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Dye-Based Bifacial Silicon Solar Cell Fabrication

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Abstract: ***Solar photovoltaic (PV) is a well-known energy harvesting technology or a semiconductor device that is used in generating electricity from the sunlight via the conversion process. Currently, solar photovoltaic is increasingly growing as an alternative renewable energy in conventional power generation. There are two types of solar photovoltaic cells which are monofacial and bifacial solar cells. The difference between these two solar cells is, monofacial, only generate electricity when the light touches the front side whereas the bifacial solar cell does generate electricity from both the front and rear side. In this research project, the bifacial solar cell is used to fulfil the purpose of increasing the power conversion efficiency as it can generate power from both surfaces. The bifacial is known to produce more energy up to 27 % than the monofacial according to the claims of some manufacturers. The base of this bifacial solar cell is silicon. Silicon purely contains an atomic structure that makes it suitable and more stable to be the raw material of a semiconductor due to its behaviour to block and conduct electricity. This is mainly due to silicon having the conductive properties of metal as well as an insulator. The silicon wafer will undergo the whole fabrication process to become the semiconductor devices. However, there is a problem encountered with the PV cell when it is consistently improving and when analysing the potential areas: on the power conversion efficiency. This is one of the challenges that can be solved with a strategy to increase the availability of the photon trapping of the solar cell which we called as the surface passivation of the bifacial solar cell. Surface passivation is a way that can minimise the recombination loss and efficiency loss while enhancing the optical path length of the solar cell on the photon absorption. It is the most significant step to increase the efficiency of the bifacial solar cell which is also known as an anti-reflection coating (ARC) using dye-based coating techniques. The development of the anti-reflection (ARC) lays on the fabrication techniques, optical performance and the light trapping structures as well as their impact on its efficiency.***

Keywords: Bifacial solar cell, power conversion efficiency, dye-based coating, surface passivation, anti-reflection coating.

I. INTRODUCTION

Surface passivation is the most significant step to keep the recombination loss at a tolerable minimum and avoid an unacceptably large efficiency loss when moving towards thinner silicon material. The surface passivation was investigated by using nanostructure molecules of DiO. This indicates that the light trapping inside the interface layers of silicon has a slow process of charge recombination before it reaches an equilibrium state. This is due to the interaction bonding between interfaces within boundary layers and dye molecules nanostructure. The short circuit current density increases as the dye molecule is applied on the solar cell. Bifacial solar cells are designed to trap light in both the front side and rear side. The main issues in the back surface were identified such as low efficiency, low photo generated current and low recombination losses. However, poor passivation and wafer thickness also can be one of the reasons that contribute to the recombination losses. Thus, to reduce the back-surface recombination in crystalline silicon solar cells is by using doped junction technique. These junctions are commonly known as back-surface fields (BSF). In general, the passivation techniques commonly use inorganic materials which may not give advantage on the research such as Silicon Nitride and Silicon Dioxide even though these materials can produce higher efficiency. Surface passivation is important in producing good dielectric properties but the use of silicon dioxide is unsuitable as it requires higher temperature and has a low reflective index. Meanwhile, as for the silicon nitride, even though it provides higher stability in trapping the light, it does release hazardous gas that might be harmful to people.

Bifacial solar cells offer numerous benefits, such as their applicability and compatibility with thin wafers, ability to endure high temperatures, utilisation of minimal metal materials, enhanced power generation, and a straightforward manufacturing process. Furthermore, this particular cell exhibits the ability to enhance the power density of the photovoltaic module in comparison to single-sided cells arranged in a side-by-side configuration, while simultaneously decreasing the expenses associated with the area of the photovoltaic system. One of the benefits includes a reduction in temperature within the working cell, as well as an increase in the maximum power output. This is attributed to the absence of aluminium metal, which results in a decrease in infrared absorption. A notable benefit of this particular cell is its ability to function optimally in a vertical arrangement, in contrast to the commonly employed single-sided solar cells that are typically mounted at a predetermined angle.

