Correlations in Characteristic Data of Concentrator Photovoltaics

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Introduction

- This study is motivated by reports of immediate on-sun degradation or failure in concentrator photovoltaic cell assemblies for ~1% parts.
- Over 500 bare III-V multi-junction cells were initially characterized, put on-sun, and evaluated.
- Correlations between initial characterization and immediate degradation are discussed.

Procedures

- Light and dark current-voltage traces (IV) and EL images were recorded for over 500 bare cells before packaging. High and low pass filters are used to image GaInP and GaAs junctions.
- IR images were taken of cells lacking adequate EL emission (at 50mA).
- Bare cells were then packaged into receiver assemblies and the voltage response at 10mA was recorded (Figure 1).
- Cell assemblies were fit into modules and exposed to outdoor solar stress of at least 750DNI for a minimum of 4 hours.
- Voltage response at 10mA was also recorded after exposure.

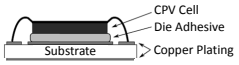

Figure 1. Cross sectional diagram of CPV receiver

Results - Initial IV and cell change due to on-sun exposure

Representative bare cell dark IV curves are presented in Figure 2. Current data at 1.5V bias is plotted against the change in voltage (recorded at 10mA) between pre and post on-sun exposure (Figure 3). This produces a distribution of points comparing the cells' initial IV condition to the change after solar stress.

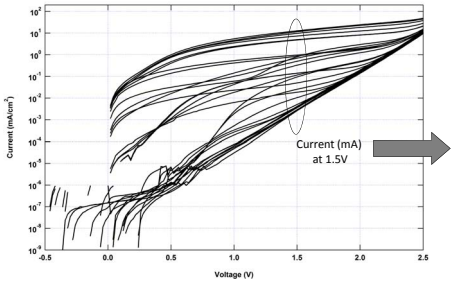

Figure 2. Initial Bare cell dark IV plots of several samples tested. Current information at 1.5V is recorded for comparison.

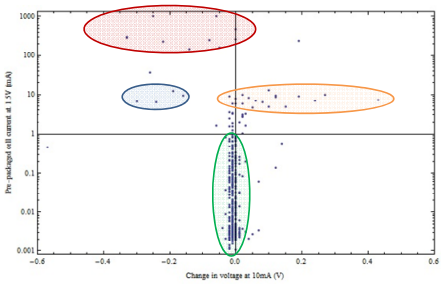

Figure 3. Current (mA) data from bare cell dark IV traces at 1.5V is plotted with the change in packaged cell voltage response to 10mA due to solar exposure.

Approximately 500 bare cells are shown in a current point plot (Figure 3). Areas of the graph are highlighted for further review. Highlighted colors correspond to graphs and images throughout this poster.

The majority of all cells showed an initial response of less than 1mA at 1.5V (highlighted in green, Figure 3). These cells experience minimal change due to solar exposure, with a voltage change between -0.04V and 0.04V at 10mA, if any.

Cells with pre-exposure IV tests above 100mA (at 1.5V) are severely shunted. These cells, highlighted in red, had no detectable electroluminescence emission.

The region between 1mA and ~10mA includes a large number of cells that experience positive change where Vf>Vi, highlighted in orange, or negative change Vf<Vi, highlighted in blue (Figure 3).

Analysis of light IV curves suggest that the change in cell response is primarily due to a change in shunt resistance, while negative or positive change corresponds to a decrease or increase, respectively. It is suspected that all cells in the orange highlighted region experienced shunt improvement due to solar exposure.

Results - Initial IV, EL and cell change correlations

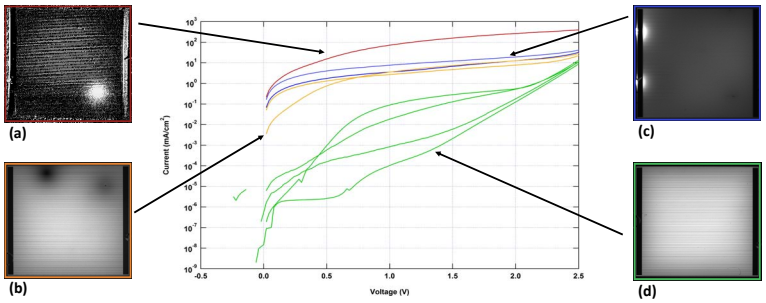

Figure 4. Initial bare cell dark IV trace curves are plotted on log scale for various cells that reside in highlighted regions of Figure 3. Each unfiltered EL image is representative of a typical cell in each region. Colors correspond accord-

All cells in the red region of the current point plot (Figure 3) are shunted and did not sufficiently emit at 50mA for EL imaging. An IR image of a severely shunted cell shows the shunt location where high current density produces excess heat (Figure 4a). The shunt location varies from cell to cell in this region.

Samples in the orange highlighted region have two distant dark IV shapes (shown in orange, Figure 4) with some variation in the EL images artifacts. An example of such is shown in Figure 4b.

All samples in the blue region of the current point plot (Figure 3) have a shunt that produces an EL image with bright spots on the edge of the cell near the bus bar (Figure 4c). This is due to manufacture probe damage for all cells in this region. Additionally, all cells share a similar IV shape as in the blue dark IV curve (Figure 4).

Cells in the lower current point IV range experience minimal change due to solar exposure (green region, Figure 3) and produce clean initial bare cell EL images (Figure 4d).

Results - Filtered EL Images

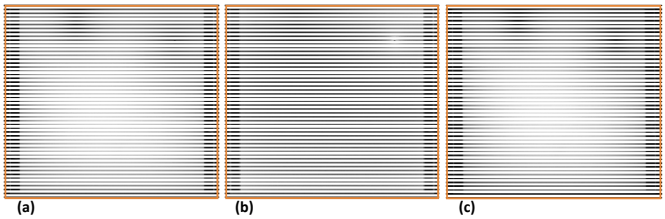

Figure 5. Initial bare cell images of one cell unfiltered (a) that display two types of artifacts seen in multiple cells in the orange highlighted region of Figure 3. Low and high pass filters are used to obtain images of the GaInP (b) and GaAs (c) junctions.

Shunts primarily affecting the GaAs layer may appear as a bright spot in the GaInP layer (Figure 5b) with a corresponding dark area in GaAs layer (Figure 5c). The bright spot is due to current crowding in the GaInP area adjacent to the GaAs shunt. Greater shunting in the GaAs compared to GaInP layer is confirmed by analysis of filtered light IV curves.

Conclusions

A large majority of cells that experienced change due to immediate solar exposure, tested above 1mA at 1.5V in current-voltage bare cell analysis before packaging and solar exposure. Functional cells experiencing change due to exposure predominantly show ~10mA response at 1.5V in bare cell IV tests.

Correlations exist between the initial dark IV characteristic and artifacts found in the bare cell EL images. Results suggest that artifacts observed in the bare cell may serve as an indicator for early on-sun degradation. It is suspected cells experiencing short term change due to solar stress may be correlated to a change in shunt resistance.