Higher Efficiency N-type Photovoltaic Cell Through Reclaim Cleaning Process

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ABSTRACT – The reclaim process may improve yield loss by salvaging defects and is part of high contributions in the manufacturing industry to minimize overall operational costs. This study will focus on improving diffusion process yield loss through the reclaim process of scratches defects in the solar industry. Reclaiming of the defects is performed by cleaning and removing the diffusion layer back to its original condition before the diffusion process. Selected cleaning recipe from this study was validated with higher Power Conversion Efficiency (EFF) value at 22.98% observed from the experimental run compared to the normal existing process at 22.84% without reclaim process.

1. INTRODUCTION

The reclaim or rework process is common in the industry to reduce yield loss costs to the company. However, it is crucial to ensure the rework process does not jeopardize the quality of the product. This study will utilize a cleaning machine of N-type silicon photovoltaic technology for rework flow with experimental validation to ensure no additional impact on the quality of the product. Photovoltaics (PV) is one of the most rapidly growing energy generation that utilizes semiconductors that exhibit the photovoltaic effect to convert solar radiation to direct current electricity. Photovoltaic energy generation utilizes solar panels comprised of several photovoltaic solar cells. These cells are assembled into solar panels as part of a photovoltaic system to generate solar power from sunlight [1]. N-type silicon has more electrons than silicon, including phosphorus (making it negatively charged). For crystalline silicon photovoltaics, the most efficient modules are produced from N-type silicon wafers due to higher tolerance for defects [2].

In photovoltaic wafer manufacturing, one of the biggest scrap or defects happens in the boron diffusion process due to operator manual handling. Manual handling is carried out usually because of automation failure that requires manual collection of wafers in the reject bin. Those defective wafers must be scrapped and thrown away as the handling causes scratches on the diffusion layer that will be captured as electrical shunt loss at the end of the line cell tester. One of the options to reclaim the defective cells is through boron diffusion layer removal using wet chemical process. For this rework process flow, the reclaim will require the wafer for the second run in wet chemical (cleaning module) to remove the diffusion layer. In this study, developing the cleaning recipe is critical to ensure the cleaning module is able to remove the diffusion layer. The reclaim flow is illustrated in Figure 1. Selected recipe will be validated through experimental run and analyzed on the Power Conversion Efficiency (EFF). The finding of this study will help to improve the operational cost as less wafers will be thrown away and scraped if the defective wafer undergoes the reclaim cleaning process.

