Contribution ID: **90** Type: **Oral Presentations**

Characterisation of Defects in Photovoltaic modules using Electroluminescence and Large-Area Light Beam Induced Current (LA-LBIC) techniques

Thursday, 7 May 2015 12:00 (20 minutes)

1. Introduction
   The performance and longevity of photovoltaic (PV) modules can be severely limited by poor material, manufacturing defects and physical cracks. Cell mismatch can occur when a solar cell in a series-connected string produces a lower current than the other cells in that string[1]. The current output of the entire string is limited by the weakest cell in the string so damage to a single cell in a module can affect the entire module's current output. These material defects are not always identifiable in visual inspection so additional characterisation techniques are necessary.
   In this study Electroluminescence (EL) imaging and Large-Area Light Beam Induced Current (LA-LBIC) measurements were used. EL is an effective, fast and non-destructive characterisation technique for PV modules and is widely used in PV module manufacturing to assess the quality of the finished module[2, 3]. The EL emitted under forward bias is related to the recombination, optical and resistive properties of the cell. LA-LBIC is also a non-destructive spatial characterisation tool capable of measuring the photo-response of PV modules[4]. The PV module is spot-illuminated using a light source mounted above the module on a motorised x-y scanning stage. At each point the current output of the module is measured at a set voltage level. This provides a photo-response map of the PV module related to the wavelength of the light source used.
2. Results
   Figure 1 shows an EL image of a mono-crystalline silicon module with striation rings visible as a dark circle in the centre of the cell. In this region of the cell the presence of oxygen precipitates results in the recombination of electron hole pairs. This defect occurs during the wafer growth stage and affects the efficiency of the cell and will lower the module efficiency. However, it is not regarded as a module failure. The corresponding LA-LBIC photo-response map is shown in figure 2. The striation ring is visible in the centre of the cell as an area of decreased photo-response. LA-LBIC and EL measurements have shown good agreement in measurement results and the two techniques have proved complementarity in PV module characterisation.

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Session Classification: Presentations

Track Classification: SACPM