Enhancing Efficiency of Thin Film Silicon Solar Cell

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Abstract:- Monocrystalline Silicon is the best material for semiconductor industry such a solar cell and unfortunately it is expensive. Because the demand of renewable energy is increasing today especially silicon solar cells, the cost of photovoltaics is still expensive and over 50 percent of it is the material cost contribution. One of the approaches to reducing it is by making a flexible and thinner solar cells. The conventional monocrystalline silicon solar cell are in range 300µm-400µm thickness. By reducing the thickness of monocrystalline silicon solar cell to range 5µm-50µm, we hope the cost reduction per Wp of photovoltaics is 5 to 35 percent [1]. Although the cells efficiency will drops after thinning solar cell process, but its still have a high efficiency [3]. The optimization for their electrical performance, flexibility and mechanical strength are important to get a good flexible , high efficiency and thin monocrystalline silicon solar cells.

Keywords:- thickness, thin silicon solar cell, electrical loses, optical loses,

1 Introduction

In typically , solar cells made from monocrystalline silicon wafers are thick. It is about 300µm to 400µm thick. The modern slicing ingot technology is based on wire sawing, where a thin wire (160µm diameter) web pushes an abrasive-based slurry into the silicon to be cut. In this way, the process needed high mechanical precision and also a highly automated. However, this process had a limitation, silicon ingot cannot be cutting into 5µm-50µm thin silicon wafer. The only way to get a thinner cell is by doing a thinner process on silicon wafer and then reuse it again for producing another cells. Currently, there are some of thinner process using a Layer Transfer Process (LTP) were develop such a Quasi Monocrystalline Silicon process (QMS), Porous Silicon process (PSI) and Smart Cut process (SC) an so on.

There are some effect on efficiency of silicon solar cells when the thickness is reduce. Mechanical strength yield, electrical loses and optical loses are some of the effects. This review paper is focuses on effects of thickness on silicon solar cell efficiency.

2 Mechanical strength

When decreasing a thickness of silicon solar cell, we must clearly understood the related mechanical yield and different thickness, so that benefit and improvement potentials of thin silicon solar cells can be further explored. An evaluation of mechanical wafer strength has been measured using ‘biaxial flexure strength test’ [1]. The thin silicon wafer rests on three symmetrically spaced points near its periphery. Then the force is applied at a prescribed constants rate in compression test machine until the wafer breaks. The breaking load, the dimensions and elastic constants of the wafer, and the radius of the support and load are used to compute the maximum tensile stress at the center of the convex tension surface, as published in [2]. The measured force for breakage and the corresponding flexure for the wafers are depending with different thickness and different surface structures. Figure 1. shows the fracture force on wafer thickness. The brakeage force for texture wafer is lower than flat wafer. Also, the size of the texture pattern has a significant influence on the wafer breakage behavior. Wafers with a large textured (10–20 µm) break at lower fracture force than wafers with a small textured (2–5 µm). Wafers which were texturized on both sides were the weakest with the lowest fracture force values.

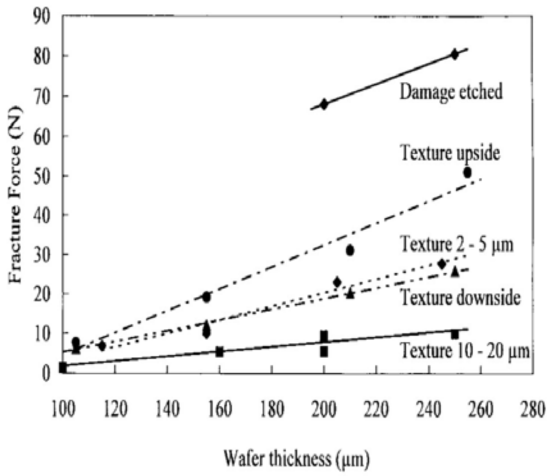

Fig. 1: Fracture force of silicon wafers with different surface preparations as a function of the wafer thickness.

