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COMPARISON OF MODIFICATION OF PHOTOVOLTAIC SURFACE STRUCTURE BETWEEN GALLIUM ARSENIDE AND SILICON SOLAR CELLS USING SILVACO SOFTWARE Abstract The simulation modeling of surface structure with 1x1017 ion / cm2of phosphorus doping content using SILVACO software on photovoltaic made from Gallium Arsenide and Silicon has been conducted. Comparison of modelling simulation of these two different types of materials is aimed at obtaining a high degree of efficiency in photovoltaic devices.

Both of these modelings need to be compared in order to obtain comparative accuracy to achieve a final conclusion on photovoltaics to determine the highest level of efficiency in the comparison of solar cells made from Gallium Arsenide with solar cells made from silicon. This comparison will produce the output in the form of the best structural model and material type as photovoltaic.The lighting simulation has been selected at an angle of 900 againstboth types of photovoltaic device materials in the four surface structure models performed to obtain the best level of light absorption efficiency.

The results show that for photovoltaic made from silicon, the highest solar cell simulation current value is in the four-sidedstructure model (5.71636E-09 Ampere) and V-trench structure with current value of 4.53455E-09 Ampere. The highest absorption efficiency is in the four-sided and V-trenchstructure which are 4.05E-10% and 3.17E-10%, respectively. For Gallium Arsenide solar cell, the best solar cell simulation is on the V structure model (Isc=3.57520E-09Ampere)and semi-spherewith its current value of 3.58372E-09 Ampere. The highest absorption efficiency is in the V-trenchsurface structure (4.61E-10%).

Structural modeling for the two different types of materials at 900incident light beam angle iindicates that for silicon materials, the best solar cell device structure is the four-sided and for the solar cells made from Gallium Arsenide, the structure of the device that has the best efficiency is the V-trench structure. Therefore, based on the types of material, then the type of the structure can be different to obtain the maximum absorption of light and efficiency. .

Keywords: Gallium Arsenide, Solar Cell, Si Solar Cell, Phosphorus Doping, TCAD Software. Introduction Photovoltaics is the process of generating electrical energy from solar energy source that occurs when two layers of semiconductor hardware are exposed to sunlight. These two layers of hardware will produce a voltage differencewhen exposed to sunlight.

The voltage differencewill produce the current flowing through the output circuit producing electrical energy. Solar cells are basic components in photovoltaic system which are devices that can convert solar energy to electrical energy.This conversion may occur through the effects of photovoltaics or through natural conversion process, such as solar energy is converted into heat energy or chemical energy.

However, most of the energy conversionprocess occur in photovoltaics. Since semiconductor technology has evolved, solar cells from silicon or other materials have grown widely and rapidly. There are three different technological approaches in the research of GaAs and Si solar cells.

Nomenclatures _ _Cm2 Ion A Isc CO2 w/m2 AM0 AM AM1 k R T p n Eg hf h / ? ? nm eV Ef Ei Pm Pin ? Vm Im FF Voc μm Al 0C _Square Centimeter Atom or Molecule Ampere Short Circuit Current Carbon Dioxide Watt per square meter Zero atmosphere Air mass One atmosphere Angular wave number Reversed Transmitted Photon Neutron Energy gap Enormous Energy Momentum Wave length Nano meter Electron volt Atom’s final energy Initial energy of an atom Maximum Output Power Input power Efficiency Maximum Voltage Maximum Current Fill factor Open circuit voltage   Micro meter Aluminum Celsius _ _Do _Ratio of diameter of nose blunting to cylinder diameter (2ro/d) _ _d _Body diameter, m _ _Kb _Correction factor for base drag _ __ _Original nose length of pointed conical nose (Fig.

1), m _ _M _Freestream Mach number _ _pb _Base pressure coefficient for cylindrical boattail _ _Re _Reynolds number _ _ro _Radius of nose blunting (Fig. 1), m _ _Sref _Reference area(?d2/4), m2 _ _xcp _Centre-of-pressure location measured from the nose apex, m _ _ Greek Symbols _ _? _Angle of attack, deg. _ _? _Mach number parameter, _ _ _?BT _Ratio of base diameter to cylinder diameter (dBT/d) _ __ _Ratio of cylindrical part length to nose length of pointed cone shape _ __ _Fineness ratio of original pointed cone (_) _ _? _Semi-vertex angle of the conical nose (Fig. 1), deg.

