IBC c-Si(n) solar cells based on laser doping processing for selective emitter and base contacts formation

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This work report on the use of laser doping technique to create both selective emitter and base contacts using appropriate dielectric layers as dopant sources as passive layer, i.e. Al\textsubscript{2}O\textsubscript{3} and a-SiC\textsubscript{x}(n) stacks for the p\textsuperscript{+} and n\textsuperscript{+} regions respectively. A simplified fabrication process for IBC n-type c-Si solar cells is shown, combining laser doping and a conventional boron emitter passivated by Al\textsubscript{2}O\textsubscript{3} films. Very low emitter recombination currents in the ~10-50 fA/cm\textsuperscript{2} range before laser processing are reported. In addition, selective emitter contacts can be created by laser doping with recombination current densities at each contact point around 4.4 pA/cm\textsuperscript{2} in relatively low and shallow doped boron doped profiles (sheet resistance ~400\,Ω/sq). Finally, IBC solar cells, 3 cm x 3 cm device area, were fabricated combining selective laser-doped emitter and base contacts reaching efficiencies up to 20.8%.

Abstract

**IBC solar cell baseline process**
- Boron diffusion (\(T_d = 925\, ^\circ\text{C}\))
- n-type c-Si
- Emitter definition by isotropic wet etching
- Thermal Oxidation
- n-type c-Si
- Front side SiO\textsubscript{2} etching and random pyramid texturing
- Al\textsubscript{2}O\textsubscript{3}/a-SiC\textsubscript{x} both sides deposition
- Base regions defined by dry CF\textsubscript{4} etching
- Annealing 400 °C 10 min in H\textsubscript{2}/N\textsubscript{2} atmosphere
- Rear side a-SiC\textsubscript{x}(i)/a-Si(n)/a-SiC\textsubscript{x} stack deposition
- Laser processing of selective emitter and base contacts
- e-beam Ti/Al evaporation (rear side)
- Metal patterning
- Annealing 275 °C 10 min in H\textsubscript{2}/N\textsubscript{2} atmosphere

**ALD Al\textsubscript{2}O\textsubscript{3} boron emitter passivation**

<table>
<thead>
<tr>
<th>(T_d (, ^\circ\text{C}))</th>
<th>(R_{th} (, \Omega/\text{sq}))</th>
<th>(\tau_{em} (, \mu\text{s}))</th>
<th>(V_{oc} (, \text{mV}))</th>
<th>(J_{0e} (, \text{fA/cm}^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>62</td>
<td>225</td>
<td>641</td>
<td>49</td>
</tr>
<tr>
<td>950</td>
<td>119</td>
<td>408</td>
<td>666</td>
<td>21</td>
</tr>
<tr>
<td>900</td>
<td>177</td>
<td>379</td>
<td>663</td>
<td>17</td>
</tr>
<tr>
<td>850</td>
<td>411</td>
<td>1200</td>
<td>702</td>
<td>9</td>
</tr>
</tbody>
</table>

**Test Devices (Selective emitter contact characterization)**

**c-Si(n) IBC solar cell results**

<table>
<thead>
<tr>
<th>#</th>
<th>(j_e (, %)</th>
<th>(j_c (, %)</th>
<th>(J_{sc} (, \text{mA/cm}^2)</th>
<th>(V_{oc} (, \text{mV}))</th>
<th>(FF (, %))</th>
<th>Efficiency (, %)</th>
</tr>
</thead>
<tbody>
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<td>40.4</td>
<td>675.1</td>
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<td>40.1</td>
<td>673.5</td>
<td>72.2</td>
<td>19.5</td>
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<td>86</td>
<td>1.0</td>
<td>40.3</td>
<td>673.4</td>
<td>69.6</td>
<td>18.9</td>
</tr>
</tbody>
</table>

**Conclusions**

- Excellent ALD Al\textsubscript{2}O\textsubscript{3} passivated boron emitters with \(J_{0e}\)'s values in the range of 10-50 fA/cm\textsuperscript{2}.
- Al\textsubscript{2}O\textsubscript{3} films and a-SiC\textsubscript{x}(n) stacks are used as dopant sources to perform both selective emitter and base contacts by means of laser-doping technique.
- High efficiency IBC solar cell (up to ~20.8 %) has obtained by only one thermal step (boron diffusion) paving the way for obtaining a full cold process to fabricate high efficiency IBC solar cells.

**Acknowledgements**

This work has been supported in part by the Spanish Government under FPU grant (FPU13/04381) and through projects ENE2013-48629-C4-1-R and TEC2014-59736-R. It has also received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under project HERCULES (Grant agreement: 608498).

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**Legend**
- Boron Diffusion
- Al\textsubscript{2}O\textsubscript{3}
- a-SiC\textsubscript{x}
- a-SiC\textsubscript{x}(i)/a-Si(n)
- Ti/Al
- \(\varphi\text{~74 nm}\)
- \(\text{Front surface with random pyramids}\)
- \(\text{Laser spot (~1 W)}\)