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Performance Analysis, Comparison and Optimization of Solar Cell Based on SiO_2-Ph

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Abstract— ***In this paper, solar cell SiO2-Ph based design has been presented with good efficiency as per industry scenario. The present works concentrate on how to optimized structure effectively with the different parameters which are essential for any solar cell. In this work, optimization has been done by considering four parameters specifically doping concentration of boron and phosphorus which creates PN junction, energy used aimed at ion-implantation, diffuse time and diffusion temperature. The present work has been performed using SILVACO TCAD (Technology computer –aided design) software. Result reveals that, boron at concentration of 8.1e16cm^{-3}, phosphorus on concentration of 1e15cm^{-3} and energy by 20 Kev gave a result of stable fill factor (FF) value of 82.1568 at slightly noise factor contributing efficiency of 11.0626%. In addition, comparison between aluminum based single layered SiO_2 and Polysilicon based double layer SiO_2 solar cell structure has also been presented.***

Keywords –Antireflection coating (ARC), Double layer SiO_2, SILVACO TCAD.

I. Introduction

Solar energy is now a day's acting as one of the most fundamental and valuable energy resources in order to meet electricity demand of the world due to its free availability, inexhaustible as well as clean energy resource. Earth receives sun rays in one minute would be enough to meet the human electricity needs for one year if properly utilized the radiation in term of device application which are used in daily life. However, solar power technologies presently needed to progress their cost-effectiveness (solar panels cost a lot and they are not that efficient) thus optimization is necessary rather than jumps to new composites material to improve effectiveness of solar cell. Amongst various solar power technologies [1], solar photovoltaic (PV) is the most extensively used technology. Solar cells are the most essential part in PV power systems since these cells are responsible to convert the solar light radiation energy into electrical energy and such conversion process is called photovoltaic effect.

Silicon material is one of the most important materials used in the solar cell fabrication. Presently, PV industries are using this material as poly-silicon [2]. Fundamentally, silicon based solar cells [3] are creation of p-type and n-type semiconductor material that creates a PN junction [4]. The PN junction layered protected with anti-reflecting coating (ARC) to deception more light radiation near into the cell and connected with the cathode contact circuit that links the solar cell with the load [5]. In recent years, there has been much interest of using alternative low-temperature oxidizing layers in contrast of amorphous silicon nitride (Si_3N_4) [6] and aluminium oxide [7]. In order to use low temperature SiO_2 into commercial solar cells, surface recombination of photon velocities (SRV) must be as low as <100 cm/s on ineffective surfaces, which require the interface trap density at the Si/SiO_2 interface. Also, that on effective surfaces recombination velocities there is found to be deliberately increases as the doping concentration changed, even with high quality of thermal oxides stack [8]. Frequent studies have shown increases of ≥1% complete in solar cell systems efficiency by simply substituting a different layer of various material loads with an oxide layer. Based on the Stoicism and other elements are currently used, oxides layer can be used for the purpose of light adopting, surface passivation of electrical defects e.g. high resistance, large electrostatic field, leakage charge carrier etc., photo-carrier generation, charge departure, and charge conveyance and help in reduction of leakage charge in a solar cell [9]. In this Current work, the most usually used material is oxides whose profits for solar cells have been proven both in a laboratory as well as industrial environment [10].

II. Optimization of Solar Cell

The process followed to design the solar cell is same as used by most research centre and manufacturers of photovoltaic cell. Although, it is the most reliable procedure for evaluating the performance of a cell, but it is still costly and time consuming. Going on the other hand, modelling using software provides a fast, reliable and relatively inexpensive way to design solar cells. Modeling and simulation allowed for thousands of combinations to be investigated beforehand the fabrication of actual device. The SILVACO software has capability to simulate together process and device simulation [2-6]. Many factor directly effect on the solar cell efficiency e.g. shading in solar cell, irradiance, light intensity, light of wavelength, internal series resistance effect on solar cell, angle of incident light, temperature, surface condition of solar cell, type of material [13], doping concentration [4], light absorb at surface area and substrate. Using maximum power transfer theorem (photovoltaic cells must be operated on their maximum power point, Maximum Power Point varies with illumination, temperature, radiation dose and other ageing effects) [2], reduce the finger width to increase the efficiency Ion implantation fabrication step process [14] and efficiency directly depend on exceed the band gap of the material. At present many researcher's to focuses on to the operational of new material which are highly stable in term of performance parameter like efficiency, fill factor, photon current, short circuit current etc., yet there is many observations that can be useful for us for further optimization like proper doping concentration of the P-N Junction, ion–implantation energy to substrate, diffusion temperature of the solar cell respectively. Without taking the advantage of new material which is not only costly e.g. gold, silver, platinum but also qualitative and analytic properties of such material making them increases in cost and somewhat dominate it for industry scenario. Also, that major role of antireflection coating (ARC) is exact important for any solar cell design area. In the present work, single layer of SiO_2 having thickness of 1nm has been used and also observed that the efficiency is going to improve if double layer of SiO2 is taken in to consideration.

