American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-10, Issue-01, pp-369-375
www.ajer.org
Research Paper Open Access

Factors Affecting the Morphology of Pyramids Formed on The Silicon wafer Surface

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ABSTRACT : *Texturing process to reduce light reflection is very important to high efficiency silicon solar cell . In this paper, a potassium hydroxide solution was used to etch the surface of the mono-crystalline silicon wafer, , and the concentration of the solution was changed by adding the following quantities:(0.1678, 0.3357) M0l, changed the KOH solution temperature between(60:82)° C, varying etching time between(7-20) min, and the percentage of additive texturing material that is added to KOH solution between(100:300)ml.the observed results taking by Scanning Electron Microscope (SEM) indicated the sample prepared at 0.33 Mol , solution temperature 82° C,14 min etching time and by adding 1% of additive texturing material to KOH solution give more homogeneity, good grain size of pyramids and efficiency of silicon solar cell between (16.7 % : 18.69%) ,*P_{max}*(4.502)W,* I_{sc}*(9.73)A and* V_{oc}*(0.626).*

KEYWORDS *Solar cell, texturing process, efficiency , light reflection, homogeneity*.

Date of Submission: 15-01-2021 Date of acceptance: 30-01-2021

I. BACKGROUND AND OBJECTIVE

In many optical devices such as mono crystalline solar cells Light capturing is a main part . We conducted this study with the aim of obtaining the greatest degree of homogenization of the pyramids which formed on the mono-crystalline silicon solar wafer surface . to obtain the highest efficiency and improve light trapping. A simple controllable etching technique was utilized to realize this objective .

We have presented in this paper a study of many factors that affect the homogeneity of the pyramids formed on the surface of the silicon wafer, which increase their ability to absorb light, which increases the efficiency of the solar cell and the factors that have been studied practically within the Egyptian-Chinese Laboratory for New and Renewable Energy in Sohag are (the concentration of the additive material which called(mono-crystalline silicon solar cell texturing additives without alcohol) , changing the temperature of the solution, Change the concentration of the chemical inside the tank which called(KOH) and change the time which the wafer takes in a tank) , And we have changed all the previous factors in order to obtain the greatest degree of homogeneity of the pyramids formed during the texturing process , which increases the efficiency of the silicon solar cell formed the morphology of the samples is studied utilizing the Scanning Electron Microscope (SEM) In order to see the details and calculate the grain size of the random pyramids that were formed during the texturing process. We found that the addition of the additive active material in an appropriate proportion(230ml) significantly affect the homogeneity of the surface of the solar cell and play an important role in mono crystalline silicon solar cell Fabrication . as showed microscopic results and It was also found that the best temperature for the solution at which the texturing process occurs is 82 degrees Celsius, also in the case of adding the appropriate amount of potassium hydroxide (0.3357 M0l) and the grain size(1.453 µm)
, we found that there is an incredible homogeneity between the pyramids formed on the surface of the mono-crystalline silicon solar wafer in addition to that the etching that occurred to the cell was within the required limits, and when the cell was kept for 14 minutes in the tank, it resulted in homogeneous pyramids and the grain size(1.85µm).

II. INTRODUCTION

Overall energy utilization has been expanding quickly [1] dramatically because of the industrial revolution . This expanding pattern of energy utilization has been quickened by enhancements in the personal satisfaction. As of now, the majority of the energy necessity overall is met by the burning of petroleum derivatives [1], which have become a fundamental part of present day human advancement, being progressively depended upon since the industrial revolution . The need to the overcome developing interest of energy in earth and to utilize clean fuel sources so as to relieve the a dangerous atmospheric devation brought about by the discharge of ozone harming substances because of petroleum product utilization [2], have permitted the advancement of different frameworks that eoploit the sustainable power sources over the previous many years. Among these sustainable sources, sunlight based energy, specifically its immediate transformation into power through the photovoltaic impact has encountered a significant development. Photovoltaic (PV) energy is the third most significant sustainable power for power creation after hydropower and wind power[3] . the mono- crystalline silicon solar cells plays an important role in photovoltaic (PV) manufacture because of its simplicity of process and the developed technology [4]. Therefore, many researchers and those interested in the field of manufacturing solar cells improve the process and get the highest efficiency and at low cost [5-6]. Generally, Silicon with a lot of structural morphologies is more used for optoelectronic devices[7].where The reflection of light at the surface of si solar cell is one of the most loss mechanisms; so a lot of efforts have been made to decrease this optical loss[8]. Previous studies have shown that the absorption of the light which converting into electricity increase by texturing process of the si wafer [9].