While the fracture force decreases with thinner wafer, it flexure elongation are increases rapidly. The limited flexure elongation of 2 mm showed that damage etched silicon wafers of less 200µm thickness were not broken. Figure 2. show the flexure elongation on wafer thickness with different surface textured. As a result , a flexure of thinner wafer was much higher than typical wafer (300µm) which formulas are adequate, a wafer elongation less than 1/3 of the wafer thickness. Therefore, with proper preparation on thinner process and texture etch process, a sufficient mechanical stability of the silicon cell should be achieved.

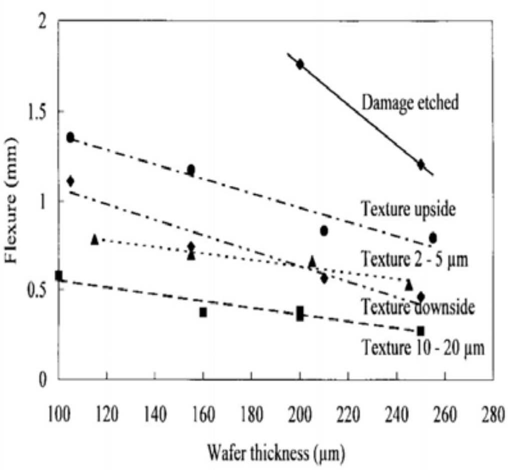

Fig. 2: Biaxial flexure of silicon wafers with different surface preparations as a function of the wafer thickness.

3 Electrical loses

Thickness will influence the open-circuit voltage of silicon solar cell. The open-circuit voltage V_{oc} depends on the dark diode current density Jo which is analyzed in term of current components from the silicon layer and a thin emitter layer on the surface of the base. The dark current can be calculated as

$$J_0 = \frac{q \cdot n_i^2}{N_D}\frac{D}{L}\left[\frac{(SL/D)\cosh(W_b/L) + \sinh(W_b/L)}{\cosh(W_b/L) + (SL/D)\sinh(W_b/L)}\right]$$

Where q is electronic charge, *ni* is the intrinsic carrier concentration silicon, *ND* is the base doping concentration and *S* is the back surface recombination velocity. *L* and *D* are minority carrier diffusion length and diffusivity in silicon base which are sensitive to doping levels and material quality. W_b is the thickness of the silicon base. The dark current can be simplified to equation

$$J_0 = \frac{q \cdot n_i^2 \cdot S}{N_D}$$

as the diffusion length will normally be longer than layer thickness ($W_b/L < 1$).

In such cases, the dark current does not depend on diffusion length, but is directly propotional to the surface recombination velocity, thus underscoring the importance of surface passivation in thin silicon devices.Higher doping concentration N_d will decrease *Jo*, so long as the doping does not degrade *L* such that $L<W$ and bulk recombination becomes significant. Another consideration of high doping but which not evident from the above equations are bandgap narrowing effects. As doping levels exceed 10^{19} atoms/cm^3, which higher than in thick silicon, the effective bandgap of silicon is reduced, leading to increased intrinsic carrier concentrations *ni*, and correspondingly increased J_o. Thus increasing doping to increase V_{oc} becomes self-defeating after a certain point.

Sensitivity to minority carrier recombination were decreased on thin silicon solar cells. Therefore, this allow a higher doping and leads to better tolerance of impurities and defects. Minority carrier lifetime τ and diffusion length L are related

$$L = \sqrt{D \cdot \tau}$$

Where D is the minority carrier diffusivity which proportional to the minority carrier mobility. Figure shows a sensitivity analysis of solar cell efficiency to device thickness and minority carrier lifetime.

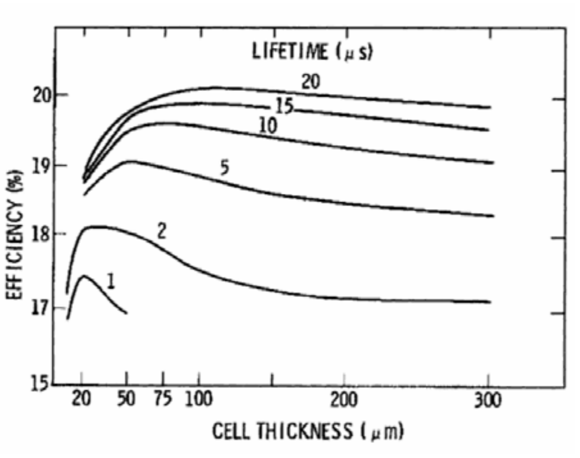

Fig. 3, Sensitivity analysis of solar cell efficiency to device thickness and minority carrier lifetime[10]

From the graph with low minority carrier lifetimes the optimum thickness is less than 50 μm.

