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IMPROVEMENT OF SOME EFFECTIVE PARAMETERS OF C-SI SOLAR CELL FOR BETTER EFFICIENCY

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Abstract: To overcome the Shockely-Queisser efficiency limitations, considerable research into the various solar cell loss parameters such as higher reflectance, higher surface recombination, transmission, low light absorption, high series resistance and low shunt resistance is under way. In this paper, some effective solar cell parameters such as reflectance of light from the cell surface, emitter layer thickness and series resistance are investigated using both experimental and simulation studies.

Keywords: *Solar Cell, Texturization, Plasmonic Effect, LIP, Quantum Efficiency.*

I. INTRODUCTION

Nowadays, and due to their high demands, Non-renewable energy sources are decaying gradually. Their uses are causing more contamination to the environment and an increase in global warming. So people are going towards renewable energy sources like solar, wind, water etc as the complement of existing energy sources. For 1kWh of PV solar plant generated electrical energy reduces the emission of 0,568 kg carbon dioxide (CO_2) into the atmosphere [1-2], [3−5]. Thin film and crystalline silicon solar cell has some advantages for different purposes like, solar modules using crystalline silicon are more suitable for the areas with predominantly direct sun radiation, while solar modules of thin film are more suitable for the areas with predominantly diffuse sun irradiation [1,2]. Higher solar cell efficiency is achieved from silicon solar cell and different parameters are under taken to improve the efficiency of solar cell. Considerable research effort has been undertaken to develop rear dielectric passivation layers that minimize surface recombination, enabling high open-circuit voltages (V_{ocs}) of silicon solar cell [6]. In the past two decades of the solar history since the passivated emitter and rear locally diffused (PERL) solar cell was introduced and showed the record efficiency [7]. The parasitic absorption in the reflector at industrial Pluto cells of Suntech Power has paid attention, and recently demonstrated a dramatic increase in the sub-bandgap reflectance from 25% to 65% [8]. Kray et al. showed the rear internal reflectance and total reflectance of structures using dielectric/metal reflector and flat or textured surfaces [9]. Reduction of reflectance is important as polished silicon surface has a high natural reflectivity (35%) with a strong spectral dependence [10]. A variety of other approaches have also been developed to minimize the reflection losses through modifying surface topography [11, 12]. Using micro texturization and nano texturization reflectance can be reduced significantly. For nano texturization by using different technique like selective etching through alumina template, silicon dioxide (SiO_2) micro-masks, catalytic action of various metals and nano-imprint lithography have been developed for the fabrication of SWS surfaces to produce 'black silicon'[13–21].

Several external parameters (or surface parameters) of solar cell are effective to reduce the efficiency and performance. Different types of techniques are introduced like light induced plating to reduce the series resistance of front contact, texturization to reduce the reflectance, emitter layer thickness to obtain high current, surface passivation layer to overcome the surface recombination, back surface field to overcome the problem regarding the low mobility of hole. In this paper the effects of pyramid height, light induced plating, different emitter thickness and plasmonic effect are discussed to enhance the efficiency of solar cell.

II. SIMULATION AND EXPERIMENTAL DISCUSSION

Some simulation is done by using PC1D5 software. Figure 1 shows the model of solar cell. In simulation work texturization height changes, emitter layer thickness changes, intrinsic layer introduced in between p-layer and n-layer to see the different parameters. Comparative study on texturization of mono crystalline silicon surface was done by conventional method using NaOH solution. Low resistivity (0.5Ω-cm -1.5Ω-cm), <100> oriented P-type mono crystalline silicon wafer was used for the experimental

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study. The bath temperature was maintained at 85°C for getting the better result. Texturization was done in two different time, different concentration and different temperature of NaOH solution. One is done by taking 1.7% NaOH at 90°C for 45 minutes and another was 1.1% NaOH at 92°C for 30 minutes, and for light induced plating (LIP) experiment Potassium Argentum Cyanide (PAC) is mixed in 1000 ml DI water, and stirred the PCA solution for five minutes. Ag-plate of Round shaped is taken as anode and Solar cell as cathode. P-side of solar cell is connected with the anode plate by a conducting wire. Solar cell is placed horizontally on the bottom of the beaker and Anode plate was placed around the solar cell and applied variable light energy of maximum intensity 1000 w/m^2.

