is no different in the final results and efficiencies. By time saving consideration during the computation, the Dual Pearson implantation model is suggested to be use in this case.

Key-Words: - implantation, modeling, thin solar cell, efficiency

1 Introduction

A good solar cell simulation involves all the best models for each part a manufacturing processes. Ion implantation is one of the first steps in p-n junction processing that could effect on the final results [1-2]. Analytical models are based on the reconstruction of implant profiles from the calculated or measured distribution moments. There are four different analytical implant models that consider for implantation according the temperature, impurity, time and particles energy [3]. Gaussian implant model that is using the Gaussian distribution, Pearson implant model which calculate the asymmetrical ion implantation profile and more better Dual Pearson model that extend toward profiles heavily affected by channeling [4 - 8].The statistical technique uses the physically based Monte Carlo calculation of ion trajectories to calculate the final distribution of stopped particles [13,14]. Silvaco software as a wide application in VLSI design and particular in solar cell was chosen in order to compare different implantation models [5].

2 Mathematical Approach

2.1 Gaussian Implant Model

There are several ways to construct 1D profile. The simplest way is using the Gaussian distribution, which is specified by:

$$C(x) = \frac{\phi}{\sqrt{2\pi}\Delta R_\rho} \exp \frac{-(x-R_p)^2}{2\Delta R_p^2} \tag{1}$$

where ϕ is the ion dose per square centimeter specified by the dose parameter. R_p is the projected range. R_p is the projected range straggling or standard deviation.

2.2 Pearson Implant Model

Generally, the Gaussian distribution is inadequate because real profiles are asymmetrical in most cases. The simplest and most widely approved method for calculation of asymmetrical ion-implantation profiles is the Pearson distribution [2].The Pearson function refers to a family of distribution curves that result as a consequence of solving the following differential equation:

$$\frac{df(x)}{dx} = \frac{(x-a)f(x)}{b_0 + b_1 x + b_2 x^2} \tag{2}$$

in which *f(x)* is the frequency function. The constants *a, b0, b1* and *b2* are related to the moments of *f(x)* by:

$$a = -\frac{\Delta R_p \gamma(\beta+3)}{A} \tag{3}$$

$$b_0 = -\frac{\Delta R_p^2 (4\beta - 3\gamma^2)}{A} \quad (4)$$

$$b_1 = a \quad (5)$$

$$b_2 = -\frac{2\beta - \gamma^2 - 6}{A} \quad (6)$$

where $A = 10\beta - 12\gamma^2 - 18$, γ and β are the skew ness and kurtosis respectively.

2.3 Dual Pearson Model

To extend applicability of the analytical approach toward profiles heavily affected by channeling, Al Tasch [3] suggests the dual (or Double) Pearson Method. With this method, the implant concentration is calculated as a linear combination of two Pearson functions:

$$C(x) = \Phi_1 f_1(x) + \Phi_2 f_2(x) \quad (7)$$

where the dose is represented by each Pearson function *f1,2(x). f1(x)* and *f2(x)* are both normalized, each with its own set of moments. The first Pearson function represents the random scattering part (around the peak of the profile) and the second function represents the channeling tail region. Equation (7) can is restated as:

$$C(x) = \Phi[\Re f_1(x) + (1-\Re) f_2(x)] \quad (8)$$

where $\Phi = \Phi_1 + \Phi_2$ is the total implantation dose and $\Re = \Phi_1 / \Phi$.

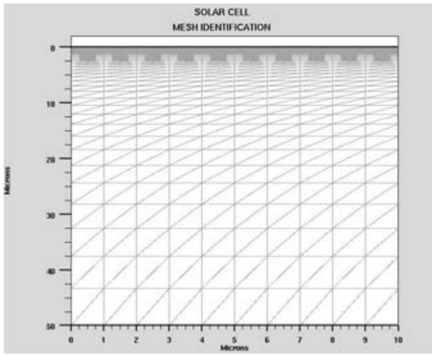
2.4 Monte Carlo Implant Model

The most flexible and universal approach to simulate ion implantation in non-standard conditions is the Monte Carlo Technique [15]. This approach allows calculation of implantation profiles in an arbitrary structure with accuracy comparable to the accuracy of analytical models for a single layer structure. This model based on the Binary Collision Approximation (BCA) and applies different approximations to the material structure and ion propagation through it [14].

3 Computer Simulation

SILVACO software's including ATLAS and ATHENA predicts the electrical characteristics of physical structures by simulating the transport of carriers through a two-dimensional grid. To enter the structure and composition of a solar cell into SILVACO, several parameters must be defined. These include the definition of a fine, two-dimensional grid, called a mesh Fig 1(a).