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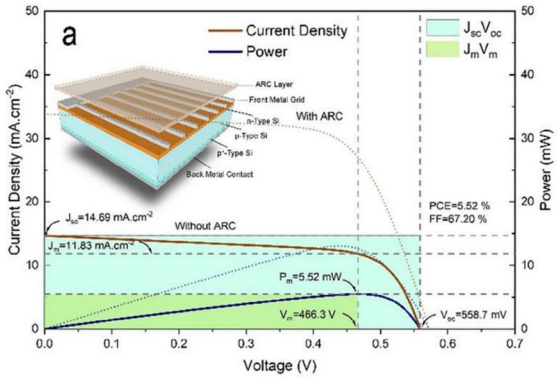


Figure 1 I-V measurement of Bifacial Silicon Solar Cell with ARC

II.MATERIALS AND METHODS

The cleaning process of wafer is very important in order to remove unnecessary residues on the surface that made it into pure silicon before fabricating the bifacial silicon solar cell using several methods such as doping, back surface field passivation, oxidation, screen printing and metallization of RTA as shown in Figure 2.

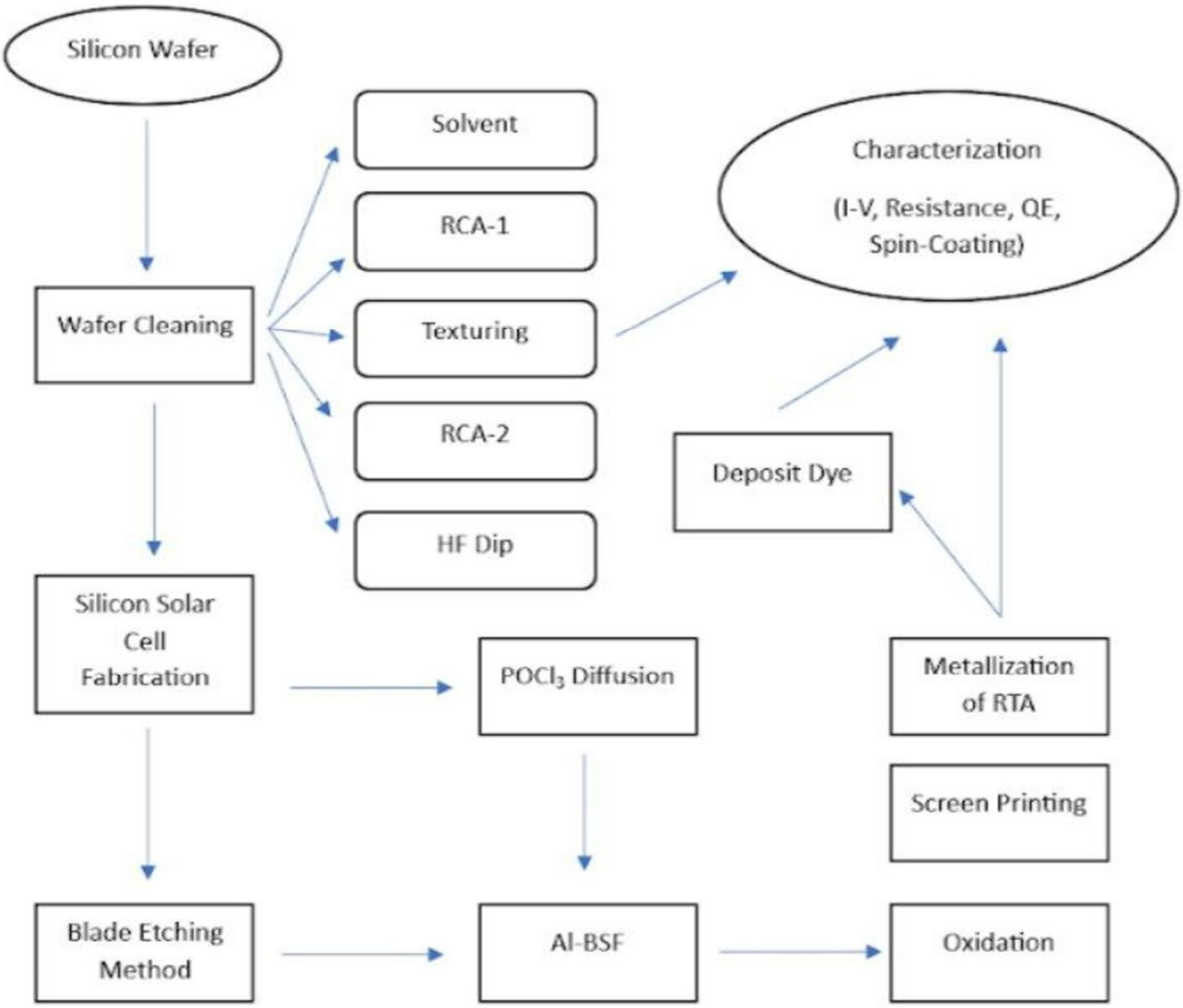


Figure 2 Flowchart of Bifacial Silicon Solar Cell Fabrication

A. Deposit Dye

A dye powder of 3,3'-dioctadecyloxacarbocyanine, DiO was used in this study as a dye-molecule nanostructure that will be coated on the rear side of the bifacial silicon solar cell. A 0.015 M concentration of DiO was prepared by diluting the power in chloroform solution. Before using the spin coating techniques for the dye concentration, the sample was first needed to be hydrophobized by using hexamethyldisiloxane (HMDS) solution to form carbon-hydrogen (C-H) bonds. The silicon wafer was put in a container and a few drops of HMDS were added in the container to leave it overnight (24 hours). The hydrogen bonds found in the silicon layer will combine with the carbon atoms found in the HMDS structure and subsequently bind to the