III. Research Elaborations

Physical Structure

In this work, for making physical structure, various essential terms are considered such as type of materials, different orientation like 100,110,111, background doping, substrate concentration which can be specified by resistivity or by the concentration in atom. Boron and phosphorous are most commonly used dopants for p and n type silicon [11].The flow chart for making structure of solar cell using SILVACO TCAD software is shown in Fig.1

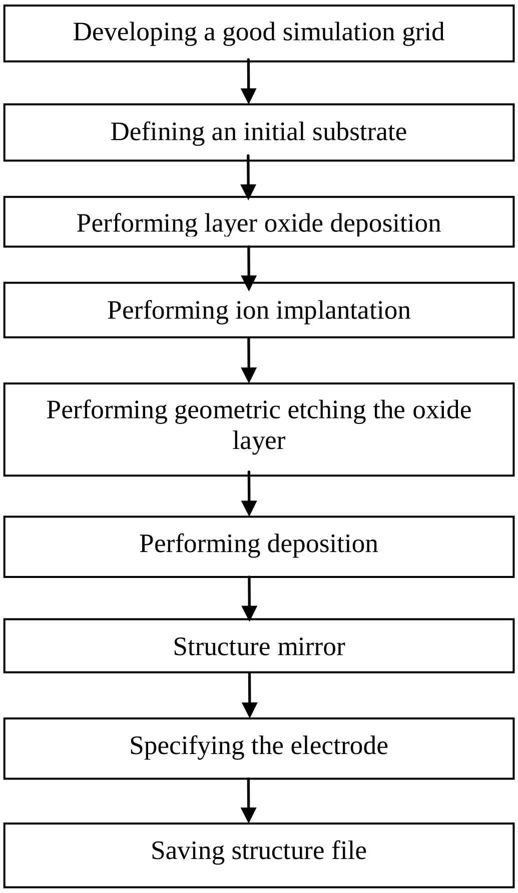

Fig.1 Flow chart for making structure of solar cell

The appropriate result has been found by taking boron and phosphorus with concentration of 8.1e16 cm^{-3} and 1e15 cm^{-3} respectively, along with implant energy of 20 Kev and orientation of 100. It has also been observed that solar cell is to be optimizing not only dependent on to doping concentration for junction but also depends on thickness of the antireflection coating, energy bombardment etc. The structure of solar cell as shown in Fig.2 and Fig.3 illustrates the beam light structure with 100 orientations in solar cell.