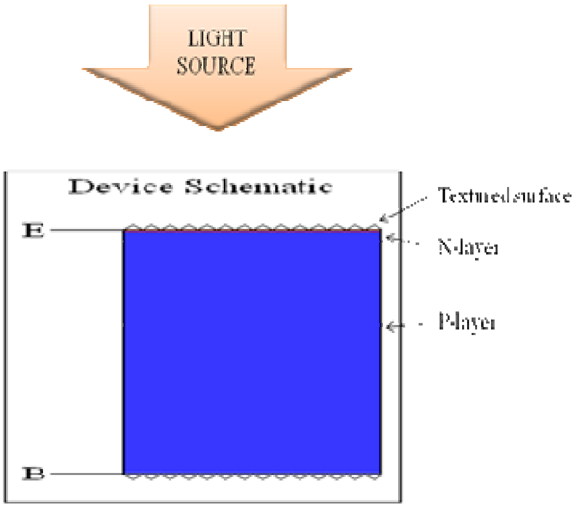

Figure 1. Schematics model of solar cell

III. RESULTS AND DISCUSSION

The effective simulation parameter and some fabrication parameter are discussed. In the simulation part the current is measured with respect to textured height where the standard height is 5 micro meter. Figure 2 shows that if the textured height is varies 3 micrometer to 6 micrometer the uniform cell current is achieved is 10mA but when below (up to certain height) and above this range a decaying current and after that unchangeable result achieved because increasing number of reflection depending on angle of pyramid and height of pyramid. But when goes to 300nm or 400nm which are related to optical wavelength at that time the optical behavior changes as the structure goes to nano structure and also due to nano size surface to volume ratio increases and as a result optical absorption increases.

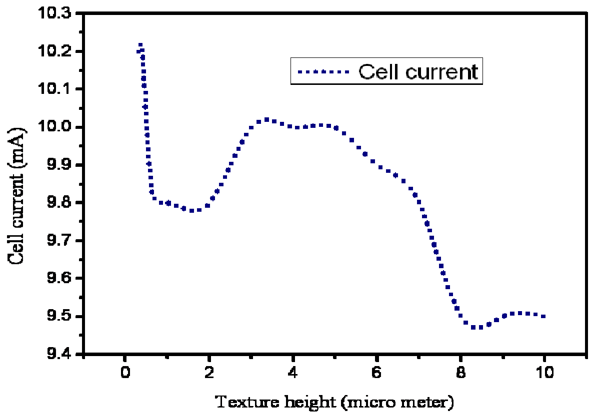

Figure 2. Cell current changes with textured height

When the fabrication is done it is seen that for standard height of pyramid the reflectance is 11 percent but when the height is near about optical wavelength reflectance goes down to 9% as a result cell current increases [22].

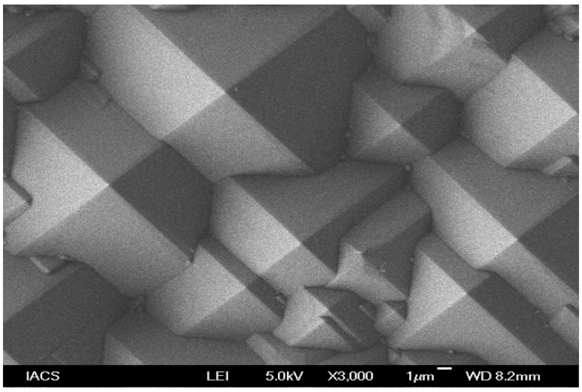

Figure 3. Pyramid structure for 3 to 6 micro meter height

Solar cell performance also depends on emitter layer thickness. In the simulation study it is seen that when the thickness of emitter decreases the junction thickness also decreases and due to the thin junction recombination at function reduces as a result cell current increases (Figure 5).

