ABSTRACT

This study originated from an evaluation of the performance of a commercially available high concentration point focus concentrator PV system. The effect of module design flaws was studied by using current-voltage (*I-V*) curves obtained from each module in the array. The position of reverse bias steps revealed the severity of mismatch in a string of series-connected cells. By understanding the effects of the various types of mismatch, power losses and damage to the solar cells resulting from hot spot formation can be minimized and several recommendations for improving the basic performance of similar systems were made.

Concern over the extent and type of defect failure of the concentrator photovoltaic (CPV) cells prompted an investigation into the use of a light beam induced current (LBIC) technique to investigate the spatial distribution of defects. An overview of current and developing LBIC techniques revealed that the original standard LBIC techniques have found widespread application, and that far-reaching and important developments of the technique have taken place over the years. These developments are driven by natural progression as well as the availability of newly developed advanced measurement equipment. Several techniques such as Lock-in Thermography and the use of infrared cameras have developed as complementary techniques to advanced LBIC techniques. As an accurate contactless evaluation tool that is able to image spatially distributed defects in cell material, the basis of this method seemed promising for the evaluation of concentrator cells.

The theory of the interaction of light with a solar cell was investigated. Factors that affect the efficient operation of solar cells were identified and their influence at high photon flux densities and changing cell biases discussed. The use of a beam of narrowly focused monochromatic or concentrated solar light as an LBIC beam probe was also dealt with. The interactions of the beam with the different parts of a solar cell structure were also discussed.

In order to study the effects of mismatch on concentrator cells, a test platform based on the LBIC technique was designed. The limitations of the standard LBIC technique lead to the development of a novel Solar Light Beam Induced Current (S-LBIC) technique that was incorporated into the test platform. Practical limitations were found when using a concentrated solar beam to perform S-LBIC scans. Measurement precautions also had to be taken into account when dynamically applying an alternating voltage to a solar cell. Steps that were taken to limit these effects were found and discussed.

The biasing of the cell from reverse bias to beyond the open circuit voltage while it was scanned by a beam of full spectrum concentrated solar light created opportunities to study the spatial distribution of typical bias dependant loss mechanisms in partially saturated photovoltaic cells. S-LBIC results obtained from a flat plate cell demonstrate that the defects scanned by the system yielded a signal response that more closely resembles the electrical behaviour of defects under full spectrum outdoor solar radiation. This statement was verified by comparing the results from the S-LBIC system with results obtained by using a high intensity He-Ne laser as a beam probe.

The biasing and scanning of flat plate multi-crystalline and EFG Si solar cells with full spectrum solar radiation, revealed that the grain boundaries are visible even under high carrier saturation conditions. The induced current response from certain grain boundaries seems also to be bias independent. Results of S-LBIC scans on one of the point-contact concentrator Si cells revealed that no material related defects or degradation occurred.

The *I-V* data of a cell were extracted from the measured bias dependence of the S-LBIC data. A basic one-diode model was developed and used to programmatically fit cell parameters to the extracted *I-V* data for each scanned point. Although the extracted cell characteristics are not directly quantifiable, the results from the fitted *I-V* characteristics show that the relative values obtained for R_{shunt} and R_{series} give a useful impression of the spatial distribution of these parasitic resistances. It was found that erroneous conclusions are made as to the relative impact and distribution of these parasitic resistances when simply mapping the shunt and series slopes obtained from the measured *I-V* curves. Trends and features that would normally not be visible by using the measurements from standard LBIC techniques are highlighted by using the newly developed parameter fitting technique. This curve fitting and parameter extraction procedure proved to be a valuable complementary technique to the newly developed S-LBIC technique.

Keywords: Photovoltaic concentrator cells, Solar Light Beam Induced Current (S-LBIC), Bias dependant induced current maps.