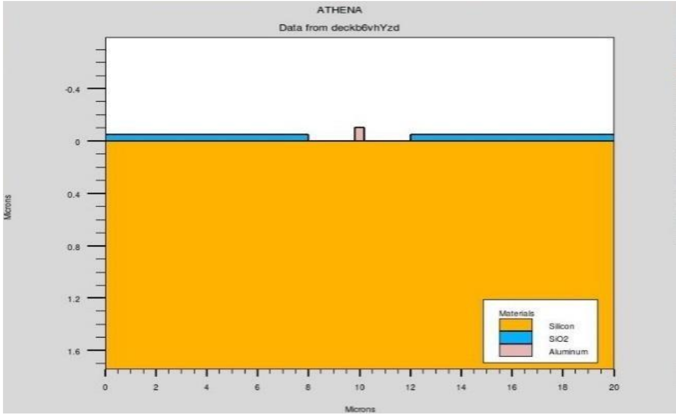

Fig.2 Aluminium based single layer SiO_2 solar cell

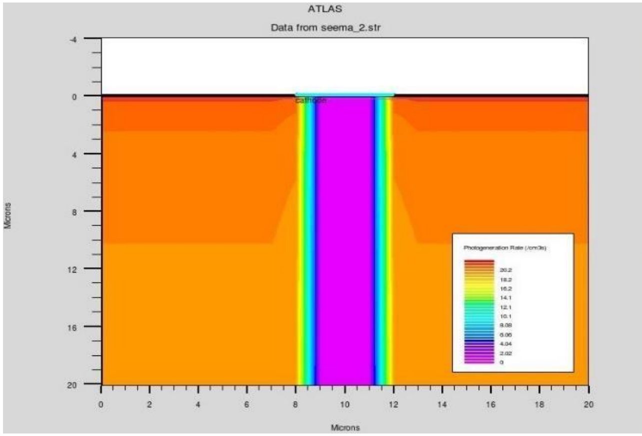

Fig.3 Aluminium with single layer SiO_2 having beam line with 100 orientation

IV. RESULT

The experiment has been performed using SILVACO TCAD tool. In the present work, SiO_2-Ph doped structure has been optimized so that high efficiency and high fill factor of solar cell can be achieved. In this work, basic materials like aluminium or poly-silicon has been used in making electrode instead of costly materials like gold, silver, platinum etc. In this work, we have made a comprise in the selection of costly materials and efficiency by using the optimization of basic materials. The structure should have proper doping with phosphorous and boron concentration in the P-N junction which is responsible for carrier concentration resulting generating current in the device for load source, which is the function of interface oxide trap charges. When the cell is illuminated, the photons requiring energy greater or equal to the energy band gap of the semiconductor may be absorbed by the bound electrons and cause the formation of an electron-hole pair, which is immediately separated due to the internal electrostatic field. A solar cell cannot convert the entire amount of solar radiation received on its surface hooked on electrical energy. A portion of the radiation is reflected from the surface of the cell and diffused back into the environment. Afterwards, from the radiation that penetrates the semiconductor, those photons having energy smaller than the energy band gap cannot be engrossed. For these photons, the cell behaves like a transparent body. Short the terminals of the device, the extra electrons of the n-region move through the external circuit to counteract the additional holes in the p-region. The current due to this flow of excited carriers is called photocurrent, as exposed in equation 1.

$I_{ph} = [I_{SCR} + K_i (T_K - T_{ref})] * \lambda / 1000$ ………… (1)

Where

I_{ph} = Light generated current at the normal condition

I_{SCR} =Short-circuit current

K_i = Short-circuit current /temperature coefficient (0.0017Ampere/Kelvin)

T_K = Actual temperature in Kelvin

T_{ref} = Reference temperature in Kelvin

λ = Irradiance on the device surface w/m^2 with normal irradiation (1000 w/m^2)

Various currents like cathode current, available photon current, efficiency source photon current are shown in Fig. 4 and Fig. 5.

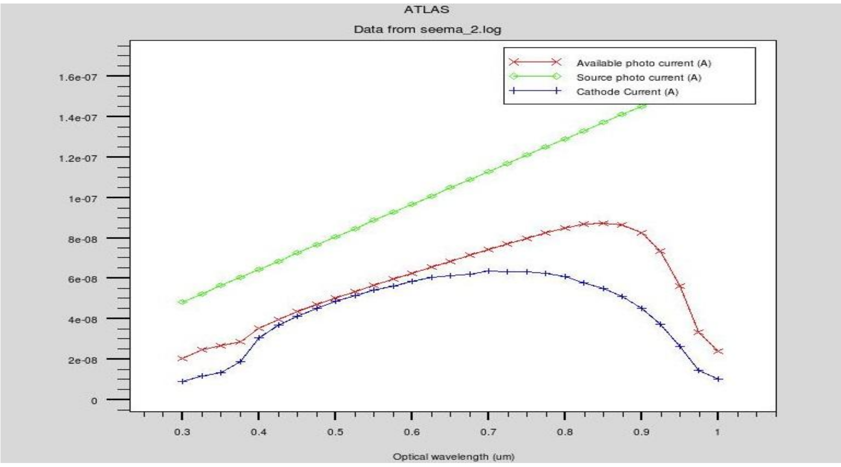

Fig.4 Cathode current, available photo Current and source current in aluminium with Single layer SiO2 Silicon Solar cell

It has been revealed from Fig.4 that the Cathode current, available photo current and source photon current in aluminium based single layer SiO_2 silicon solar cell respectively linearly increases w.r.t cathode current up to an instant point then falls abruptly. It is due to the various parameters like diffusion time, diffusion temperature etc. Once photo generated rates are achieved, terminal current can be evaluated to determine the quantum efficiency of the solar cell [15].