_ _ Abbreviations _ _SILVACO _Name of Software _ _GaAS Si TCAD ATHENA ATLAS _Gallium Arsenide Silicon Process and device simulation software Tool performs structure initialization and manipulation, and provides basic deposition and etch facilities Predicts the electrical characteristics _ _WHO _World Health Organization _ _The approaches follow the types of crystal lattice used, namely: single crystal technology, polycrystalline technology, and thin film technology or amorphous crystal technology [1] - [4].In this study, the technology used in both types of materials is the one to increase the percentage of appliance efficiency by studying the effect of surface structure modeling and the density of phosphorus doping of Gallium Arsenide and Silicon photovoltaic devices simulated by ion implantation [1] - [3], [5] - [8].Actually,the optimization process needs to be done to get the structure of solar cells that have high efficiency.

Optimization process itself can be done in two ways, namely: the experimental optimization, which is conducted through the process of repeated experiments; and simulated optimization, which is done through theoretical assessment of physical processes occurring in solar cells [2,5,8]. Both methods have their own advantages and disadvantages. The advantage of the first method is that the results obtained reflect what actually occured.

However, it has weakness in the process that it is expensive, while the second method is cheaper because it only uses simulator. Basic Principles of Conversion of Solar Energy Into Electrical Energy By Photovoltaic Devices Solar radiationon earth is lesser when compared to that at outer surface of Earth's atmosphere. This is because of the process of reflection and absorption by gases such as carbon dioxide (CO2)), water vapor and ozone.

These factors do not apply in the spaceso that the spreading of the sunlight is higher which is 1350 w/m2defined as AM0 with the value of 5800 K [5]. On earth, the spectrum of light for the normal beam angleis defined as AM1 which has a power of approximately 1000 w/m2 while at an angle of 450 above the horizon, the light spectrum is defined as AM 1.5 which is 844 w/m2.

The concept of understanding of the theories of physics that apply during the process of solar energy conversion by photovoltaic devices will be very helpful in this study. Photovoltaic devices will convert solar energy into electrical energy when p-n junctionis emitted by sunlight. Some amount of sunlight radiating on the device is reflected back.

Some other is absorbed whilesome will go through the device.

The sunlight absorbed by the photovoltaic devices will run the outer electrons at a higher energy state and this makes them free electrons. This is because the wavelength of light can ionize the atoms in silicon and the inner electric field, to produce electrons. These free electrons will move freely in all directions within the crystal and leave the holes, where the electrons are.

Electrons accumulate in n layer and holes in p layer even though these opposing energies are pulling from each other, most of them will recombine through an external circuit of material due to their power energy. When the external circuit is closed, the electric current will flow. The concept of light absorption in photovoltaic devices Some monochromatic beam of light emitted perpendicular to the surface of the photovoltaic device, with an incident voltage, R will be temporarily reversed, T will be transmitted and enters into the semiconductor.

The light entering the semiconductor material can be absorbed into the semiconductor using its internal energy,where the energy can generate electrons from low to higher energy state. The diffusion is particularly applicable when the photon energy from light is greater than the energy gap(Eg) of the semiconductor [7]. Loss or absorption of photons by generation of the electrons from the conductor, thereby leaving the holes in the valence band .Both energy and momentum should be preserved and maintained in this electron transfer. Photons have enormous energy (hf) but small momentum (h / ?).

Smaller photonic momentum compare to crystal momentum causes hf energy to be maintained during electron transfer. This energy differs at thebeginning and final statetogether with the photonenergy. Ef–Ei=hf (1) The absorption of photons will depend on the concentration of electrons in related energy.

The absorbed photons will produce pair of electron and hole if the hv energy is greater or equal to Eg. The charge carrierwill move towards a coalition that has a field and will generate current. The photons which energy (hv) are smaller than Eg will not be absorbed and the generation between the pair of electrons and holes does not apply.

The efficiency of the photovoltaic device is the measure of the output between the maximum outputpower (Pm) and the input power (Pin) of light energy emitted on the surface of the photovoltaic device. Efficiency value ??for photovoltaic devices can be measured using the following equation: ?=VmIm/Pm (2) In addition, this efficiency value can also be calculated using the following equation: ? =FFIscVoc/Pin (3) WithPin,The input power is the result of the multiplication of observed light observation with device's area.

The purpose of this study is to determine the best photovoltaic materials and structures in absorbing photons from all four simulated structures, namely simple structure, v-trench structure, semi-sphere, and four-sided structure of solar cell made from gallium arsenic and silicon materials. This study also aims to obtain high levels of energy efficiency in both gallium arsenac and silicon materials.

Research Method The Construction of Photovoltaic Device Simulation The simulation of the constructed modeling of structure has been started by calling and activating the ATHENA software in the DECKBUILD SILVACO environment. The work station will describe the process simulation results in the form of a two-dimensional transistor structure, while the results of the analysis simulation are presented in the form of data and graphs. Simulation was built using ATHENA software components.