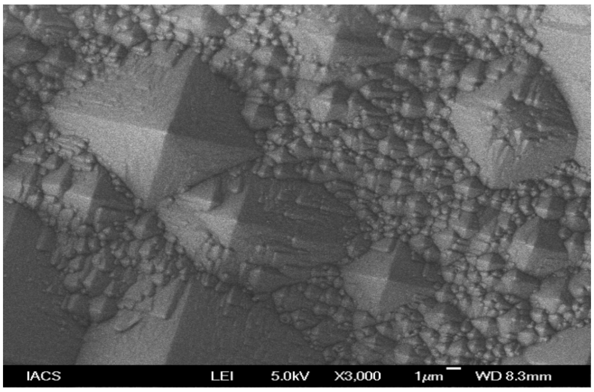

Figure 4. Textured height is near to optical wavelength

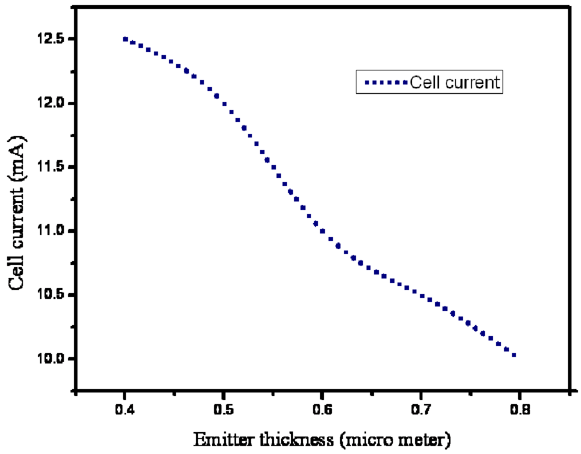

Figure 5. Emitter thickness decreases cell current increases

The generation and recombination of carrier are shown in figure 6. At AM 1.5 when light is on then generation and recombination both are started but generation rate is higher than recombination rate. In figure 6 curve shows that the generation and recombination is less at the surface. The green shows generation and red curve shows the recombination. After that saturation region of generation and recombination is obtained. In the simulation study it is also observed the intrinsic layer between p-layer and n-layer. Figure 8 shows that intrinsic layer increases as cell current increases because as the intrinsic layer increases the generation rate at the depletion region increases and effective depletion parameter dominates on the collection due to higher field and generation as a result higher current.

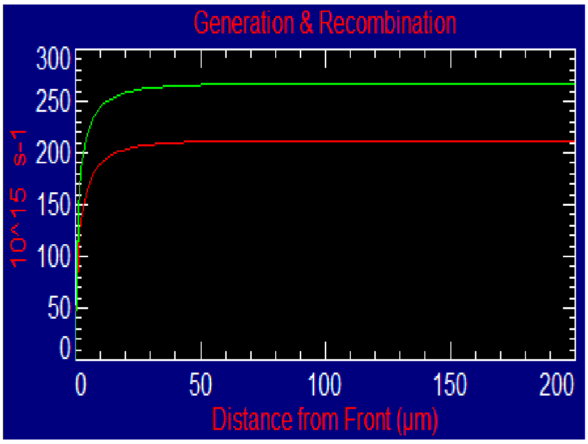

Figure 6. Generation and recombination Vs Distance from front

Making of surface passivation layer is very much important for this nano textured surface so due to use of doped silver paste for contact the surface recombination velocity problem reduces and as surface recombination velocity decreases short circuit current decreases (shown in figure 7)

