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Article

A Practical Study of The Fabrication and Optimization of The Weight of Monocrystalline Silicon Solar Cells

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Abstract

This industrial research sheds light on the manufacturing of monocrystalline silicon solar cells, the optimization of the weight of the cell during manufacturing, and the effect of each stage of manufacturing on the color and weight of the solar cell. During manufacturing, the solar cell goes through six stages: texturing, diffusion, plasma etching, remove phosphorous silicate glass (RPSG), anti-reflection coating (ARC), and screen printing. The success of each stage determines the cell weight and cell color. This weight of the cell depends on the weight of the silicon wafer (*p*-type) and each stage from the manufacturing stages affects this weight. After many experiments were carried out, we found that some stages lead to weight gain and some stages that lead to weight loss. The texturing stage leads to weight loss ranging from 0.7 to 1.1 grams, it is the most stage leads to weight loss. The diffusion stage leads to a slight weight gain ranging from 0.008 to 0.0148 grams. The plasma etching stage leads to a slight weight loss ranging from 0.0005 to 0.005 gram. RPSG stage leads to a small loss of weight ranging from 0.0151 to 0.0176 gram. ARC stage leads to a slight weight gain ranging from 0.004 to 0.0123 grams. Screen printing leads to weight gain, screen printing 1 leads to weight gain from 0.0039 to 0.0084 grams, screen printing 2 leads to weight gain from 1.122 to1.3 grams, it is the most stage led to high weight gain, screen printing 3 leads to weight gain from 0.0782 to 0.0865 grams.

Keywords: Monocrystalline silicon cell, Screen printing, Solar cell weight, Texturing, Diffusion, Anti-reflection coating.

1. Introduction:

One type of semiconductor device that directly transforms solar energy into electric energy is the solar cell. Its highly developed technology and steadily declining cost have led to its growing significance in the new energy sector [1-3]. Crystalline Si (c-Si) wafers are the paramount material in the field of solar cells. c-Si wafers have experienced significant development in the worldwide photovoltaic market because of their high conversion efficiency, long-term stability, and simple, optimized manufacturing process [4,5].

The manufacture of solar cells is a complex and meticulous process, as the efficiency of the final product is tightly intertwined with the precise control of various manufacturing parameters, including chemicals, gases, other materials, and processing times. Each stage in the manufacturing process has a specific purpose. Texturing the surface of a Si wafer with random pyramids is an essential process for improving the efficiency of c-Si solar cells by reducing reflection. The texturing process creates a rough surface that scatters light, which reduces the amount of light that is reflected. This results in a higher absorption of light and a higher efficiency of the solar cell [6-10]. Diffusion process used to form pn junction, phosphorus oxychloride ($POCl_3$) diffusion is now the most important and critical process for the production of industrial n-type emitters [11]. During the diffusion process, phosphorous dopant was diffused into the side and edges of the solar cell, which caused a short circuit, This reduces the open voltage circuit (V_{oc}) of the solar cell. To prevent this, edge isolation is used to isolate the n-type and p-type regions of the solar cell. This is done by etching the edges of the solar cell using a plasma etching machine. At 850-900 °C and in the presence of oxygen, a hard material layer known as phosphorus silicate glass (PSG) layer $(P_2O_5.SiO_2)$was formed as PSG removal is done using a mixture of hydrofluoric (HF) and Deionized (DI)-water. To improve the efficiency of solar cells, anti-reflection coating (ARC) layers are often used to reduce the amount of light reflected off the surface of the cell [12]. ARC are typically made of thin films of dielectric materials, such as silicon nitride (Si_3N_4). In the production of solar cells, the metallization process creates metal contacts on the surface of the cells to collect the photo-generated current [13].

In this study, monocrystalline silicon (mono-Si) solar cell is fabricated practically and studies the effect of manufacturing stages on solar cell weight and color. This study is important for solar cell production lines, as good cell weight is a powerful factor in increasing production and reducing waste during manufacturing.