PV industries utilize progressed metallization products [10] to decrease the electrical loss; and antireflective coatings [11] with surface texturing [12] to decrease the optical losses and enhancement the efficiency . It was found that The surface texturing has been accomplished by various ways [13], for example, chemical etching, Texturing process is an essential step in the industrialization of a Silicon solar cell. This step to clean the wafer from saw tooth damage .Scientists have discovered that The random texturing of mono-crystalline silicon solar cells is a technology used to enhancement the conversion efficiency by rising the amount of light absorption [14,15] . The main objective of the Egyptian-Chinese National Renewable Energy Laboratory was the production of solar cells in Sohag achieve high efficiency silicon solar cell with reducing production cost Through continuous work on developing manufacturing processes. Texturing is the first process in fabrication of industrial silicon solar cells which carried on the front solar cell surface during manufacture to decrease reflection losses from the cell surface [16],[17]. in Figure 1. The essential model of a textured silicon wafer is shown.

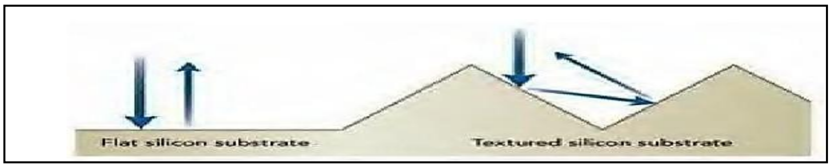


Fig. 1. Basic model of a textured wafer.

III. PURPOSE OF TEXTURING

1. Reduce surface reflection 2. Improve internal light absorption

it has been found that Texturing process of the mono-crystalline silicon surface improve its responsively and it increases its efficiency [18]. Anisotropic etching of silicon has a discovered a wide agreeableness in manufacture of industrial mono-crystalline silicon solar cells so as to decrease reflection losses from the front surface [19-20] .

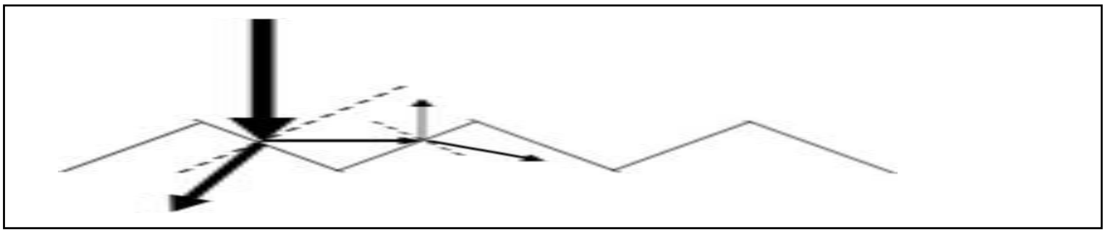


Fig.2. showing an increase in the path of the photon falling on the surface of the cell, after the texturing process .

IV. EXPERIMENT

The experiment was carried out at the Egyptian Chinese National Renewable Energy Laboratory. The apparatus used for texturing process is show in figure 3 , it is consist of eight tanks (28 × 28) cm and a depth of (32) cm were used as shown in the picture .

Fig.3. Shape of the tanks that were used to complete the experiment.

1. Effect of Texture Additive in Pyramid Homogeneity

The effect of changing the active material was studied and the etching value of the cell was recorded in four cases And the added quantity was as follows: (without additive material ,100mL,200 mL, 220 mL and 230 mL,250mL,300mL).

the steps of texturing process With the change of the amount of added additive texturing material:-

a) preparation of 0.1678 MOL of KOH solution and

inserting the wafer inside it for 4min at 70° C. this step to clean the wafer from saw tooth damage.

b) preparation of 0.3357 MOL of KOH solution and

inserting the wafer inside it for 14min at 82° C with varying the additive material to make the etching of the wafer and formed the pyramids .

c) inserting the silicon wafer in 4.44% HF for 4min at 25° C to remove the oxide layers.

d) inserting the silicon wafer in 3.88% HCL for 4min at 25° C to remove the organic material

After each step The cells were well washed with deionised water with nitrogen for 3 minutes. Then the silicon wafers are drying in the prescience of N2 gas at 45° C for 5 min.

we use optical microscope magnification force 60 times in order to see the homogeneity of the pyramids.

