The influence of optical materials on the performance of concentrated Triple Junction Cells used in H-CPV modules.
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Outline:

- H-CPV technology.
- Current generation from CTJ cells.
- Mechanical Reduction.
- Optical Reduction.
- Conclusion.
Introduction:

- Multijunction (MJ) cells comprise of a number of monolithically grown subcells.
- Offer a better absorption of energy from a wider solar spectral range than that of conventional PV cells.
- Ideal for concentrator systems.

<table>
<thead>
<tr>
<th></th>
<th>Si</th>
<th>CTJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Density</td>
<td>20.89 mA/cm^2</td>
<td>13.10 mA/cm^2</td>
</tr>
<tr>
<td>Voltage</td>
<td>0.6 V</td>
<td>2.61 V</td>
</tr>
<tr>
<td>Power</td>
<td>9.28 mW</td>
<td>31.40 mW</td>
</tr>
<tr>
<td>Efficiency</td>
<td>15.21%</td>
<td>31.42%</td>
</tr>
</tbody>
</table>
Identification of the Influence of the Optics:

**Current Generation:**

\[ J_{sc} = \frac{I_{sc}}{A} = \int R(\lambda) \phi_i(\lambda) d\lambda. \]

**Device Influence:**
- Semiconductor material.
  - Spectral response
  - Temperature

**Optical Influence:**
- Spectral content.
  - Absorption
- Receiver Area.
  - Intensity distribution
Identification of the Influence of the Optics:

\[ J_{sc} = X_o \cdot \min \left\{ \int S(\lambda_n) \cdot \Phi_i(\lambda_n) \right\} \quad n = 1, 2, 3 \ldots \]

\[ V_{oc} = \sum \frac{kT}{q} \ln \left( \frac{C \cdot I_{scn}}{I_{0n}} \right) \quad n = 1, 2, 3 \ldots \]

\[ \eta_c = \frac{P_{out}}{P_{in}} \times 100 = \frac{V_{max} \cdot I_{max}}{X_o \cdot I_{rd} \cdot A} \times 100 \]
Influence of Optical Concentration:

Combined intensity profile of $336X_0$ concentrated sunlight on a CTJ cell.
Mechanical Misalignment:

- Secondary Misalignment
- Primary Lens Misalignment
- CTJ cell Unit Misalignment

Current (Å)

Voltage (V)
Spectral Absorption:

- Average transmission of 85%.
- Gross current production from the Ge subcell.

InGaP subcell is the most affected.
Spectral Change:

<table>
<thead>
<tr>
<th>Time (h)</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>InGaP (mA/cm²)</td>
<td>6.60</td>
<td>8.82</td>
<td>8.45</td>
<td>9.91</td>
<td>10.45</td>
<td>10.22</td>
<td>9.51</td>
<td>8.89</td>
</tr>
<tr>
<td>InGaAs (mA/cm²)</td>
<td>11.22</td>
<td>11.23</td>
<td>11.46</td>
<td>11.50</td>
<td>11.51</td>
<td>11.48</td>
<td>11.43</td>
<td>11.33</td>
</tr>
<tr>
<td>Variation (%)</td>
<td>42</td>
<td>22</td>
<td>17</td>
<td>14</td>
<td>10</td>
<td>11</td>
<td>17</td>
<td>21</td>
</tr>
</tbody>
</table>
Intensity profile of each subcell taken at solar noon.
Optical Intensity Profiles:

**Chromatic Aberrations:**

InGaP

InGaAs

Ge
Chromatic Aberrations Effects:

InGaP

1.52A

2.20A

0.9A

InGaAs

0.4mA

1.56A

2.08A

1.51A
Current Mismatch:

InGaP: 4.33 Å
InGaAs: 4.90 Å
Ge: 5.49 Å

InGaP: 4.33 Å
0.90 Å
5.40 Å
4.33 Å
Cell Damage:

MISV at Stallage age:

- Non-uniform luminescence pattern of cell encapsulant.
- Corresponds to the current density pattern at 330X.
- Decrease in active cell area.
- Decrease in power density in low luminescence intensity areas.
- Could lead to deficiencies in the free carrier concentrations.
Conclusions:

- That the performance of the H-CPV module is highly dependent on the optical system.
- That the optical system can create a non-uniform intensity distribution resulting from mechanical misalignment and chromatic aberrations.
- The optical system materials reduce the concentrated spectrum unevenly within the subcell region.
- These reductions created an uneven current production from each subcell which may lead to current mismatch.
- Current mismatch lead to a decrease in performance, cell damage or complete device failure.
Acknowledgements:
References:


Intensity Distribution Measurements:

- X-Y raster scanner programmed in LabVIEW.
- Optic fibre allows for measures of the spectrum at each point.
- Creates an intensity topography for the cell area.