Simplified Fabrication of Screen Printed Interdigitated Back Contact Solar Cell Based on Wet Etching Process

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Abstract: - In this paper, a simplified fabrication of Interdigitated Back Contact (IBC) solar cell based on screen printing contact and self align wet etching process is presented. In the fabrication, conventional Phosphorous Trioxychloride ($POCl_3$) was used to form emitter (n+) region on p-type base substrate. Silver (Ag) and Silver/Aluminium (Ag/Al) paste were used as emitter and base contact respectively. Both contacts were electroplated with Copper (Cu) to protect from alkaline wet etching process. The best cell yield V_{oc}, I_{sc}, FF, and efficiency of 461mV, 8.42 mA, 0.523 and 2.03% respectively. Over etching process will result undercutting that lead to metal contact detachment. Low overall solar cell efficiency due to non-optimized geometrical design and low lifetime starting substrate used. Nevertheless the simple process provides an alternative approach toward lithography free fabrication of IBC solar cell.

Key-Words: - Screen-printed IBC solar cell, Wet Etching, Copper Electroplating.

1. Introduction

IBC solar cell has attracted many attention recently due to high cell and module conversion efficiency [1]. Other interesting features of IBC solar cell are zero shading losses, all rear contact structure and co-planar module connection [2-4]. Moreover IBC solar module has uniform dark appearance that suitable for building integration [5].

However, fabrication of IBC is more complex and difficult. IBC solar require fine definition of emitter region, base region, emitter contact and base contact. Hence the conventional way fabrication of IBC solar cell is base on photolithography process [6, 7]. Despite this, there is growing number of research for lithography free fabrication of IBC solar cell. The overall objective is to simplify the fabrication process. This would lead to low cost and high efficiency IBC solar cell.

Some of photolithography free fabrications involve the use of diffusion barrier paste [8], masking and laser ablation [9], self align trenches and mesas structure [10, 11] and screen printing diffusion paste [12]. While some of these method seem promising, the fabrication can be considered complex when compare to conventional silicon solar cell fabrication.

In this paper, an IBC cell fabrication based on conventional solar cell equipment and simple alkaline etching process will be investigated.

2. Solar Cell Design

The schematic of the solar cell is shown in Fig. 1. The emitter is created using conventional $POCl_3$ furnace. The base region is defined by screen printing Ag/Al paste. This will counter doped emitter region underneath and create back surface field (BSF). The metal contact is electroplated with copper to protect from wet etching process.

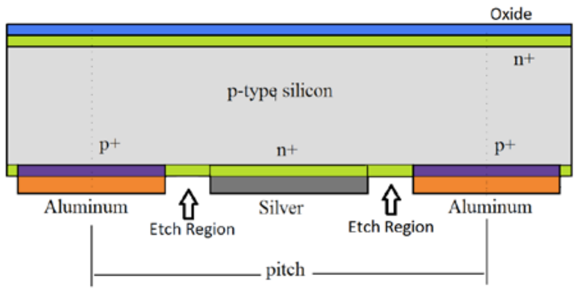

Fig. 1 The cross-section of the IBC solar cell based on screen printing metallisation.

Isolation of emitter and base region will be based on conventional alkaline etching solution. Alkaline solution is widely used in silicon solar cell texturing and thinning processes. There are several advantages of using alkaline etchants such as NaOH and KOH. They are inexpensive, widely available and offer fast etching rate for silicon, which can leads to high throughput batch processing. Although, alkaline solutions are generally corrosive, they are less hazardous than other etchants such as highly toxic Tetramethyl Ammonium Hydroxide or TMAH.

3. Cells Fabrication

Boron-doped, CZ-grown, p-type wafer with <100> crystal orientation, bulk resistivity of 1-2 Ω.cm and thickness of 200 µm was used as a starting substrate. The wafer was first subjected to saw-damage removal in hot NaOH solution. The saw-damage removal wafer was subsequently textured using KOH and IPA solution for 20 minutes at 80 °C temperature. The textured wafer was diffused to form n+-emitter in $POCl_3$ diffusion furnace. The diffusion process was carried out at 900°C for 20 minutes. An in-situ oxide was grown for 10 minutes at 900°C in oxygen rich ambient. This oxide film reduces light reflection and passivate the silicon front surface.