2. effect of temperature on the rate of etching and pyramid homogeneity

In an experiment studying the effect of temperature on the homogeneity of the pyramids formed and the percentage of etching that took place in the wafer, steps of texturing process with the change of the temperature:-

The same steps that were taken in the case of adding the active substance with changing the second step, as we add 230 ml of the additive active material with changing the temperature of the solution as follows(60,70,82,85) ° C.

3. Study the effect of KOH concentration on the rate of corrosion and pyramid homogeneity :-

In an experiment studying the effect of KOH concentration on the homogeneity of the pyramids formed and the percentage of etching that took place in the wafer, the same preceding steps were done completely with fixing the amount of active substance added in the basin and 230 mL of it was added, but the KOH concentration of the second basin was changed (0.1678 , 0.3357, 0.6714) Mol .which is the basin responsible for the texturing process and the formation of pyramids On the surface, the KOH concentration was changed in order to study its effect on the texturing process. The following table shows the added quantities of chemicals in each basin, as well as the temperature of each basin in addition to the time period that the Wafer took in each tank.

4. Study the effect of the time period for the wafer to remain in the tank:-

the steps of texturing process With the change of the time period of the wafer inside the tank:-the same preceding steps were done completely with fixing the amount of active substance added in the basin and 230 mL of it was added, but the The time period of the wafer inside the tank was changed, as the wafer was kept for 7 minutes, 14 minutes, and 20 minutes, indicating the effect of the time period on the size and homogeneity of the pyramids formed on the surface of the silicon solar .

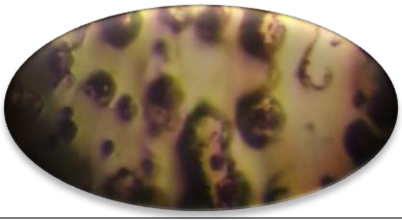
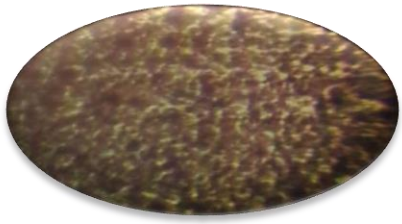
V. RESULTS

The silicon wafers samples are tested by Scanning Electron Microscope (SEM) and microscope is used to indicate the homogeneity.

A. Effect of Texture Addition in Mono crystalline Silicon Solar Cells:-

the amount of the additives material which called (mono crystalline silicon solar cell texturing additives without alcohol) Increase the consistency of the solution and control the reaction rate.

Table 1. shows the shape of the pyramids formed, the extent of their homogeneity and the way they are distributed over the surface of the wafer after the completion of the texturing process under the microscope.

texturing without any additive. 	 texturing with 230ml of additive.

in the case of the addition of an active material less than 230 ml affect the homogeneity of the surface of the cell as it pyramids are not homogeneous on the surface in addition to the emergence of some Spots resulting in the addition of the active substance by 230 ml in the potassium hydroxide solution basin in the Egyptian National Laboratory for Renewable Energy to obtain a homogeneous and shiny surface free of spots.

B. **effect of temperature on the rate of etching and pyramid homogeneity** :-

the temperature significantly affects the shape of the pyramids, in addition to they have a significant impact on the rate of etching. SEM picture of silicon wafer surface after etching at different temperatures, which are (60, 70 and 82) degrees Celsius

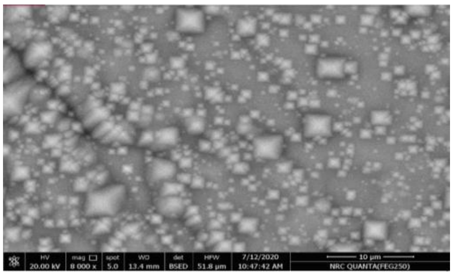


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Fig.4. SEM images of silicon surface after etching at 60° C.

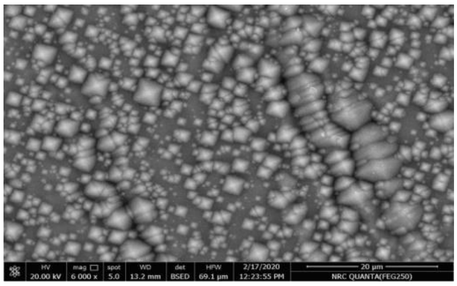

Fig. 5. SEM images of silicon surface after etching at70 °C .