Once the physical structure of a solar cell is built in SILVACO, the properties of the materials used in the cell must be defined. A minimum set of material properties data includes: band gap, dielectric constant, electron affinity, densities of conduction and valence states, electron and hole mobilities, optical recombination coefficient, and an optical file containing the wavelength dependent refractive index n and extinction coefficient *k* for a material. ATHENA includes a wide selection of models that can be employed in device simulations. These models include the implantation models that capable to be used in propose. The implantation stage, annealing process, electrode definition are introduce in Fig. 1 (b) to (d) respectively. Photo generation and recombination rates are shown in Fig. 1 (e) and 1 (f). Spectral response and internal, external and total quantum efficiency are shown in Fig. 1 (g) to 1 (i) respectively for comparison. In order to define the I-V curve, a subroutine is used by changing the open circle voltage. The short cut current could be found as it will be introduce in next section.



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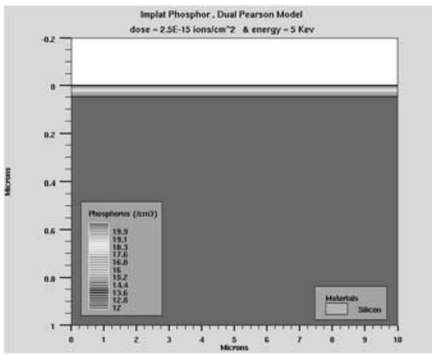

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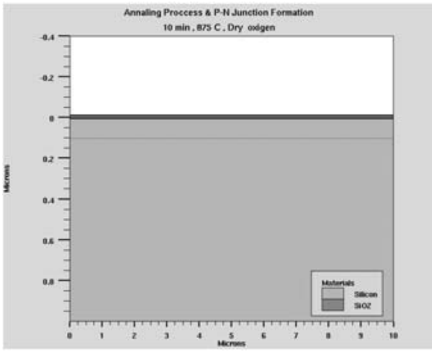

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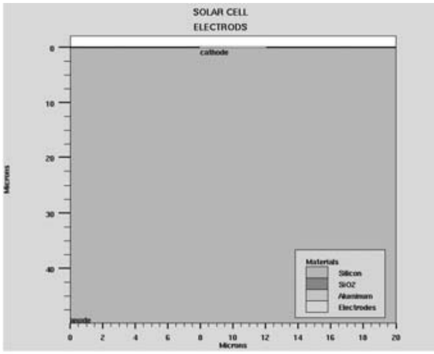

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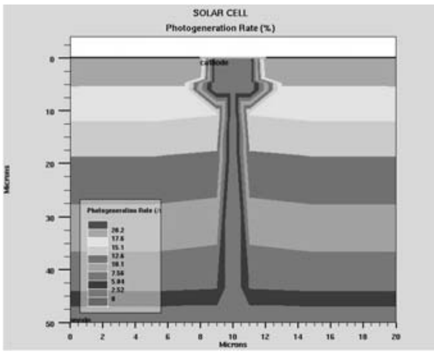

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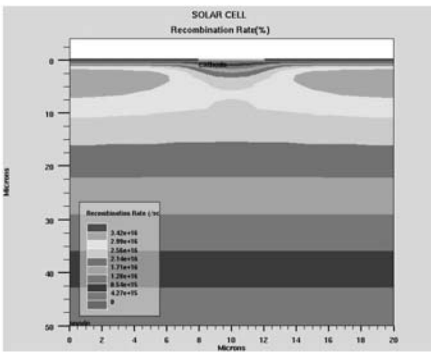

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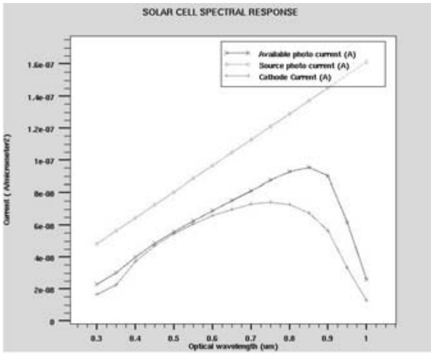
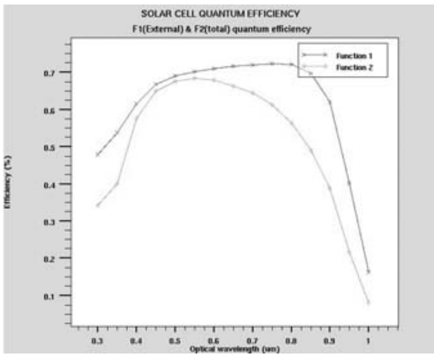
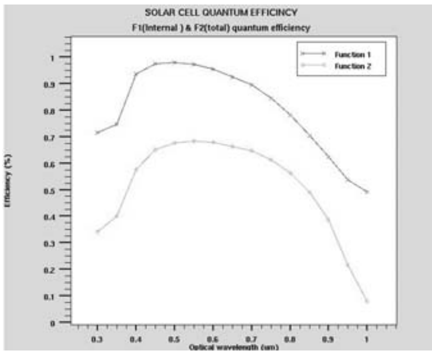


