Several Aspects on the Optimisation of Screen Printed Si Solar Cell

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Abstract: - The dependent of the usage of petroleum to produce energy need to be reduce since the fossil fuel price is not predictable. The alternative way to generate energy need to be done to encounter this situation and solar is one of the solutions. Solar cells are used to capture the photon which is then generate the energy. However the efficiency of the cell to turn the amount of photon to electricity needs to be high. Therefore cell enhancing is needed. To enhance a cell involve the whole process developing the cell from A-Z. In this paper, only Si solar cell will be discuss and optimising this kind of cell will only be focused at back end process or the processes after wafer texturing. The process involve in back end process will be PECVD nitrate deposition, metal contact screen printing and metal paste co-firing.

Keywords: - solar cells, optimisation, high efficiency, crystalline silicon, textured

1 Introduction

The world energy demand is expected to reach 70% of what between the years 2000 and 2030 (Li \textit{et al.} (2006)). Considering the finite quantity of the fossil fuel, world attention is now moving towards identifying sources for energy supply in the future. Currently, fossil fuel supplies almost 80% of worldwide energy consumption. However, petroleum is projected to be consumed within 40 years, natural gas in 60 years, and coal in 200 years and. The world is currently facing extreme natural calamities arising from global warming caused by fossil-fuel use. There is therefore an urgent need for development of environmentally-friendly and sustainable energy technologies.

Solar is one of the options that we have. The direct conversion of sunlight into electricity is called photovoltaic (PV) which is generally based on semiconductor materials. Solar cell design involves specifying the parameters of a solar cell structure in order to maximise efficiency in a certain set of constraints (Honsberg et al, 2007). Basically, solar cells operate on two principles: (i) photo generation of charge carriers (electrons and holes) in a light-absorbing material, and (ii) Conversion of the charge carriers into electrical current collected by metallic, low-resistance conductive contacts.

Optimisation involve in this paper discussions is the second principles. This part is also involved in the few last process of the silicon solar cell development. The process start after the wafer was textured and the edge has been isolated.

2 Passivation

Process involve in this passivation is plasma-enhanced chemical vapour deposition (PECVD) for
silicon nitrate (SiNₓ) deposition. It is a high temperature process which creates 100-200 nm thick silicon nitrate. This layer serves as a single layer antireflection coating on the front surface. The layer also provides the required surface passivation on both sides, keeping the surface recombination velocity of charge carriers as low as possible. This will actually complete the semiconductor specific processes (A. Goetzberger et al (1998)).

The PECVD process is considered a low-thermal-budget process because it is usually performed at a relatively low temperature, in the range of 250-400°C. PECVD SiN is widely used in the fabrication of silicon solar cells to increase their efficiency (Chen (2008)). Figure 1 shows the schematic layer of a p-type wafer after going through PECVD process.

3 Metalizing Front and Back Contact
Front and back contact metallization can be realized by screen printing of a metal paste. Silicon wafer that usually used is p-type [100]. After the doping process the wafer is covered by n-type substrate. The rear of the cells will be applied with a layer of aluminium and alloyed into the cell at temperatures above the Si-Al eutectic. This process will produces a layer of p-type Si heavily doped with Al at the rear silicon substrate (Green, 2001).

The top contact design is one of the critical parts to deal with. The top contact typically consists of busbars and fingers. The tricky part is to design this busbars and fingers so that it is optimum enough to collect electron and also the cell surface has enough area to receive photon from the sun. Ag paste is one of the commonly used to make this top contact. Figure 2 shows the schematic diagram of various designs of screen printed silicon solar cells.

Hot-melt screen printing is a new and promising technology for solar cell contact formation (figure 3). Some of the advantages of this technology over the conventional screen-printing are the possibility of making thin front contacts with high aspect ratios and the use of inks that release significantly less contamination of volatile organic compound compare to the conventional metal pastes (Olainsen et al, 2005). This method may also reduce investment cost since no drier required after the printing process since the pastes solidify just after the solar cell is removed from the printing station.

To date, researches were done in metallization. As an example, consider the experiment work reported by J. Lee, (et. al, 2008) in which lead-free aluminium paste (Ferro 53-102) was used for about...
20 ± 2µm thickness for the rear surface while for the front surface, silver paste (Ferro 33-462) was used. Sufficient oxygen gas was introduced during the co-firing process in conjunction with rapid cooling to complete the co-firing cycle. This approach managed to eliminate the aluminium ball generation during the firing process. In this experiment, optimised temperature profile was in 500-700-832-913 °C range for the four zones of the belt furnace. The belt speed was 155 inches per minutes. Figure 4 shows a comparison of the performance parameters (efficiency, fill factor, $I_{sc}$ and $V_{oc}$) from J. Lee’s study.

4 Present Work
Current research has been done by using 6” p-type Si wafer [100]. After the doping process the cell has been through the passivation process. In this process a layer of SiN has been created about 105-200 nm. For metallization process, Ferro AG (33-462) has been used for the front contact while Ferro Al (53-038) has been used for the back contact. The cell is then fired with the temperature profile from 400-900 °C with 5 zones. After the cell has been tested, it was found out that the fill factor is 56.71 with 0.58V of $V_{oc}$ and 4.95A of $I_{sc}$. The IV curve is shown in figure 5 below.

Further research is still going on in order to improve and optimise the cell.

5 Conclusions
As mention by Lin in 2008, the design of the top contact involves not only the minimization of the finger and bus bar resistance, but also the overall reduction of losses associated with the top contact. These include resistive losses in the emitter, resistive losses in the metal top contact and shading losses. In J. Lee’s experiment, the silver metal coverage is about 7% of cell top surface with metal thickness was thicker than 15µm. The width of the metal line was smaller, so relatively this provides significant cross-sectional area of the finger line. J. Lee’s work demonstrates that their method manage to achieve cell efficiency of 17.12%. Other than metallization process, passivation process with
nitrate deposition may also help to improve the solar cell efficiency.

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