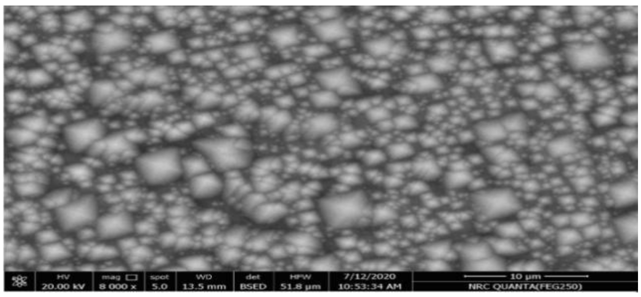

Fig. 6. SEM images of silicon surface after etching at 82° C

We observe a strong influence of the etching temperature on pyramid size. The results obtained showed that:-

in Figure(4) at a small temperature of 60 ° C it was found that the pyramids formed on the surface of the silicon cell were not fully developed with many voids and the size of the pyramids formed is small and also there is no homogeneity between the pyramids formed on the surface with the average grain size(1.31µm).***In Figure(5)***at a greater temperature of 70 degrees Celsius, it was found that the pyramids formed on the surface of the silicon cell began to grow, as well as the voids in the limitation began, and it was also found that there is an increase in the size of the pyramids formed on the surface of the silicon cell .***In Figure(6)***at a temperature of 82 degrees Celsius, which is the temperature used in the work in the Egyptian Chinese Laboratory for New and

Renewable Energy. We found that the pyramids consisted of a large size with the average grain size(1.82µm), and there is a large degree of homogeneity between them.

So at 82 degrees Celsius the pyramids were more homogenous with lower reflectivity. These outcomes are in a good agreement with the outcomes announced by Ammar Mahmoud Al-Husseini et al[21] . and Wang et al . [22], who reported similar pyramid sizes.

C. study the effect of KOH concentration on the rate of etching and pyramid homogeneity:-

the potassium hydroxide acid concentration was reduced to half the effect of this on the cell pyramid as the pyramids did not form completely on the surface as the corrosion rate was fewer than the permissible value and in the case of increased concentration the etching value was within the permissible limit but a direct effect on The shape of the pyramids SEM images of silicon surface after etching at different KOH concentration , which are (0.1678 mol ,0.3357 mol , 0.6714 mol)are shown .

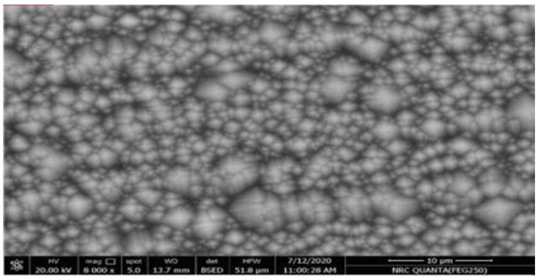

Fig.7.SEM images of silicon surface after etching at (0.3357 mol) KOH concentration.

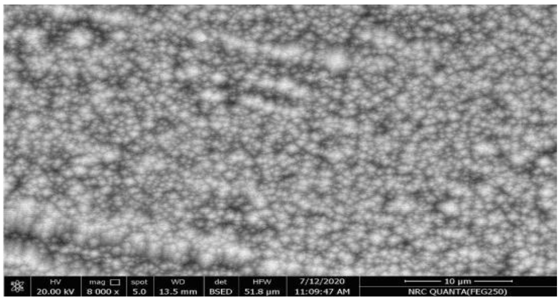

Fig.8.SEM images of silicon surface after etching at (0.1678 mol) KOH concentration.

We observe a strong influence of the etching temperature on pyramid size. The results obtained showed that:-

in figure(7), when the appropriate amount of potassium hydroxide was added (which is the amount that is added in the Egyptian-Chinese Laboratory for New and Renewable Energy in Sohag), it was found that the pyramids were formed in an appropriate size on the surface of the cell in addition to that a homogeneity was found in the size of the formed pyramids, which leads to an increase in efficiency The solar cell, we found that the average grain size(1.453µm)

But in figure(8) , it was found that when adding a small amount of potassium hydroxide (which is half the amount usually added), it was found that the pyramids were formed in a random way and are not homogeneous in size or shape, It was also noted that the size of the pyramids is very small ,and The corrosion that occurred to the cell was not within the required limits.in this case the average grain size of the pyramids is(0.56µm).

