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Large Area LBIC Measurement System for Thin Film Photovoltaic Modules

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Abstract

A laser beam induced current system has been developed for large area thin film technology. Employing a non-destructive laser scanning approach, such a system is used as a characterisation tool that is able to perform local performance investigation and allows efficient defect detection in large scale devices. In this paper, the results are shown for large area single junction amorphous silicon modules. The scanning images reveal an inhomogeneous current signal. Cross-section analysis illustrates that in some modules, there is considerable performance variation between cells. Certain cells are nearly or completely inactive. Interconnection problems, tiny cracks and defects that cannot be detected by visual inspection can also be identified.

Keywords: LBIC, module, characterisation, a-Si

1. Introduction

Thin-film modules are produced as a single entity and not as the conventional cells being made up of pre-tested smaller units. Thus, the quality of an entire module is a crucial issue for the performance of such devices. One bad spot on a plate can deteriorate the photovoltaic (PV) performance of the module significantly. Thin film devices are produced on large areas and have large numbers of cells connected in series as part of the process. There are normally only two terminals available for connection to external circuits in an encapsulated commercial module, which makes characterisation extremely difficult.

It has been observed that certain small areas containing defects can cause the performance of the whole module to decrease. In order to investigate such losses, the conventional tools that illustrate the performance of PV devices, i.e. solar simulator measurements of the current-voltage (I-V) characteristic, are thus not sufficient to fully characterise various thin film technologies. Thus, a spatially resolved measurement process is needed. This can be done by thermographic or optical scanning. Thermography in our case has the disadvantage that it works only to a limited extent through glass and hence optical scanning is chosen.

A laser beam induced current (LBIC) system has been developed for application to large, multi-cell solar modules. LBIC systems are not uncommon, with small scale LBIC measurements commercially available [1]. The custom made systems found in certain research groups mostly work on laboratory size devices (of a few cm²), a single separated cell of mono- or multicrystalline silicon or polycrystalline (CdTe, CIGS) mini modules [2, 3]. It is, however, rarely found in large scale, module-size thin film applications, as the problems of signal recovery are significant.

This paper presents the scanning results of commercial size, single-junction amorphous silicon (a-Si) modules. The results show the current signal maps for both cells and modules. We demonstrate the ability to detect cracks in the module, inhomogeneous deposition as well as some contacting problems and otherwise weak module characteristics.
2. Experimental Details

The LBIC system uses a laser scanner to map the photocurrent signal of the entire PV module. System structure is made up of aluminium frame, providing a stable platform and externally covered by PVC sheets to eliminate glare and for safety reasons. A Helium-Neon laser with a wavelength of 632.8 nm, 5 mW is currently installed.

The laser beam is then guided by SCANgine 14 and varioSCAN20 both made by Scanlab. The former is a galvanic mirror deflecting the laser beam in the x-y directions while the latter is a focusing system, focusing the laser beam on the working surface. They are fixed next to the laser 2000 mm above the sample allowing a two dimension control of the laser focus and guiding it to different points on a sample. These instruments are connected to a control PC via an RTC3 interface card and controlled by custom made software implemented in LabView. The RTC3 card, also made by Scanlab, provides a real time and interference-resistance control of scan systems and lasers. More detail about system components and schematic diagram can be found in the references [4].

The measurement is carried out using a lock-in amplifier. It allows the measurement of small signals (laser-induced photocurrent in this case) as a function of position, even when they are in a high noise condition by using phase sensitive detection. By doing this, the lock-in amplifier needs an AC signal which is achieved by chopping the laser beam at specific frequencies (500 Hz for the results shown in this paper), then a phase and frequency sensitive AC signal analyser extracts a required signal corresponding to the reference phase and frequency.

The LBIC system is also equipped with an array of halogen lamps working as background illumination to provide a measurement in different illuminated conditions. With a chamber floor area of 1.5 m$^2$, it can allow PV modules up to 1.2 m$^2$ to be investigated. The system generates the 2 dimensional scan of current signal of the sample with a resolution on the order of sub-millimeter.

3. Results and Discussion

Measurements were taken on single junction a-Si modules with dimensions of 0.3 m x 1.0 m and 28 cells connected in series along the length. The scanning images presented here are not to scale; however they display the whole module area unless otherwise stated. About 95,000 measurement points were taken per module with 500 points down the length of the module and 190 points across the width.

3.1 Non-uniform photocurrent

The scanning results reveal several possibilities of sources that can be attributed to performance and efficiency losses of PV devices. One of those is exhibited by a PV module with a non-uniform photocurrent signal as shown in Figure 1.