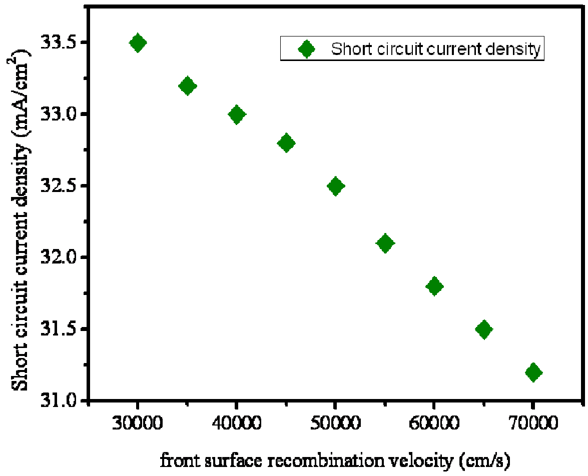

Figure 7. Increased short circuit current density with decreased front surface recombination velocity

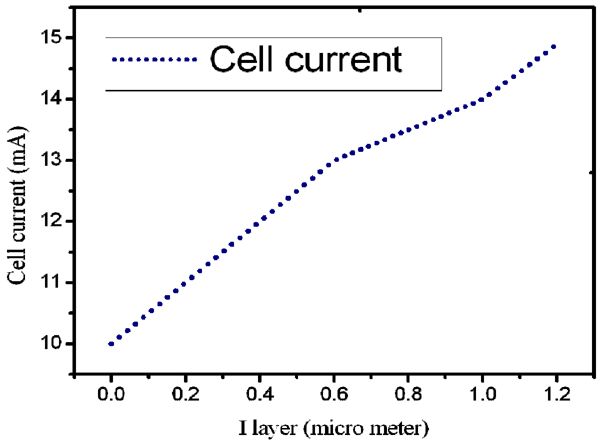

Figure 8. Intrinsic layer Vs solar current

Another important parameter is series resistance of solar cell. At the time of screen printing series resistance increases for the significant effect of contact resistance. Solar cell contact is generally made by screen printing method. At the time of screen printing method pores are created (shown in figure 14) at the surface and pores increases series resistance.

For theoretical analysis a bar of length L having some pores found during the time of firing is considered (as shown in figure 9). W1 and W2 is the width of the bar without considering the pore area. So, from the figure 9, W= W1+W2+ΔL where ΔL is the diameter of the pore. Considering the pores distributed at X and Y axis randomly or for arbitrary distribution of pores a model equation can be derived as

$$R_{eff} = \rho \left(\frac{L}{W * t}\right) * \left[1 + \frac{f_v}{1 - \frac{\Delta L}{t}}\right] \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where ρ = *resistivity of bar*;
t = *height of bar*; f_v = *Voidfraction*

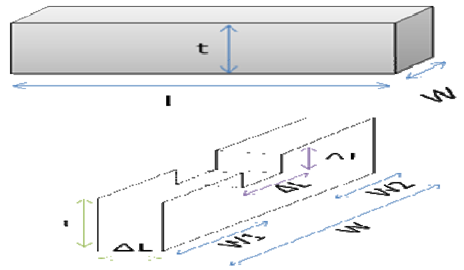

Figure 9. Model of finger with pore

L- Length of bar, W- with of the bar, t- thickness of the bar, ΔL-diameter of pore.