(g)



(h)

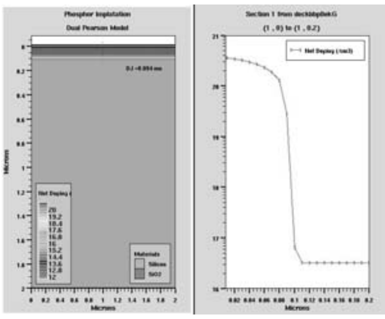


(i)

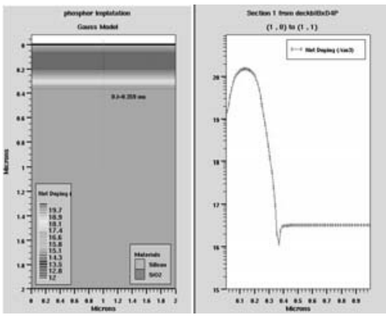
Fig. 1: Different output stages in solar cell simulation including (a) mesh definition (b) implantation (c) annealing (d) electrode definition (e) photo-generation rate (f) recombination rate (g) spectral response (h) external and total quantum efficiency (i) internal and total quantum efficiency.

4 Results and Observation

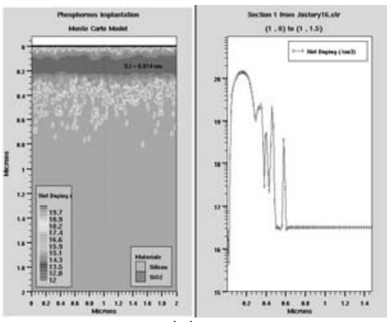
In order to achieve the concentration profiles for solar cell, a test model were used in 2×2 μm^2 silicon which boron concentration is 0.5 Ω and its orientation is [100] was selected. By implant of phosphor with 2.5 x 10^{15} and energy 10eV, the p-n junction depth about 0.1 μm was formed under the top surface. The diffuse time is considered 10 min and the temperature is considered 850˚C. In order to finding the I-V curve, the dimensions were increased to 50 × 10 μm because of accuracy. By using ATHENA software we try to change any implantation model sequentially. The illumination is considered as in geometrical optics as ray tracing. We try to trace the ray with only 90˚ incident angle. Fig. 2 (a) , 2 (b) and 2 (c) show the computer simulations of solar cell concentration profile of net doping according to Dual Pearson, Gaussian and Monte Carlo Models with 0.094 μm, 0.359 μm and 0.014 μm p-n junction depths under the top surface respectively. In Fig. (3) shows the output of I-V curve regarding to these three models demonstrated. It shows the all the I-V graph have the same size and shape that introduce the same efficiency.



(a)



(b)



(c)

Fig.2: Concentration profile of net doping in (a) Dual Pearson Model (b) Gaussian Model and (c) Monte Carlo Model

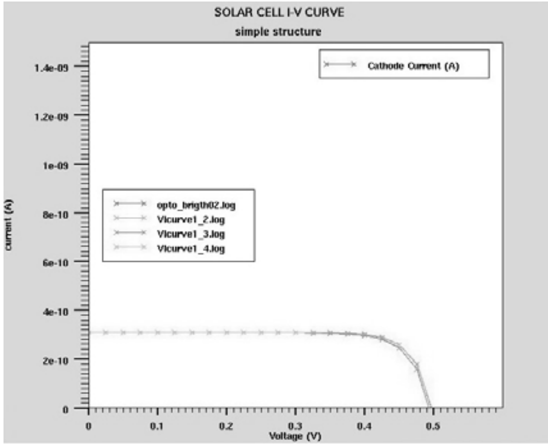


Fig.3: Output of I-V curve regarding to Dual Pearson, Gaussian and Monte Carlo models.

5 CONCLUSIONS

Although the p-n junction depths in three models are different and the net doping profile introduce different size and shape but simulation in I-V curve graphs are shown the same results for all three models and the same efficiency. These results shows there is not important which models should be used in our thin film solar cell simulation but may be because of time consumption it is better to use Dual Pearson model.

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