4 Optical losses

Thinner silicon solar cell will absorb less light and directly it reducing the short circuit current of the solar cell . this matter also decreasing the cell performance and power output. The reflecting of solar radiation are occurs on the top surface of the cell and it affecting a weak absorbtion near-bandgap energy photon. Light gets reflected due to reflectivity of Si(~0.35). Loss due to reflection is given as

$$R(\lambda)\phi(\lambda)\exp^{-\alpha(\lambda)x}$$

Where *R(λ)* is reflectivity of the *Si, Ø(λ)* photons incident on the surface, and α(λ) is absorption coefficient of Si. Since the internal quantum efficiency are depends on reflectivity of Si. The internal quantum efficiency was given as

$$IQE = \frac{EQE}{1 - R(\lambda) - T(\lambda)}$$

Where EQE is external quantum efficiency,

$$EQE = \frac{\Delta J}{q\Delta\emptyset(\lambda)}$$

From the both 2 equations, reducing reflectivity at front surface Si are increasing the short circuit current *Isc* and the efficiency. So that, by using an antireflection coating and light trapping at back side, it may enhanced the optical path length of light within solar cell structure. Thus, it increasing the maximum absorption of light. The basic idea of light trapping in a thin solar cell is shown in figure 4.

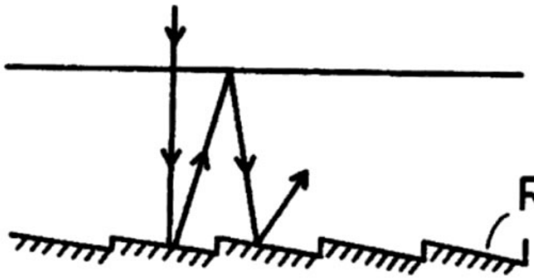

Fig. 4, Light trapping concept[5]

Light trapping to enhancing performance was actively discussed since the 1970s[6,7,9]. Maximizing the reflection at back surface giving optical path lengths greater than the thickness of device. The analysis were done by [8], doping level was adjusted to yield a minority carrier diffusion length twice the layer thickness, thus insuring good collection efficiency. Example result of the determination of optimal solar cell thickness as a function of light trapping is shown in figure 5.

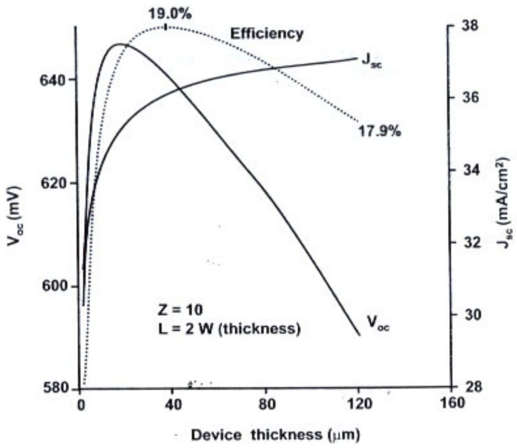

Fig. 5, Thin silicon device performance predictions for the case where the optical thickness due to light trapping (Z) is ten times the device thickness and the diffusion length is twice the actual device thickness. For this set of assumptions, the optimum efficiency occurs at silicon thickness between 30 and 40 μm.[8]

5 Present work.

As we understood from the literature above, we are now beginning to find a simulation for optimum thickness of monocrystalline silicon solar cell by using computer software such PC1D and etc.

6 Conclusion

As a conclusion, we know that the optimum silicon thickness for good efficiency and flexibility thin solar is below 50 µm. So we need to work on these thickness range to get good solar cell.

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