Effect of Different Lamination Temperature on the Quality of Solar Module

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Abstract:- This work is to determine the most suitable temperature for the small scale solar module. The main problem most of the industry face when they did laminate solar module is that the appearance of bubbles in the module. We use a small scale solar module as our sample and test it on bottom side heat source (BSHS) and upper side heat source (USHS) laminator. Initially we start by using a high temperature and we gradually decrease the temperature until there almost no more bubbles within the modules. The solar cell module appeared free of bubbles when the lamination temperature was set to 133^{o}C. The appearance of the module is still fine even after repeat the processes by using the same temperature.

Key-Words:- BSHS and USHS laminator, EVA, TPT, crystalline silicon solar cells

1 Introduction

It is very common nowadays that people are now seeking for renewable energy in order to replace the current fossil fuels. This is due to the extinction of fossil fuel in the beneath surface of the earth and people cannot depend to it forever. One of the most potential renewable energy found is solar energy. Solar energy is the radiant heat and light from the sun that has been used by humans since ancient times using a wide range of technologies.

One of the wide applications of solar energy is photovoltaic (PV). PV is the field of technology and research related to the application of solar cells for energy by converting sunlight directly into electricity. On the other hand, a solar cell or photovoltaic cell is a device that converts sunlight directly into electricity by the photovoltaic effect. The term solar cell is specially utilized to capture energy from sunlight, while the term photovoltaic cell is used when the light source is unknown. Solar panels, solar modules, or photovoltaic arrays are made by assemblies of solar cells.

In Malaysia, there was 4 type of solar panels was studied such as mono-crystalline silicon, multi-crystalline silicon, amorphous silicon and copper–indium–diselenide (CIS) solar panels (Nowshad et al. 2009)

The most important aspect in producing good solar cells is fabrication processes. One of that processes to completing solar cell module is lamination. Solar cell lamination is heating the solar cells with adhesive material so that solar cell can stick with cover outside of the solar cell such as glass. The lamination process is purposely to protect the outside surface of solar cells. In fact, lamination is one of the crucial steps before it become the final product of the solar cell module and panel because it will effect the appearance and the performance of the solar cells. The scope of this paper is to determine the most suitable lamination temperature so that will provide free-defections within solar cell module.

2 The Lamination Processes

Before starting lamination processes, the first step is to stack some materials at the upper and lower side of the solar cell before it can become solar module. Solar cell that will be use for this lamination is crystalline silicon solar cells. Usually, the upper side or the first layer of the solar module is made from glass and then followed by Ethylene Vinyl Acetate (EVA) as the second layer. EVA is the adhesive sheet which is melt in certain high temperature and act as an adhesive material between the glass and solar cell. Then for the lower side of the solar cells is also covered by EVA. But for the next layer which is also the lowest side of the module cell is made from Tedlar-Polystester-Tedlar (TPT) instead of glass. This is because TPT functioning as to resist heat and thus protecting the lower side of the cells. The dimensions of this module is 20.5cm x 20.5 cm. Figure 1 shows all the layers needed to built the solar module.

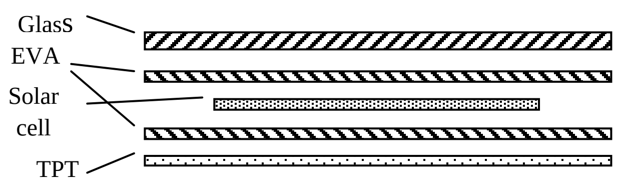

Fig. 1 The layers of the solar module

The experiment was carried out by using laminator at the Gratings Incorporated’s laboratory. Figure 2 shows two laminators used for this test. Bottom side heat source (BSHS) laminator is automatic and manual laminators which use the heat source from the coil that come from bottom side of the lamination chamber. This laminator need to use a vacuum pump to reduce air and holding the solar module during heating. It also has the silicon sheets at the top side of the lamination chamber and it use to put some pressure when the vacuum pump is on. It is also able to withstand the high temperature and prevent heat from leaking to the outside of the lamination chamber.

Meanwhile upper side heat source (USHS) laminator has similar characteristic with BSHS laminator but the only difference is that heat source was located at top side of the lamination chamber and silicon sheet was at down side of the lamination chamber. And USHS laminator only operates by using manual mode. It is interesting to see whether the location of the heat source has a significant effect on the quality of the solar module.

