LOSS MECHANISMS IN HIGH-EFFICIENCY SOLAR CELLS

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Study of Material Properties and High-Efficiency Solar-Cell Performance on Material Composition: Project Tasks

(1) EFFICIENCY-LIMITING IMPURITY AND DEFECT LEVEL CHARACTERIZATION.

(2) COMPUTER MODELING OF CELL PERFORMANCE.

• (3) FUNDAMENTAL LIMITATIONS.

• (4) PRACTICAL SOLUTIONS.
  • To be discussed here.

Outline

(3) FUNDAMENTAL LIMITATIONS
  • Best Cell I-V Curve.
  • State-of-the-Art and Fundamental Limit.
  • Summary of Limiting Recombination Losses.

(4) PRACTICAL SOLUTIONS
  • Design alternatives
  • Test Structure No. 1.
HIGH-EFFICIENCY DEVICE RESEARCH

\[ I = I_L - I_m e^{\frac{qV}{mkT}} \]

or \[ = I_L - I_{SCL} \]

BEST: \( m = 1 \) or less

for \( IV = \text{max.} \)

\( J_{SC} = \text{High} \)

\( V_{OC} = \text{High} \)

1984

1985 Production 16%

--- Major Recombination loss sites:

- Interfaces: Front Contact, Back Base

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HIGH-EFFICIENCY DEVICE RESEARCH

1974 SPIRE (Spitzer) 18% N⁺P⁺⁺
1978 SANDIA 18% P⁺⁺N⁺⁺

Major Recombination Loss Sites:
Interfaces: Front Contact
Base

Green 19%

Major Recombination Loss Sites:
Interfaces: Front/Contact Eliminated
Back Contact
Base
HIGH-EFFICIENCY DEVICE RESEARCH

STATE OF THE ART AND FUNDAMENTAL LIMITED
Silicon Solar Cells

Summary of Efficiency-Limiting Mechanisms

<table>
<thead>
<tr>
<th>EFFICIENCY LIMIT</th>
<th>CURRENT STATUS</th>
<th>LIMITING MECHANISMS AND RECOMBINATION SITES</th>
<th>MAXIMUM BASE CURRENT (A/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25%</td>
<td>Most eliminate all carrier recomb. losses.</td>
<td>Interband Auger and radiative in base.</td>
<td>5.93E-15</td>
</tr>
<tr>
<td>20-24</td>
<td>Must reduce all base recomb. losses.</td>
<td>SH at traps at base and edge, all i/j interface. Use polySi barrier for contacts.</td>
<td>2.66E-15</td>
</tr>
<tr>
<td>15-20</td>
<td>Current best cell.</td>
<td>SHC at traps in base layer.</td>
<td>2.54E-15</td>
</tr>
<tr>
<td>&lt;15</td>
<td>Current best.</td>
<td>SHC at traps in both the base and emitter.</td>
<td>1.12E-12</td>
</tr>
</tbody>
</table>

Upper four theory: Ti20, n=1E10, A=1cm², 3B:50um, H=1E17, DB=20, \( \times100um, C'_{j}, C'_{i}=8-3, C'_{j}=C'_{i}^{2}, 8E-31cm^{-3} \).
Floating Emitter Solar-Cell Transistor

From