The rest of this paper is organized as follows: Section 2 outlines the methodology used in the research and describes the experiments carried out in the laboratory. Section 3 presents practical findings on the effect of fabrication stages on the solar cell weight and color, followed by a discussion of these results. Finally, Section 4 summarizes the conclusions drawn from the obtained results.

2. Experimental Details

This study was carried out in the Joint National Egyptian-Chinese renewable energy laboratory, Sohag, Egypt. As shown in Figure1, firstly P-Type mono-Si with an area of $156.75\times156.75\ mm^2$and thickness of 180 micrometer is used then the wafers are cleaned and textured using preparation of a solution from the KOH (Potassium Hydroxide): texturing Additives:H_2O DI-water with the ratio of 470 grams: 235 milliliter: 25 liter in the texturing machine. After the cleaning and texturing process has been finished, the wafer is subjected to a diffusion furnace to form pn junctions under conditions of diffusion step at 780°C, drive in at 830°C, the time of diffusion and drive in steps is 1000, and 500 sec respectively. Using a ratio of 1900/2800 (SCCM/min) in the pre-deposition step and 1200/2000 (SCCM/min) in the drive- in step. Edge isolation is employed to isolate the front and back sides using a plasma etching machine. A mixture of tetrafluoromethane (CF_4) and O_2 was used with a ratio of CF_4:O_2=150:15 (SCCM/min). PSG removal is done to remove PSG layer formed on the diffusion process using a mixture of HF and DI water according to the ratio of HF: ionized water = 3L:22L. In ARC, Si_3N_4 layer is deposited on the surface of the solar cell by using mixture of silane (SiH_4) and ammonia (NH_3) according to the flow ratio of 600:5400 (SCCM/min). Screen printed contacts were used for front Ag and back Al metallization. After finishing all the stages of manufacturing of solar cell, Light-Current Voltage (LIV) testing is done to know the performance of the solar cell.

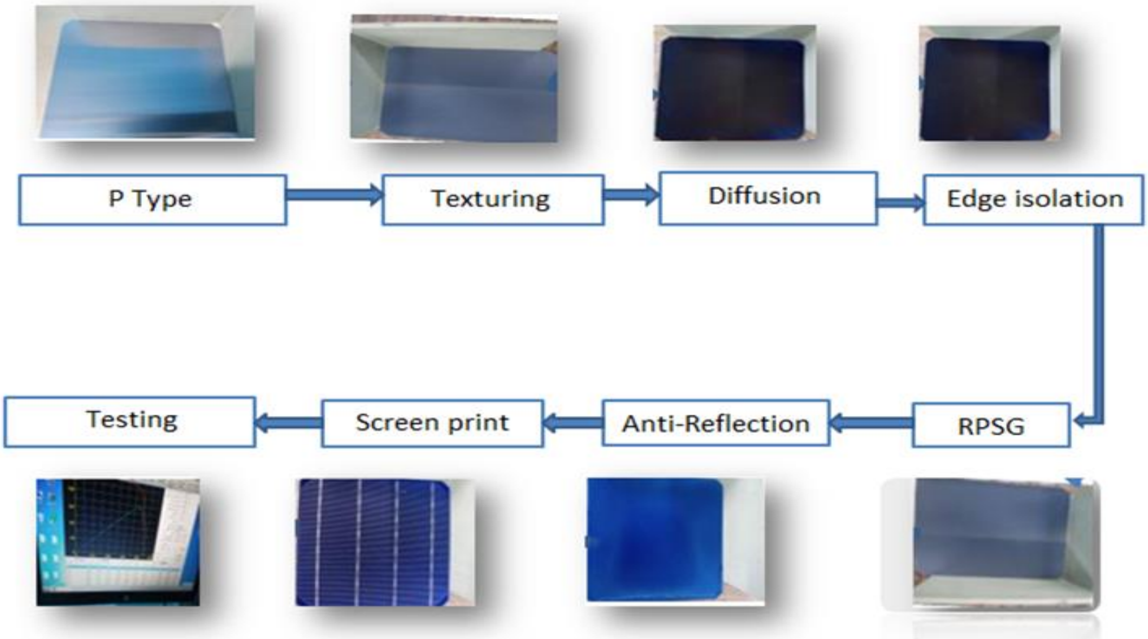


Figure 1: Sequence of the solar cell fabrication process steps.