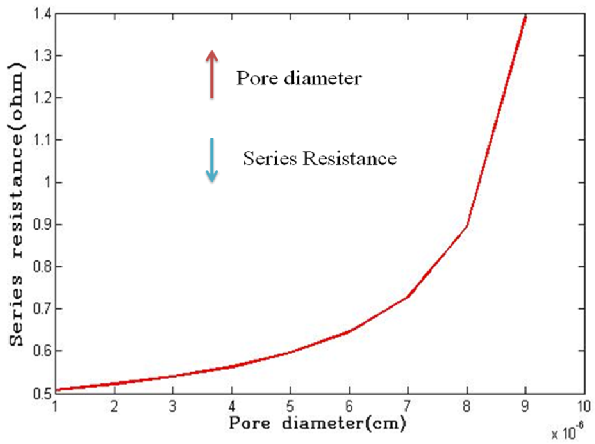

Figure 10. Series resistance changes with pore diameter

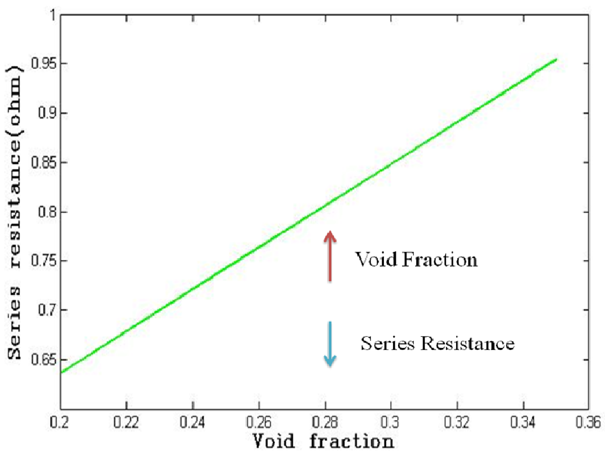

Figure 11. Series resistance Vs void fraction

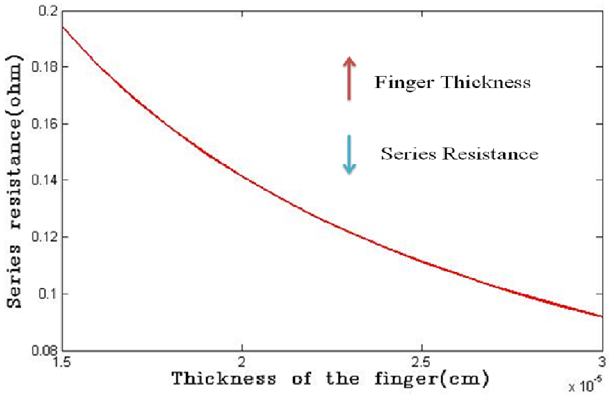

Figure 12. Series resistance changes with finger thickness

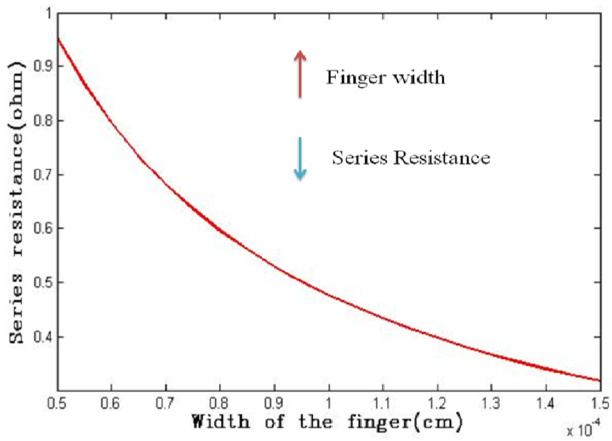

Figure 13. Series resistance Vs finger width

Using the resultant model equation a MATLAB analysis is carried out by taking different values of pore diameter, void fraction, finger thickness and finger width. Finally on the basis of MATLAB analysis different graph are obtained between series resistance and different finger parameters as shown in figure 10 to 13. Figure 10 and 11 shows that increased series resistance is due to pore increase in diameter and void fraction. As shown in figure 12 and 13 due to increase finger thickness and width series resistance decreases.

To overcome the series resistance problem light induced plating is the cost effective and prominent process. Due to light induced plating the Ag++ deposited at the pore (shown in figure 14(b) & 14(a)) due to the property of field line and also it increases the thickness of the front side finger and busbar as a result series resistance decreases and the performance of solar cell increases.