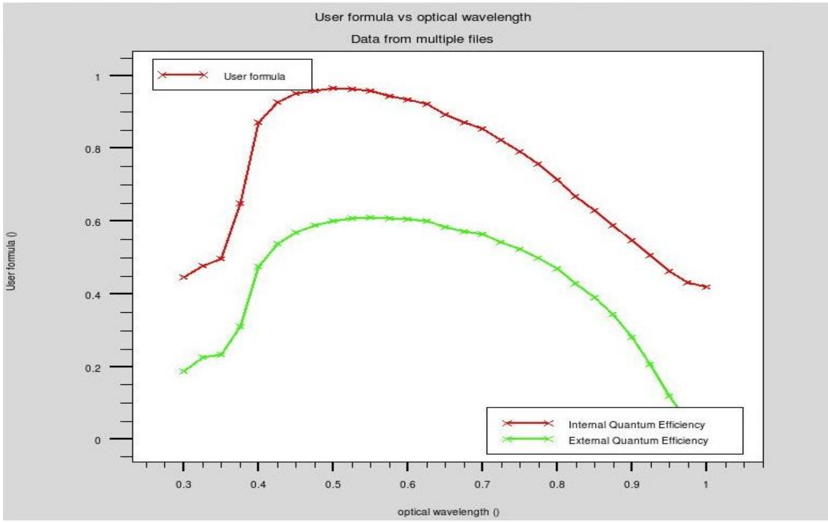

Fig.5 Internal and external quantum efficiency in aluminium with single layer SiO_2 silicon solar cell

Fig. 5 shows the internal and external quantum efficiency in aluminium based single layer SiO_2 silicon solar cell respectively decided by the recombination factor as well as velocity of the photon carriers .The absolute external quantum efficiency is defined as the number charge collected per incident photon at each wavelength.
Further, the comparison has been done in between aluminium with Single layer SiO_2 solar cell structure and polysilicon with double layer SiO_2 based solar cell as depicted in TABLE I and TABLE II respectively.

TABLE I
PARAMETERS OF ALLUMINUM WITH SINGLE LAYERED SiO_2 SOLAR CELL

<table>
<tr><th colspan="6">Aluminium Structure</th></tr>
<tr><th rowspan="3">Parameter</th><th colspan="2">Doping Concentration</th><th rowspan="3">Implant Energy
20 Kev</th><th rowspan="3">Diffusion
Temperature
700 kelvin</th><th rowspan="3">Line x=10
Space=1
Line y=160
Space=10</th></tr>
<tr><th>Boron</th><th>Phosphorous</th></tr>
<tr><td>8.1e16</td><td>1e15</td></tr>
<tr><td>Isc</td><td colspan="2">4.42292e-09</td><td>4.42728e-09</td><td>4.43442e-09</td><td>5.95724e-09</td></tr>
<tr><td>Voc</td><td colspan="2">0.58548</td><td>0.58518</td><td>0.585134</td><td>0.594834</td></tr>
<tr><td>Fill factor</td><td colspan="2">0.81887</td><td>0.81973</td><td>0.818578</td><td>0.821568</td></tr>
<tr><td>Efficiency</td><td colspan="2">0.0805621</td><td>0.0806848</td><td>0.080695</td><td>0.110623</td></tr>
</table>

TABLE II

PARAMETERS OF POLYSILICON WITH DOUBLE LAYERED SiO_2 SOLAR CELL

Polysilicon Structure					
Parameter	Doping Concentration		Implant Energy 20 Kev	Diffusion Temperature 700 kelvin	Diffusion Time (Seconds)
	Boron	Phosphorous			
	5.1 e16	0.5e15			
Isc	7.7734e-09		9.0462e-09	0.582426	7.904620e-09
Voc	0.587263		0.582426	7.90462e-09	0.582426
Fill factor	0.820741		0.8207797	0.820779	0.820779
Efficiency	0.142346		0.143563	0.143563	0.143563

It has been observed from TABLE I and TABLE II that polysilicon with double layered SiO_2 based solar cell has higher efficiency and fill factor than aluminium with Single layer SiO_2 solar cell structure. Also, polysilicon has higher adhesion capability and larger melting point in contrast of aluminium that makes the fabrication designer choice easier. Therefore, Polysilicon based structure have beneficial properties to expand the efficiency of solar cell. In addition, doubled layered SiO_2 with thickness ~1nm has better efficiency and fill factor creates another option for fabrication industry.

V. Conclusion

In this paper, optimized aluminium with single layer SiO_2 and polysilicon based double layered SiO_2 based solar cell has been designed using standard SILVACO TCAD tool (Atlas, Athena). Moreover, the comparison has also been done in between these two structures and revealed that the polysilicon based double layered SiO2 based solar cell has approximately 6% higher as compare to aluminium metallization.

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