atoms of the dye nanostructure DiO. The deposition steps of the dye molecules on the SiNWs sample are shown in the Figure below. After being left overnight, the silicon wafer is ready for processing. Next is the deposition of dye molecules. In this study, the spin coating technique was used to deposit the molecules dye with a rotation speed of 3000 rpm for 50 seconds. Figure 1, shows deposition flow of dye molecules on bifacial solar cells.



Figure 3 The process of dye deposition

III. RESULTS AND DISCUSSION

A. Textured Surface

As shown in the Figure 4, the topographical view of the wafer surface after undergoes the etching process of texturing resulted in the surface roughness that look alike pyramid shape. The pyramid pattern on the wafer surface indicates that it act like a light trapping system as the incident light interact with the surface, the chances of light absorption is higher compared to the planar surface. It minimize the reflection losses due to the amount of light reflected away.

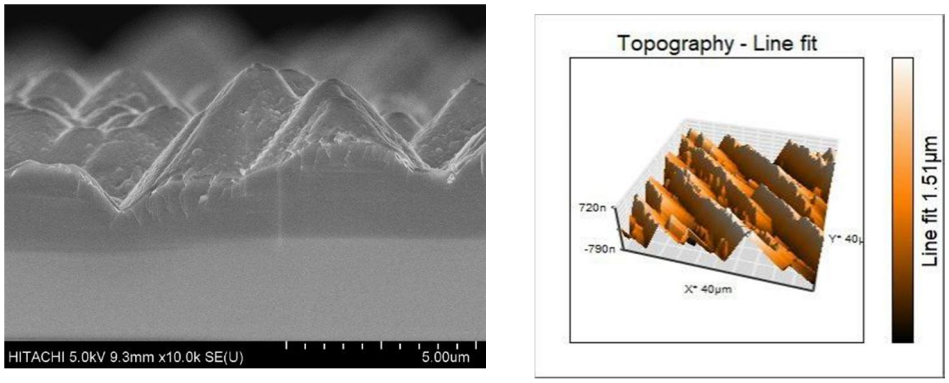


Figure 4 Textured surface of silicon using FESEM and AFM

B. I-V Measurement

The dye passivation on the back surface field has improved the solar cell performance by 1.7% from its original efficiency. Even though the efficiency increases, the solar cell performance gradually decreases due to its fast degradation.