The next fabrication process is screen printing of the emitter contact. Silver paste NS3166 from Ferro Corporation was used to form emitter contact. The screen-printed silver paste is dried for 10 minutes at 100 °C in small drying furnace. To form the base contact, a mixture of silver and aluminium paste (Ag/Al) paste, PS33-610 by Ferro, was used. Both emitter and base contacts were co-fired in IR belt furnace at maximum temperature of 850 °C. During the firing process, Ag forms an ohmic contact with emitter layer, and Al counter dopes n-type region to form p^+ region underneath base contact region.

Following the contact firing in Infra-red furnace, Cu electroplating process is carried out. The Cu electroplating process is carried in an aqueous copper sulphate solution. The electroplating process is carried for 5 minutes at amperage of 2A and supply voltage of 0.7 V. The copper electroplated protects the metal contact during the alkaline etching process. The copper electroplating also enhances the contact conductivity.

For the alkaline etching process, 1M concentration of NaOH was used. The etching process was carried out for 10 - 20 minutes at solution temperature of 70-80 °C. Prior etching process, the rear side is exposed to HF (1:50) vapour for 30 sec to remove the oxide film.

4. Results and Discussions

A custom-made LIV tester with halogen arc lamp as the light source was used for measuring the performance of the IBC solar cells fabricated. The incident light intensity was calibrated to AM1.5 using sample from NREL. Tabbing strips were soldered to form connection between probe and busbar.

Fig. 2 plots the LIV response of the IBC solar cell as a function of etching time for the cell labelled as A1. Before etching, the LIV response showed zero response that was attributed to shunting between emitter and base regions due to the presence of continuous n^+ emitter layer. LIV measurement following 5-min etching process also exhibited zero response. After 10-minutes of alkaline wet-chemical etching, weak light response described by the blue line in Fig. 2 is measured. The light response improves after etching for another 5 minutes (red line in Fig. 2) and reaches its peak at 20-minutes of etching (green line in Fig. 2). The LIV measurements indicate that alkaline wet-chemical etching process has slowly etches off the entire n^+ emitter region between base and emitter contacts.

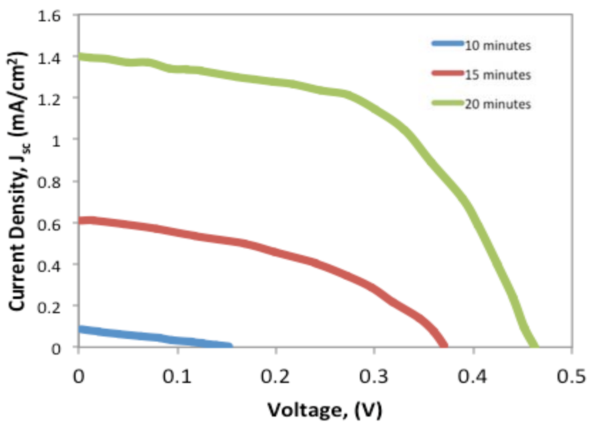

Fig. 2 LIV response for cell A1 with progressive etching time.

As etch time increases, more emitter region is etched off, thus, eliminating the shunting path between emitter and base contacts. As the etching process is continued, the IV response starts to decrease and is also accompanied by detachment of metal contacts from the wafer. LIV results of IBC cells fabricated are shown in Table 1.

IBC solar cell A1 did not have an oxide or nitride film on the front surface exhibited poor LIV response. During the etching process, besides the parasitic n^+ emitter between the base and emitter contact, the front surface is etched as well. Therefore, the front surface floating junction (doped

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Table 1 Key parameters of the IBC solar cells fabricated using alkaline wet-chemical etching process.

Cell No.	Front passivation	Etching Time (min)	Voc (mV)	Jsc (mA/cm^2)	FF	n (%)
A1	no	20	471	1.38	0.461	0.35
A2	Oxide	15	452	7.07	0.352	1.12
A3	Oxide	15	461	8.42	0.523	2.03

front surface field) is also etched away during the rear surface parasitic junction removal process. This leads to bare, un-passivated front surface. Un-passivated front surface has high surface recombination velocity [4, 13]. Since all carriers are generated at the front surface, high recombination velocity substantially reduces the photo-generated current due to recombination losses. In addition, the bare surface of silicon is more reflective than an oxide-coated surface. All these factors contribute towards substantial reduction in I_{SC}.