3. Results and Discussion

3.1 The Effect Manufacturing Stages of Mono-Si Solar Cells on The Cell Weight

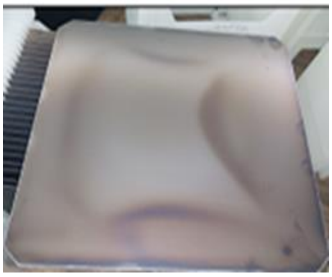
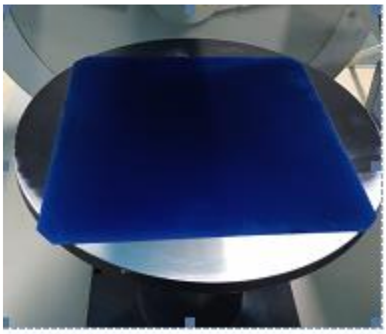
As listed in Table 1, it is clear that every stage affects the weight of the cell. The weight of the p-type Si wafer was 9.7573 grams, when the texturing process was performed the weight of the cell was reduced in the texturing process, and chemicals were used to etch on the surface of the cell to form pyramids. In the diffusion process, a n-layer and PSG layer were added. Hence, the weight of the cell was increased. In the plasma etching process, the phosphorus deposited on the edges of the cell is removed and thus the cell weight decreases. In the RPSG process, the PSG layer was removed. Hence, the weight of the cell was reduced. In ARC process, the thin film was deposited in the cell, hence the weight of the cell increased. In screen printing stages (1,2,and 3) the past was printed on the surface of the cell hence, the weight of the cell was increased.

3.2 The Effect Manufacturing Stages of Mono-Si Solar Cells on The Cell Color

As listed in Table 1, the color of the cell changes after each stage of manufacturing, and thus achieving a good color for the cell is the result of the success of all stages of manufacturing. Beginning after the texturing stage, a layer of silicon oxide is formed. If the thickness of this layer decreases, the color of the cell is greatly affected. RPSG stage: In this stage, a PSG layer is removed. If this layer is not removed, it greatly affects the color of the cell. The essential stage in affecting the color of the cell is the anti-reflection layer where an anti-reflection layer is deposited, and depending on the thickness of this layer, the color varies, and thus the cell acquires the traditional color.

Table 1 The weight and color of the mono-Si before and after every manufacturing stage

Stage	The weight Before stage (grams)	The weight after stage (grams)	The color of the cell
***p*-type**	-----------------	9.7573	
Texturing	9.7573	9.0587	
Diffusion	9.0587	9.07359	

Plasma etching	9.07359	9.0720	
RPSG	9.0720	9.0569	
ARC	9.0569	9.0661	
Screen printing1	9.0661	9.0706	

Screen printing 2	9.0706	10.1928	
Screen printing 3	10.1928	10.2710	

4. Conclusion

As a summary of this study, this research is important for solar cell production lines, as it has clarified all the stages of solar cell manufacturing and how to control them to reach the best weight of the solar cell and the best color of the solar cell, as the solar cell manufacturing process is considered an exact process, as each stage of manufacturing affects the efficiency of the cell, its color, and its weight on the weight and the color of the cell. The high effect of texturing, RPSG, and ARC process was investigated on the cell's weight and color. It is found that the texturing process and metallization process have a high effect on the weight of the solar cell and ARC has a high effect on the color of the solar cell.

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