The formation of the simulation begins with building the structure of photovoltaic device of GaAs and Silicon [1,2,8]. This device consists of p-n junction or n+ doping diodes against p-type substrate. The width of the constructed device was500µm with one type of depth of junction of 0.78 µm [6]. Two metalcontactsAl were placed on the side edge of the device structure.

The simulation has also involved ion-implantation process and doping process. The process of alloying Al is done by determining the definition of the electrode. The rendering of these definitions will be used later as input data in part two of the simulation using ATLAS. ATLAS software component contains three simulation analysis; the simulation to find outthe short circuit current density, open circuit voltage, and the simulation to find out the spectrum responsecharacteristics. In this simulation, the device is imagined as being under the sun. This has a purpose to get the its spectral counteraction.

There are several structural parameters that are specified as input data.Among those are the refractive index, angleand position of the imagination of sunshine andinput voltage.Usually, Imagination of refinement indices of electrode material will be assigned to a very high voltage so that it becomes blurred by the radiation of the sun.

Photovoltaic device modeling simulation ofsimple surface structure The flat (simple) surface structure is started with a grid-setting process for the simulation area. The grid-setting process is only performed for the left-side structure only because it will then be mirrored or reflected to the right. This is meant to simplify the simulation process. The chosen location is symmetrical of 20µmx20µm [4].

The selected distance must be appropriate for the p-n+ junctionto be generated.. This will make it easier as well as save time. Furthermore, the simulation process was extended by measuring the preparation of the substrate material used. Silicon and Gallium Arsenide type p substrate with crystal lattice orientation <100>was selected as input data [6].Then the process of forming n+layer using ion implantationtechnique using phosphorus. Next, the thin layer of oxide isgrown to act as protector during ion implantationprocess.

Then the phosphorus is implanted for all four types of device structureswith1x1017 ion/cm2. Then the inner pacu process was done to dissipate silicon into wafer with heating at 9000C for 300 minutes [10]. The next process was the formation of touch electrode using Al material where the process of growth and decay have been done.

The oxidation process isperformed as a mask on the connection window with lithography and decay processes [11]. Then the alloying process takes place by depositing the aluminum layer on the whole surface. Photovoltaic device modeling simulation offour-sided surface structure The construction ofthe four-sided structure is done after the process of ion formation of n+junction. This process is started by creating window to form a rectangular structure patterntusing lithography and decay processes.

The image overlay layer is used as a mask. Then rectangular shape was made using Reactive Ion Etching technique. Photovoltaic device modelling simulation of V-trench surface structure The V-trench surface model is constructed similarly to the simpleone.The difference is in the process of forming the surface structure.

For the process of simulating the formation of V-trench surface model is done after the process of ion formation f n + junction. This process is first done by creating a window to form a V structure using oxidation and whirl. The oxide layer is used as a mask. Then V shapeisformed by using Reactive Ion Etching technique.

Photovoltaic device modelling simulation of semi-sphere surface structure The semi-sphere structural process is also conducted after the n + junction formation of ionization. This process first started by creating a window to form a semi-sphere structure using lithography and etching processes. The photo-mask is used as a mask. Then the semi-sphere shape is formed using the Reactive Ion Etching technique [8] as well.

Simulation Modeling to find Spectrum Response Characteristics This analysis uses different light flow values. In this simulation, the short circuit current is used. The lambda parameter (?) is used to determine the wavelength of the transmitted light. The wavelength used ranges from 300 nm to 1000 nm [3,10,12]. From this simulation result, the value of the cathode current and the current value obtained in the light rail for each wavelength inserted are absorbed.

The construction process can be seen in Figure 1. / (a) / (b) / (c) / (d) Figure 1 . Simulation of solar cells (a): average structure of the device; (b): Average structure of the device; (c): the structure of rectangular shape; (d): hemispherical structure under the radiant sun of 90 degrees Result and Discussion The evaluation focused on the material, the efficiency of the percentage of solar permeation, the surface model.

