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Effect of wafer thickness on characteristics of hetero-junction silicon solar cell

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Silicon solar cells are much of interest as the best possible way to use most abundant energy on the earth. The silicon heterojunction solar cell consists n -type nanocrystalline emitter and p-type crystalline base. Wafer thickness is the major contributor in cost to power conversion ratio. Solar conversion efficiencies are compared at different thickness. The study of the solar cell is done by using one-dimensional solar cell simulation software PC1D. The efficiency is observed under ONE-SUN, AM1.5G solar radiation, and constant intensity of 0.1 W/cm^2. The simulation results show 20 µ thickness solar cells is the best in cost to power conversion ratio with the short circuit current of 3 A with open circuit voltage of 0.7818V which is quite high in the range of 20 µ thickness. The fill factor(FF) is 0.8578 with overall solar cell efficiency (Ŋ) of 20.14%.

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1. Introduction

Solar energy is the most abundant energy available on the earth. With the population rising, to answer needs of more energy, renewable energy is the only way in which solar energy looks most promising approach. Silicon is best suitable material for the solar cells. The reasons for selecting silicon are:

(i) Silicon is the most abundant element in the earth's crust, about 25.7% by mass

(ii) It is non-toxic and safe

(iii) Proven efficiencies of 23% in manufacturing, with the theoretical potential of approximately 30% reported till date [1].

Amorphous, crystalline and nano-crystalline silicon are used in context of solar cells. Amorphous silicon has a higher bandgap (1.72 eV) than crystalline silicon (1.12 eV). Lower bandgap in crystalline silicon causes less absorbency at higher wavelengths which reduces the performance of solar cells. [2]

Crystalline solar cell has a market share of about 85-90 % [3].

With the increase in thickness, higher cell efficiency can be achieved, but that will increase overall cost too. Higher efficiency and lower cost are required for better commercialization.

Keeping that in mind, a heterojunction solar cell with n-type nano-crystalline silicon and p-type crystalline silicon is simulated using PC1D and for the device of 20 µ thickness, the effect of emitter thickness is studied.

2. Simulation and modeling

PC1D is a computer program freely available at the University of NSW website and is a user-friendly program which solves the quasi-one dimensional transport of electron and holes from fully coupled time-dependent nonlinear equation in the crystalline semiconductor devices [4].

The solar AM1.5 radiation was adopted as the illuminating source with transient intensity of 0.1Wcm-^{2}(constant). Model device structure is given in Fig. 1. The model is shown in Fig. 1 is an illustration of a model for 20 µ thickness cell while solar cell efficiency is studied as a function of variation in thickness of wafer from 10 µ to 200 µ for the same structure.

Few assumptions are made to do these studies as mentioned below-

1. No surface recombination is taken into consideration.
2. Front and back surface reflectance are being set to 10 % and 95 % respectively.
3. 0.1 W/cm^2 constant solar intensity is taken into account.

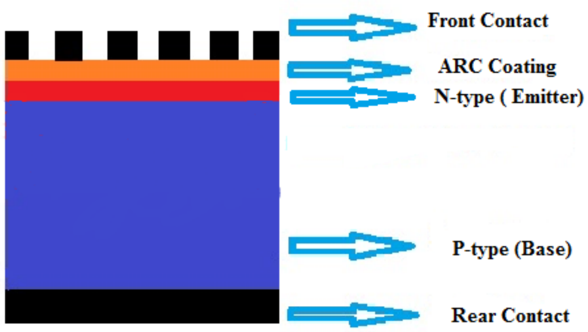

Fig. 1. Device illustration for 20 µ thickness

N-type emitter is considered as Nanocrystalline silicon with the bandgap of 1.7 eV. Device area is set to be 100 cm^2 with surface texture of 2 µ thickness to decease reflectivity. Intrinsic concentration is 1×10^{10} cm^{-3} with N-type and P-type background doping of 1×10^{16} cm^{-3}. Bulk recombination time is set for both holes and an electron is 1000 µs.

3. Results and discussion

The effect of wafer thickness on solar cell efficiency is studied by varying thickness from 10 µ to 200 µ (10, 20, 50, 100 and 200 µ). The results are shown in Fig. 2.

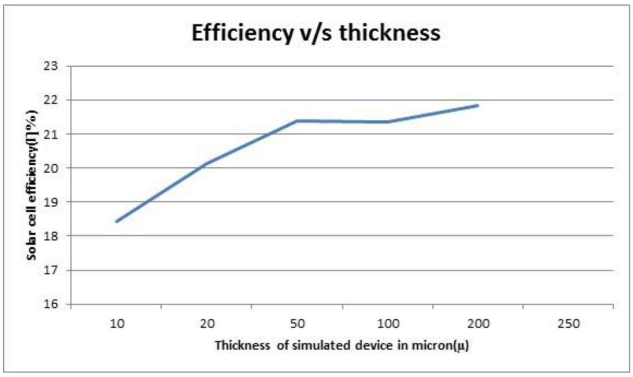

Fig. 2. Variation in solar cell efficiency as a function of thickness

The straight line increase is seen upto 50 µ but after that increase in efficiency is very less (almost saturated). 50 µ device have recorded efficiency of 21.36%. The most optimal thickness is 20 µ for such device as it has recorded efficiency of 20.14 %, which is just about 1 % less than 50 µ device but 2.5 times cheaper than 50 µ device.