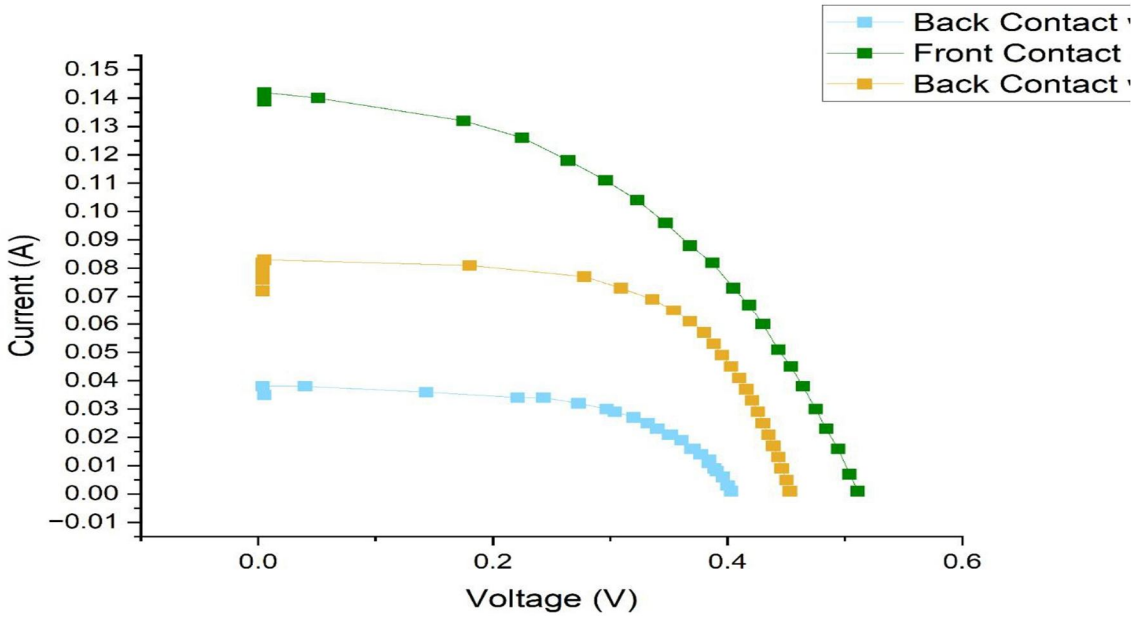


Figure 5 I-V curve of Bifacial Silicon Solar Cells for both front and rear contact with and without DiO dye.

Table 1 : Summary of electrical properties of DiO on silicon solar cell.

Sample	Voc (V)	Isc (A)	FF	Pmax (W)	η (%)
Front	0.511	0.142	0.455	0.033	3.6
Rear Side without DiO	0.403	0.038	0.522	0.008	0.8
Rear Side with DiO	0.453	0.083	0.612	0.023	2.5

IV. CONCLUSION

In this study, the three objectives mentioned in chapter 1 has been done which are first, to fabricate the bifacial silicon solar cell both front and rear side and observe its optical properties. Second, to measure the electrical properties of the bifacial silicon solar cell to obtain its Light-Current-Voltage and power conversion efficiency and lastly, to improve the efficiency of bifacial solar cells by surface passivation using dye molecules nanostructure. For the first objectives, the optical properties of the bifacial silicon solar cells have been achieved by fabricating the solar cell especially in texturing process. The topographical image of the textured surface helped in increasing the rate of light trapping into the material. The higher the surface roughness of the material, more light will be trapped inside to generate more electrical energy. Thus, the efficiency of the solar cells will be higher than non-textured surface.