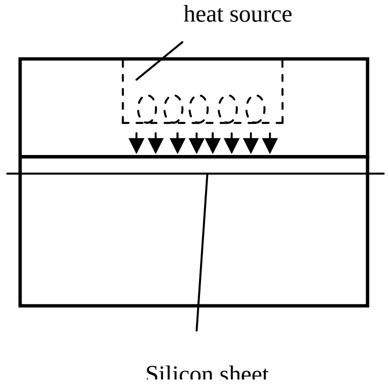

Fig. 2 (a) Schematic diagram of USHS Laminator

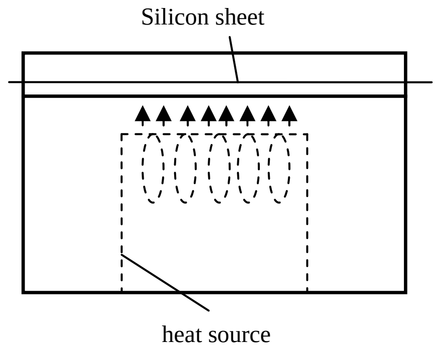

Fig. 2 (b) Schematic diagram of BSHS Laminator

Before starting using laminator, there are some procedures that need to be followed. It is to make sure that all machines operate in a safety precaution. Below are the steps on how to operate the laminator machine:

i. Prepare the layers of solar module
ii. Cover the top and bottom side of the module using Non-Sticky Polymer Sheet (NSPS) so that the module will not stick to the lamination chamber
iii. Set the desired temperatures of the laminator and wait until it reach to those temperatures
iv. After it is already heat up to desire temperatures, open up the upper laminator chamber
v. Put the module in the lamination chamber
vi. Close down the upper chamber
vii. Wait until 20 minutes.
viii. Open up the upper lamination chamber.
ix. Pull out the modules using safety gloves.
x. Put the module at the outside at ambient temperature and wait until it cool down.
xi. Take off NSPS from the module once it is already cool.

During heating, there is a heat transfer mechanism involved which mainly conduction. Heat form down side is going upward and through the layers

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of the solar module. This module will be heated at certain temperature and it will continue until all EVA was melted within the solar cells. Figure 4 shows how the heats transfer through the layers of solar module in one direction only.

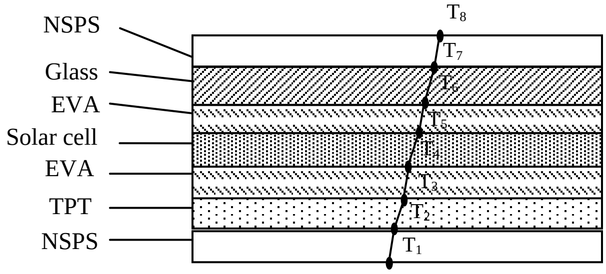

Fig. 3 heat resistance in the solar module

So for the heat transfer rate, $\dot{Q}$ in this solar module is:

$$\dot{Q} = \frac{T_1 - T_8}{R_{Total}}$$

Where the total thermal resistance R_{Total} are:

$$R_{Total} = R_n + R_g + R_{EVA} + R_c + R_{EVA} + R_{TPT} + R_n$$

$$R_{Total} = \frac{1}{k_n A} + \frac{1}{k_g A} + \frac{1}{k_{EVA} A} + \frac{1}{k_c A} + \frac{1}{k_{EVA} A} + \frac{1}{k_{TPT} A} + \frac{1}{k_n A}$$

Where,

A	= Area of the solar module
R_n	= Thermal resistance of NSPS
R_g	= Thermal resistance of glass
R_{EVA}	= Thermal resistance of EVA
R_c	= Thermal resistance of solar cell
R_{TPT}	= Thermal resistance of TPT
k_n	= Thermal conductivity of NSPS
k_g	= Thermal conductivity of glass
k_{EVA}	= Thermal conductivity of EVA
k_c	= Thermal conductivity of solar cell
k_{TPT}	= Thermal conductivity of TPT

3 Results and Observation

One of the main defects that would occur after lamination of solar module is appearance of bubbles around the solar cells. Bubbles are one thing that happens in the solar cells module if EVA is not melted at the suitable temperature. It is hard to control the appearance of bubbles if we do not know the most appropriate temperature of the lamination. Thus, we set the initial temperature as high as possible. Then we studied the appearance of bubbles and then we decrease the temperature gradually. This process will continue until we find no more bubbles appear in the solar cells module. For the heating duration, we set it as constant through out the experiment.

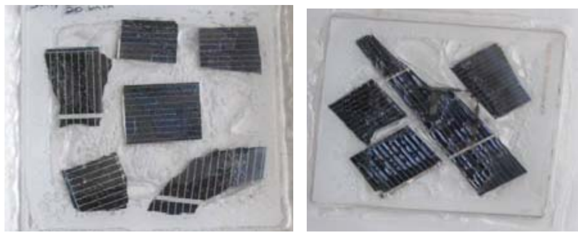

Fig. 4 (a) USHS Laminator results Temperature 350^{o}C, heating duration 20 minutes

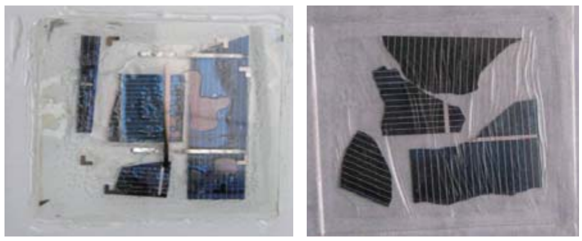

Fig. 4 (b) USHS Laminator results Temperature 325^{o}C, heating duration 20 minutes

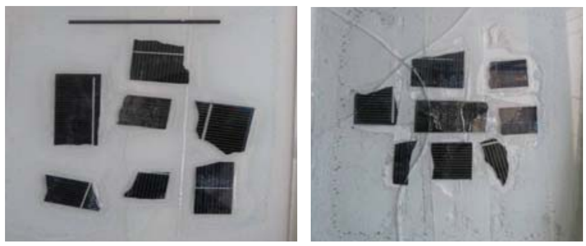

Fig. 4 (c) USHS Laminator results Temperature 250^{o}C, heating duration 20 minutes.