TOPSIS analysis is done to calculate best suitable thickness with the variables of cost and solar conversion efficiency as stated in Table 1. 20 µ thickness models found to be best with ranking 1.

Table 1. TOPSIS score and ranking for all the devices

Device Thickness	TOPSIS Score	Ranking
10 µ	0.917917	2
20 µ	**0.932208**	**1**
50 µ	0.789996	3
100 µ	0.528854	4
200 µ	0.082083	5

Fig. 3 shows quantum efficiency graphs of simulated solar cell device for 20 µ which shows almost zero efficiency in the higher wavelength range due to lack of absorbance of low energy photons in the device.

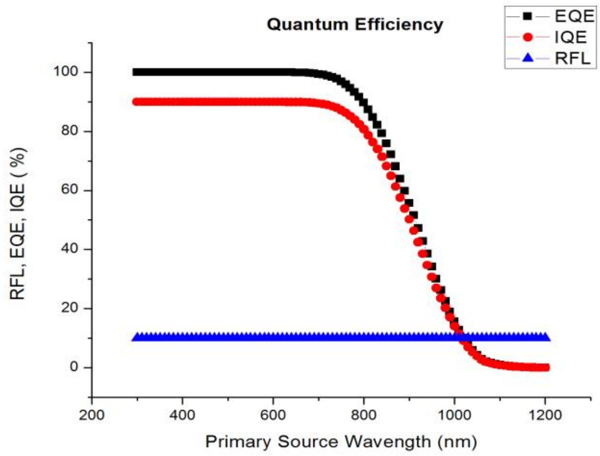

*Fig. 3. Quantum efficiencies graphs for 20 µ solar cells, including IQE in **red**, EQE in **black** and TSR in **blue***

Minority career life time period is set for 1000 µs for both electrons and holes which is quite high to achieve more possibilities of recombination [5] .

The Sun I–V characteristics of a solar cell are studied as shown in Fig 4. A relative high short circuit current (3 A) is found with current density of 30 mA/cm^2. Open circuit voltage Voc is also quite good (0.7818 V) with good fill factor of .8578 (approx .86). The result shows almost equal current density in comparison to nano-counter part with increased Voc and FF [6]. An introduction of intrinsic amorphous layer can improve overall solar cell efficiency [5].

The device performance is quite good in thinner wafer thickness compared to other reported solar cell structures of the same thickness range. Solar cell efficiency analysis is done in tabular form by Green et.al.[7]. NREL (National renewable energy laboratory) measured efficiency of 21.2 % for 240 cm^2 area and war thickness of 35 µ on the submodule designed by Solexel [8]. The reported value is almost at par of our reported values with lesser area and almost the half thickness. Other reported values of crystalline and polycrystalline Si-Solar cells are in the range of 20-25 % with thicker wafer and large surface area in comparison to our model. In case of a-si/nc-si tandem solar cell , 12.2 % efficiency is highest reported till date which shows our model is a better substitute. Although few assumptions have been made yet the model is better than previous reported ones.The industries are moving towards thin layer photovoltaics to reduce costs and this device can be a possible future [9].

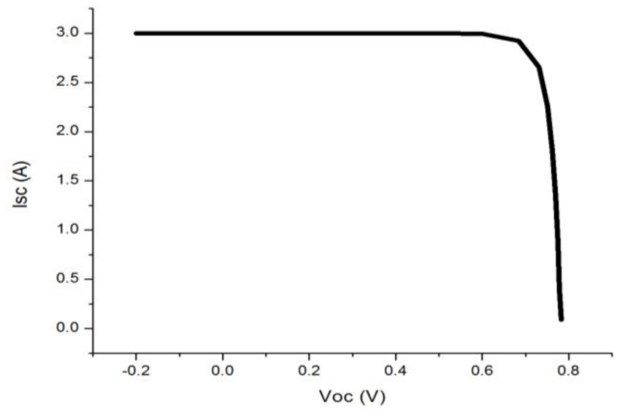

Fig. 4. I-V Characteristics of 20 μ thickness wafer illuminated under AM 1.5 G solar spectrum

4. Conclusions

Following conclusions can be drawn from the present studies-

a) Solar cell efficiency is a function of thickness of the wafer also , but increase in thickness of wafer helps in increase of solar cell efficiency up to a certain limit.

b) Solar cell efficiency of 20.14 % is achieved in 20 μ thickness wafer with good cost to thickness ratio.

c) Absorbance of longer wavelength (>1000 nm) photon to generate more charge carriers can improve cell efficiency.

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