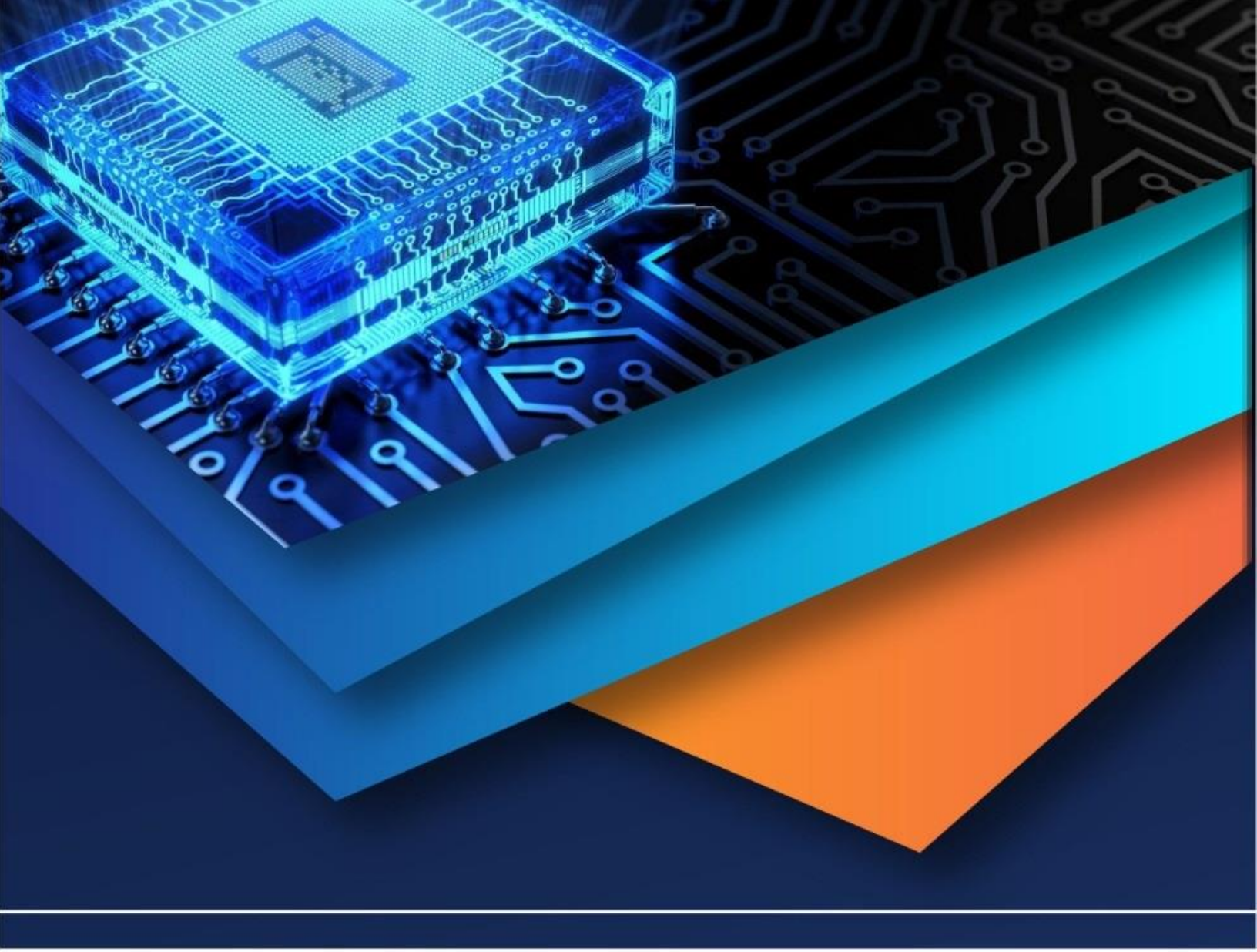
In second objectives, the electrical properties of the bifacial silicon solar cells were measured by using the I-V measurement. The efficiency calculated from the data obtain of the front side is 3.6% while the rear side has 0.8%. The result showed that the back surface field has lower power conversion energy. This is might be due to the poor passivation or the thickness of the wafer. But, the cost is too high. Thus, there are some ways to overcome this problem with lower cost need which is using the dye-based material. Therefore, the experiment proven, that the dye help to increase the efficiency of the back surface of silicon by 2.5%.

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