As we can see in Figure 4 (a), we placed two solar modules in the lamination chamber of USHS laminator which heat from the upside of the lamination chamber. We placed the first sample first and after it been laminated, we then followed by the second sample. This is to observe whether the first is consistent with the second sample. For our first experiment, we heat them up at 350^{o}C and heating duration is about 20 minutes. At the end of the results, we found that many bubbles appear within both modules. Then we decrease the temperature to 325^{o}C with the same heating duration (Fig 4 (b)). There is not much of a difference from the previous modules because there is still a numerous of bubbles in the modules. Then we decrease again lamination temperature to 250^{o}C

(Fig 4 (c)) and we notice that the appearance of bubbles is still the same with the previous test that has been done. This caused by unstable heating that may happen in this kind of laminator and we decided to take a look at the BSHS laminator whether it will yield the same results.

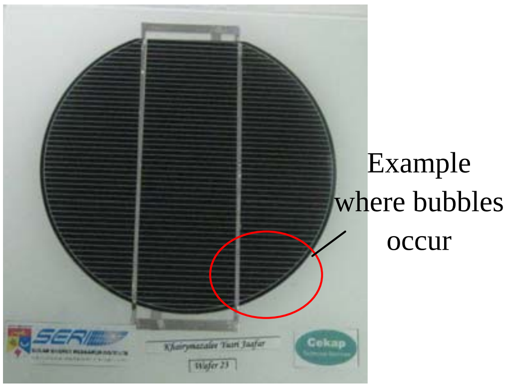

Fig. 5 Sample of solar module

Fig. 6 (a) Temperature 146^{o}C, Heating duration 20 minutes

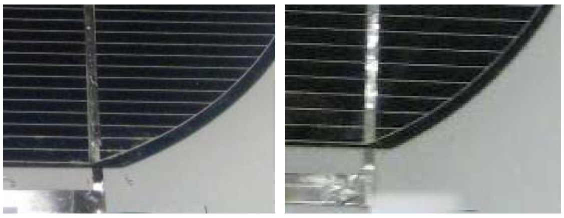

Fig. 6 (b) Temperature 135^{o}C, Heating duration 20 minutes

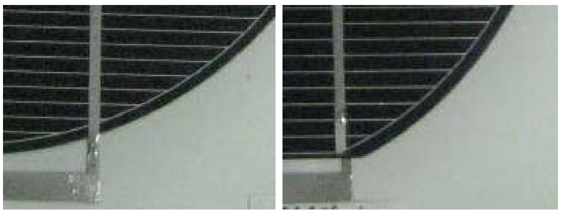

Fig. 6 (c) Temperature 133^{o}C, Heating duration 20 minutes.

For the sake of this test, we will focus on one portion of the module as shown in Figure 5. Firstly, we set the temperature to 146^{o}C and heating duration about 20 minutes. For the first sample, we observed that the bubbles still happen within modules but the difference is the bubbles is much smaller compare to results from USHS laminator. But for the second sample, it was getting worsen as the bubbles appeared more compare to the first sample (Fig. 6(a)). Because of that, we decreased the temperature to 135^{o}C and as a results, the number of bubbles in the modules was decreased enormously. But there is still some bubbles in particular area of the sample. The second sample also yields the same results (Fig. 6 (b)). Then, we decreased the temperature again to 133^{o}C and as expected we managed to improve the appearance of the first and second sample. In fact, there was almost no bubble displayed on the sample as we can see in Figure 6 (c).

Thus, the most important finding in this study is that the best temperature for this kind of solar module lamination is 133^{o}C. it also turn out that BSHS laminator will yield better and consistent results compare to USHS laminator. We also found that the lower the temperature, the appearance of bubbles is also decreased. The causes of the bubbles are mainly due to too much heat that was exerted by the EVA and it traps the excessive air within the modules. The EVA cannot be melted too quickly because it will create some space for air to infiltrate and create bubbles once it cools down. So a slower melting of EVA will reduce the time for creation of bubbles and then it will solidify uniformly.

4 Conclusion

It is important to make sure that the lamination of solar module is good and have almost zero defects once it came out from the lamination chamber. Despite to retain its aesthetic value, it is also to avoid some inefficiency that may occur once it put on the test. This work has provided some good solution to find a suitable temperature for solar module lamination. As the result, we regard BSHS laminator as the better laminator and the best temperature is 133^{o}C for lamination. For the future research, it is recommended that to laminate a bigger scale module to see whether the temperature will vary with this work.

Acknowledgement

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