Table 1 shows the comparison of solar cells made from Silicon and Gallium Arsenide with the fixed variable as follows: boron = 1e14 implant phosphor dose = 1x10 17ion / cm2 energy = 5eV diffuse time = 300 min, temp = 900C, depth = 0.789224um, 90 ° incident light. Table 1. Comparison Of Solar Cells Made From Silicon And Gallium Arsenide (Gaas) Structure _ShortCircuit Current(ISC) _OpenCircuit Voltage(VOC) _Efficiency(%) _ _ _Silicon Solar Cell _GaAs Solar Cell _Silicon Solar Cell _GaAs Solar Cell _Silicon Solar Cell _GaAsSolar Cell _ _Simple _4.09753E-09 _3.28013E-09 _0.434587 _7.98337E-01 _2.85E-10 _4.19E-10 _ _Four-Sided _5.71636E-09 _3.56999E-09 _0.442914 _8.00075E-01 _4.05E-10 _4.57E-10 _ _V-trench _4.53455E-09 _3.57520E-09 _0.437139 _8.06614E-01 _3.17E-10 _4.61E-10 _ _Semi-sphere _4.39733E-09 _3.58372E-09 _0.436348 _8.00168E-01 _3.07E-10 _4.59E-10 _ _ Solar irradianceat 900 is the best angle because it is capable of producing the highest level of sunlight absorption efficiency in Silicon and Gallium Arsenide solar cells.This can be seen in the results as shown in Table 1.

For Silicon material, the highest solar cell simulation of the short circuit current is the four-sided structure model with the current valueof 5.71636E-09 Ampere and the V-trench structure with the short circuit current of 4.53455E-09 Ampere. The absorption efficiency is also highest in the four-sided and V-trench structure(4.05E-10% and 3.17E-10%).

For Gallium Arsenide material, the best solar cell simulationis on the V-trench and semi-spheremodelwith the current valueof 3.57520E-09Ampere and 3.58372E-09 Ampere, respectively. The highest absorption efficiency is in the V-trench structure model with a value of 4.61E-10% and semi-sphere with the efficiency value of 4.59E-10%.

To conclude, It is found out that structure modelingfor the two different types of materials at the angle of the 900 light emitted simulations that for the silicon material, the best solar cell device structure is four-sided structure and for the solar cell which is made from Gallium Arsenide, the structure of the device which has the best efficiency is the V-trench structure as shown in Fig. 2, Fig. 3 and Fig. 4.

Therefore, based on the type of material, the structure type may be different to obtain maximum absorption of light. / Fig. 2. Data Chart Comparison (a). shortcircuitcurrent (ISC)forSiandGaAsmaterialfor900 incident light with high levelsofphosphorusdopingof 1x10 17ion/cm2. / Fig. 3. Data Comparison of Chart open circuit voltage (VOC) for Si and GaAsSolar cell for900incident light with high levelsofphosphorusdoping1x10 17ion/cm2 / Fig. 4.

Efficiency InSilicon and Gallium Arsenide Solar Cells Conclusion The conclusion is the formation of a flat surface model, four-sided, and also V-trenchstructure on the Gallium Arsenide and Silicon solar cells with only one type of phosphorus doping that is 1x1017 ion / cm2. A flat (simple) surface has been used as a benchmark in this study to see what percentage differences and efficiency levels obtained from modeling the surface structures of the Gallium Arsenide and Silicon solar cell 900incident light simulation against a photovoltaic device at a density of phosphor doping with four surface structure models has been done. It is found that for Silicon material, the highest solar cell simulation current value is on the four-sided structure model (5.71636E-09 Ampere) and V-trench structurewith the current valueof 4.53455E-09 Ampere.

The absorption efficiency is also highest in the four-sidedand V-trench structures with values ??of 4.05E-10% and 3.17E-10%. For Gallium Arsenide solar cells, the best solar cell simulation is on the V-trench model and semi-sphere with its current valueof 3.57520E-09 Ampere and 3.58372E-09 Ampere. The highest absorption efficiency is in the V-trench model(4.61E-10%).

The best model in this study and also a good material for improving the efficiency of solar cells is the V-trench structure with a simple surface model as a comparison on the density of phosphorus doping of 1x1017 ion / cm2. With the density of the phosphorus doping it is concluded that the highest efficiency level in both types of materials i.e

Silicon and Gallium Arsenide is obtained from V-trench structure model . The simple surface was also used as a benchmark in this study to see the percentage differences and efficiency levels obtained from the comparison of surface structure modeling of Silicon and Gallium Arsenide solar cells.

The light simulation at 900 incident lightagainst a photovoltaic device of both types of materials ie Silicon and Gallium Arsenide is conducted because high levels of efficiency of solar cells can be obtained at this incident light angle. It can be concluded that based on structural modeling for two different material types at simulated 900incident light that with silicon material, the best structure of solar cell device is the four-sided structure and for the solar cell that is made from Gallium Arsenide, the structure of the device that has the best efficiency is the V-trench model. Therefore,based on the type of material, then the types of the structure can be different to obtain maximum absorption of light.

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