For IBC solar cells A2 and A3, in-situ oxide was grown following diffusion process in dry oxygen ambient for 10 minutes at 900 °C. This oxide film acts as passivation and anti reflective coating for the front surface [14]. This oxide film also protects the n+-doped front surface during alkaline wet-chemical etching process. Therefore, the floating junction keeps the surface recombination low [15] while the oxide layer act as anti reflective coating. Therefore, in cell A1 and A2, significant improvement in I_{sc} is observed as observed in LIV measurements plotted in Fig. 3. The best cell fabricated is cell A3 with V_{oc} of 0.461V, J_{sc} of 8.42 mA/cm^2, FF of 0.523, and efficiency of 2.03%. Table 1 summarizes key parameters of the three IBC solar cells.

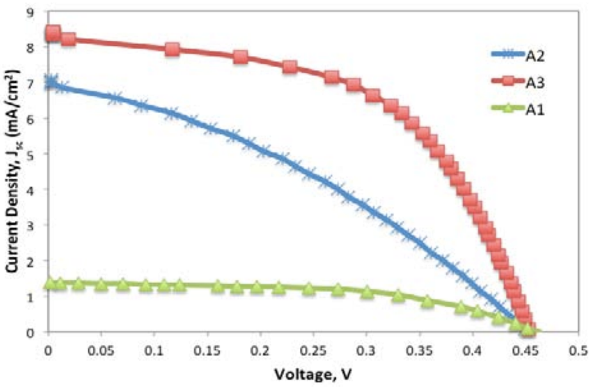
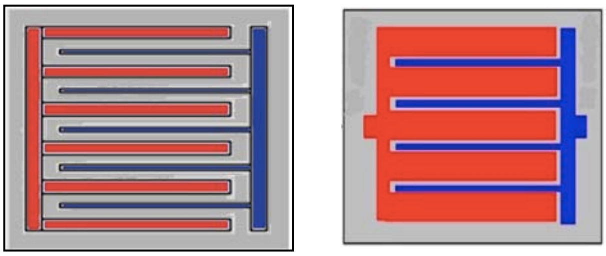


Fig. 3 LIV response of three IBC solar cells following alkaline wet-chemical etching.

The IBC solar cells fabricated above had low emitter coverage fraction of about 30%. The base area coverage was 20% with high compensate region of 50%. The compensate region is defined as the exposed region between the emitter and base contact regions which is n$^+$-doped and is etched off to create electrical separation. The high compensate region was designed in order to accommodate low-resolution and alignment capability of the semi-automatic screen printer. Clearly this is not an optimum design geometry for the IBC solar cell due to low emitter coverage [16, 17]. For example, Fig. 4 schematically illustrates emitter region (red) for lithography-based and screen-printing based IBC solar cells.



(a) (b)

Fig. 4 Schematic diagrams of the screen-printed (a) and lithography-based (b) IBC solar cells rear geometry.

The other reasons for low overall efficiency of the IBC cells fabricated is because of low lifetime wafer used. Measurement of lifetime using SPV method result minority carrier lifetime value of 4.32 µs. For decent performance of IBC solar cell, a minority carrier lifetime more than 100 µs is required [18, 19].

5. Conclusion

A simple IBC fabrication process based on conventional silicon solar cell equipment is presented. The method is based on conventional $POCl_3$ emitter, screen printed contact and wet alkaline etching process. The best cell resulted V_{oc} of 0.461V, J_{sc} of 8.42 mA/cm^2, FF of 0.523, and efficiency of 2.03%. Low overall efficiency of IBC cell fabricated are due to non-optimized cell geometry design and low lifetime starting wafer

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used. Nevertheless, the simple fabrication has demonstrated feasibility of high throughput, lithography free and simplified process. It is hope that this work would contribute toward low cost and high efficiency IBC solar cell development.

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