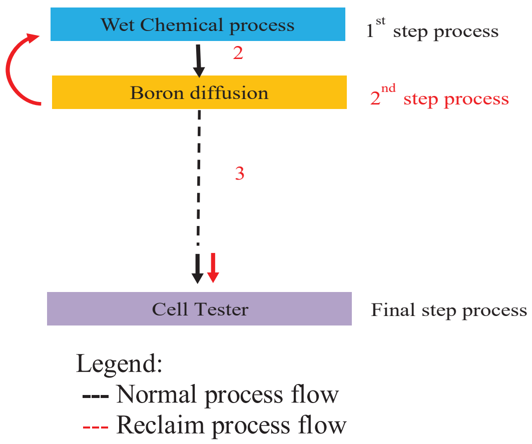


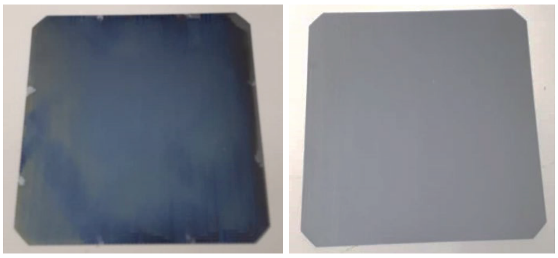
Figure 1 Silicon cell processing

2. METHODOLOGY

The materials in this study were divided into experimental and control lots. The experimental lot is collected from a scrap wafer in boron diffusion process that has undergone a reclaim cleaning process, while the control lot is from a standard production wafer. Example of defective wafer with diffusion layer and wafer condition after diffusion layer removal post reclaim process can be seen in Figure 2. The wafer was loaded at the cleaning process using reclaim recipe for the experimental lot. Once the wafer was unloaded from the reclaim cleaning process, a visual inspection was performed to ensure the diffusion layer was fully removed and cleansed without defects. The reclaim wafer will be rejected if the layer is not entirely removed. The wafer will continue run from post Cleaning until the final process step, the Cell Tester. At the Cell Testing station, the wafer will be inspected under the Cell Testing machine. Automation (robot) will load the wafer onto a "flash table" and connects the positive and negative leads to measuring equipment as it exits the production line. After then, the panel is "flashed" with calibrated sunlight recipe that is similar to actual sunlight characteristic and at the same time calculated the Power Conversion Efficiency (EFF) of each cell. Power Conversion Efficiency (EFF) is the ratio of power output to the power input. It is a stand-in for the overall efficiency of Photovoltaic cells. Power Input is the product of the area of the PV module, and the incident solar radiation gives the quantity of solar energy that can be produced. At the same time, Power Output is the sum of the highest possible current and voltage values. The equation of the electrical parameter and its relationship is expressed as in [3] such as

$$P_{out} = V_{max} \times I_{max} \tag{1}$$

$$EFF = \frac{P_{out}}{Area \times I} \times 100 \tag{2}$$



(a) (b)

Figure 2 (a) Defective wafer with diffusion layer (b) Complete diffusion layer removal after reclaim cleaning

3. RESULT AND DISCUSSION

The experimental and control data of the Power Conversion Efficiency performance were plotted in JMP statistical software and analyzed using the Wilcoxon comparison test. Comparison between the experimental and control groups as shown in Figure 3 demonstrates that the population distribution of the experimental sample of cell Power Conversion Efficiency is significantly different to the control sample with a p-value of < 0.0001. However, the mean statistical data for experimental is higher, at 22.98%, compared to the control mean value of 22.84% shown in Table 1. Higher Power Conversion Efficiency is recommended in the solar cell as it will produce a higher Watt (W) value. This comparison analysis showed better mean Power Conversion Efficiency value even though the p-value is a significant difference to control data. According to Park et al. [4], integrating such "critical cleaning" becomes important for better efficient solar cells as contamination and impurities are removed that impact the charge carrier's lifetime and increase the efficiency. In this study, the wafer undergoes cleaning twice in wet chemical cleaning process, which is explained by the increase in efficiency compared to standard production wafer as the contamination is completely and efficiently removed from the wafer surface.

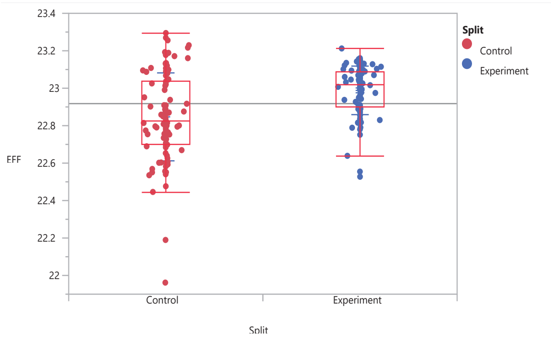


Figure 3 Power Conversion Efficiency

Table 1 Power Conversion Efficiency results

Material	Mean	Stdev	p-value
Control	22.84	0.2348	<0.0001*
Experiment	22.98	0.1296	

4. CONCLUSION

Reclaim process of N-type photovoltaic cell through cleaning process able to improve yield loss by salvaging the defects and at the same time improve Power Conversion Efficiency (EFF) compared to the normal standard cell due to contamination on the wafer surface efficiently remove from the additional cleaning conducted in the reclaim cleaning process flow.

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