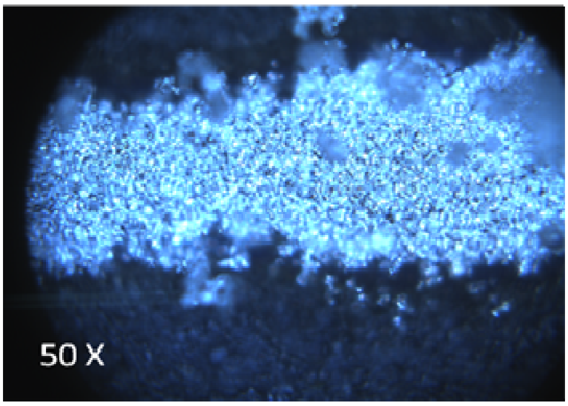

Figure 14(a). Finger before LIP treatment

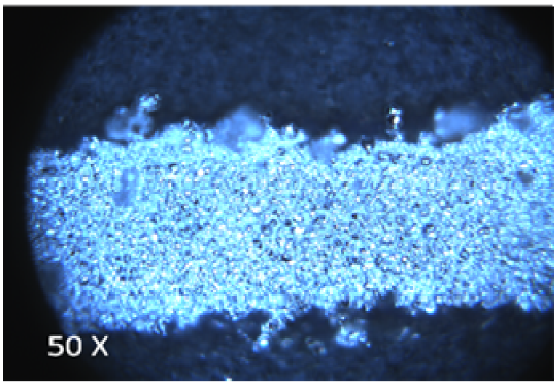

Figure 14(b). Finger after LIP treatment

At the time of light induced plating (LIP) silver particle deposited on the surface of the finger and busbar and some silver particles deposited unintentionally on the surface of the solar cell [23]. The deposited silver nano particles showed the plasmonic effect, because when light fall on the silver nano particle light start to scaterd at the surface toards the solar cell because refrective index of silicon is much more than air. The external and internal quantum efficiency increases (Shown in figure 16) increases as the electron hole pair (EHP) generation increases.

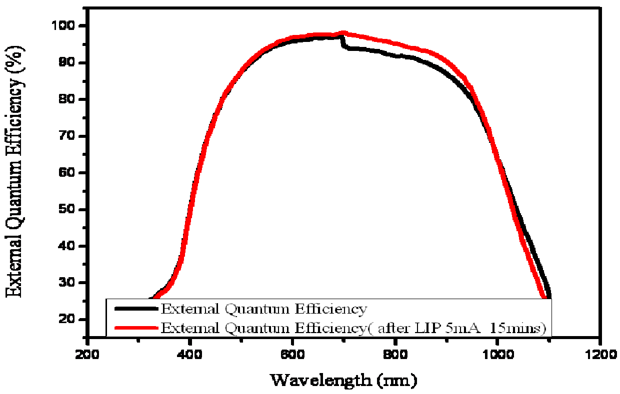

Figure 16. External quantum efficiency improvement due to LIP

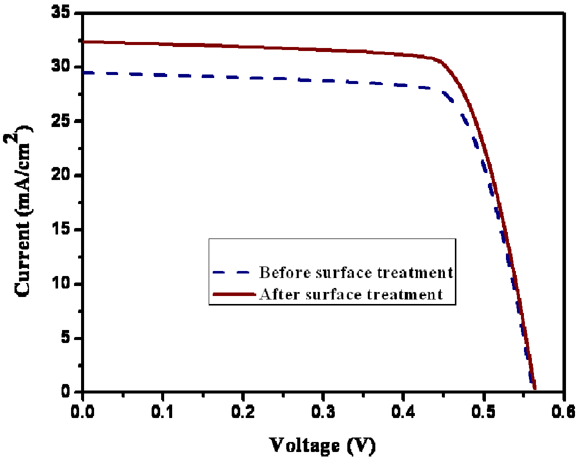

Figure 17. Efficiency enhancement of solar cell after surface treatment

IV. CONCLUSION

In this paper some simulation and some fabrication are done to enhance efficiency of solar cell. Different experiment and observation are also stated to show the improvement of solar cell efficiency (shown in figure 17) as the low fill factor problem is overcome in the performance enhancement of the solar cell.

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