Figure 1a) shows a 3-dimensional plot of the scanning result made by LBIC, where the x-y plane represents the width and length of the module while z axis is the magnitude of the photocurrent signal normalised to maximum value. The area where the signal is weak spreads over the module, shown in the bright colour indicated by the rectangle. Figure 1b) illustrates a slice along z axis by cutting off the photocurrent signal below 0.7 of the same module. It is more obvious in this figure that area in rectangle has signal less than 0.7 and covers almost every cell in this module. This is believed to be caused by unstable conditions during material deposition.

Due to large area thin film PV devices being manufactured by deposition process, the conditions during processing are crucial. Any small change of these e.g. pressure, gas flow rate, temperature etc, can lead to non-uniform deposition and as a consequence the final device may suffer from reduced absorption in certain areas and the efficiency of the device is severely reduced.
Figure 1 The scanning result illustrates the non-uniform photocurrent signal, covering all of the cells in the module.  a) 3D plot where the x-y plane is the width and length of the module while z axis is the strength of current signal normalised to maximum, the area within the rectangle shows where the photocurrent signal is weak, b) the slice of z axis with normalised photocurrent signal less than 0.7 is cut off, clearly revealing the weak area.

3.2 Cross-section of scanning results

Figure 2 The cross-section of scanning results of two identical a-Si modules, showing variation of photocurrent signal (Z axis) from cell to cell: a) relatively weak current signal in the left circle and two cells that nearly and completely failed, second and fourth cell from the right, respectively in the right circle, b) the cell indicated by the arrow is completely inactive.
The scanning results of two modules are presented in cross-section, showing the current signal (Z axis) of each cell in the module. Although both modules are identical in configuration and size and they were produced as part of an identical batch, there is a considerable variation of photocurrent signal between cells, particularly in Figure 2a). The figure also reveals two relatively poor areas. In the left circle, there are 4-5 cells of relatively low current signal. In the right circle the second cell from the right is nearly inactive while the fourth cell has completely failed.

Compared to Figure 2a, every cell in Figure 2b seems to generate a uniform photocurrent. However, this module consists of 28 cells connected in series. Without LBIC, one cannot detect the defect at the top edge of the device. In this figure, the length of Y is only 30 cm. The area in the circle was produced as part of an identical batch, there is a considerable variation of photocurrent signal between cells, particularly in Figure 2a). The figure also reveals two relatively poor areas. In the left circle, there are 4-5 cells of relatively low current signal. In the right circle the second cell from the right is nearly inactive while the fourth cell has completely failed.

3.3 Defect detection

![Figure 3](image)

Figure 3 The scanning result shows the presence of a defect about 1 cm², covering 3 cells; a) the defect is shown in the circle and does not generate photocurrent, b) magnified view of a)

Another result from the LBIC system is shown in Figure 3. Figure 3a) reveals a small defect at the top edge of the device. In this figure, the length of Y is only 30 cm. The area in the circle is magnified in b) showing that there is an inactive area covering 3 cells and is about 1 cm in length. This represents an efficiency loss of this particular module of 3.3% of the module. Since cells in such devices are connected in series, poor cells with defects generating lower photocurrent will limit the current of the overall device and thus deteriorate the whole module performance.

The cause of this type of defect is probably in the cell separation. Since thin film PV devices are generally deposited on a large area, cell separation is needed. This can be done by a laser scribing process. Although such processing is computer controlled, some error can still occur i.e. under or over cutting. As a consequence, incomplete laser scribing on some area may cause defects as can be seen in Figure 3.
3.4 Cracks and damages detection

In the case of post-outdoor installation, LBIC is capable of efficiently identifying cracks or damage that may hardly be detected by visual inspection. Such damage may be attributed to two causes; 1) due to accidentally damage (dropping of devices), 2) due to the installation i.e. mechanical force to the frame, or vibration stresses such as wind-loading.

The damaged a-Si module is scanned by the LBIC system and the result shows that there is a major crack across the middle of the module. Tiny cracks, not visible to the naked eye, are also identified, as can be seen in the middle left of Figure 4. The figure shows that although the module is broken, there are some areas where it can still generate electricity, but not at full capacity. The redder area shows higher photocurrent while bluer area shows smaller photocurrent. The area to the bottom left corner of the module has completely failed.

4. Conclusion

The CREST large area LBIC system has been introduced. The scanning results show the photocurrent generation variation, material defect and mechanical damage detection on single junction a-Si modules. The analysis of such results leads to a local performance investigation thus allowing the improvement of production processes to maintain a high quality device. These have proved that the LBIC system is an efficient characterisation tool for large area thin film technology that could be used both for in-line quality control and for post-installed module performance investigation.

References