D. Study the effect of the time period for the wafer to remain in the tank:-

After conducting the experiment, we concluded that the time spent on the wafer inside the basin directly affects the homogeneity of the pyramids formed on the surface of the silicon cell and also affects the etching that occurs to the wafer. We will show the sem pictures of mono crystalline silicon surface after etching at different time period for the wafer to remain in the tank for 7 minutes, 14 minutes, and 20 minutes.

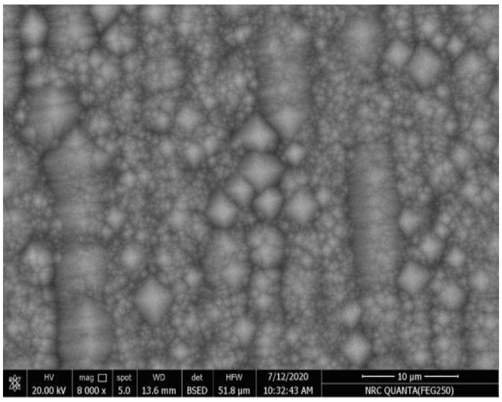

Fig.9. SEM pictures of mono crystalline silicon surface after etching for (7 minutes) time period.

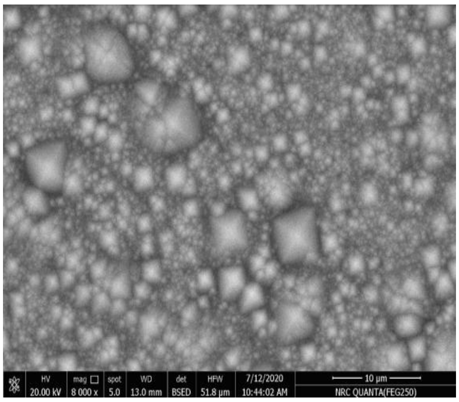

Fig.10. SEM pictures of mono crystalline silicon surface after etching for (14 minutes) time period.

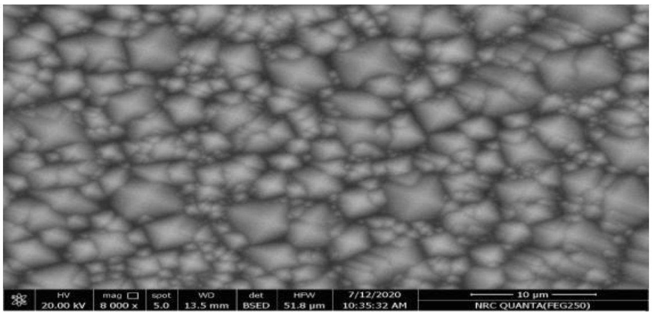

Fig.11.SEM pictures of mono crystalline silicon surface after etching for (20 minutes) time period.

It was found that the increase in time to 20 minutes did not affect the rate of corrosion, but it affected the shape of the pyramids formed. When the cell was placed in the tank containing potassium hydroxide plus the active substance for only 7 minutes, it was found that the corrosion rate was weak and that the pyramid was poor and heterogeneous. And it was found that the corrosion rate within the permissible limits and the pyramid is homogeneous from placing the wafer in the basin for 14 minutes, We concluded that with the increase in the time spent on the wafer in the basin The pyramids grew in size and became regular and uniformly distributed. By calculating the average grain size of the pyramids formed on the surface of the resulting silicon cell and it is in agreement with the outcomes announced by Ammar Mahmoud Al-Husseini et al [21]. In the event that the time exceeds 14 minutes, the effect is on the form of the pyramids only, without affecting the etching rate.

VI. CONCLUSION

showed the results of the various factors effecting surface texturing for the purpose of producing pyramidal texture on mono crystalline silicon wafer surface. The surface morphology shows that the size of the pyramidal texture changes as per the etching conditions such (the temperature , the amount of the additive material, KOH concentration and the time period for the wafer to remain in the tank). It was found through the experiment to obtain homogeneous pyramids formed on the surface of the mono crystalline solar cell, an appropriate amount of active substance is added, which is 230 ml, and the installation process is carried out when the degree of reaction of chemicals inside the basin is 82 ° C also an appropriate amount of (KOH) is added, which is (0.3357 M0l) , and the time period for the wafer to remain in the tank is 14 min also we calculate the average of the grain size in each case and the efficiency of silicon solar cell is 18.69% ,P max(4.502)W, I sc(9.73)A and Voc(0.626).

Fig.12.(I-V)curve , (P-V)curve of solar cell.

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