Non-contacting Busbars for Advanced Cell Structures using Low Temperature Copper Paste

Don Wood, Nick Powell, Adriana Zambova, Brian Chislea, Pierre Chevalier, Caroline Boulord, Alexandre Beucher, Nicolas Zeghers, Guy Beaucarne

Izabela Kuzma-Filipek, Richard Russell, Filip Duerinckx, Jozef Szlufcik
Dow Corning Cu paste: good conductivity at low cost

Copper powder
Solder powder
Polymer

ρ = 20 – 40 μΩ cm
Combination Ag screen printing – Cu paste

- Texturing
- Emitter formation
- Junction isolation
- PECVD SiNx front
- Screen printing: Ag fingers and BB
- Screen printing: Ag fingers
- Printing rear
- Co-firing
- Screen printing: low-T Cu BB
- Cure in N₂

Wood et al., Silicon PV 2014
Energy Procedia Vol.55

- Equivalent cell performance
- No detrimental impact due to Cu presence
- Full size modules passing 1 x IEC
Cu paste can also be combined with plated cells

Front end processing

Rear metallization

Laser patterning and plating
Laser patterning and plating (only fingers)
Screen printing low-T Cu BB
Cure in N₂

- Cure at 200 to 300 °C
  temperature-sensitive structures can be preserved
- Ni silicide formation/anneal and busbar curing can be done simultaneously
Does a hybrid Cu plating – busbar printing process make sense?

**yes!**

- **Capex and maintenance**
  - No laser capacity needed for ablation of busbar area
  - Screen printer much less capital intensive than laser system
  - Fewer lasers $\rightarrow$ less maintenance

- **Expected performance**
  - Less Si – metal interface area $\rightarrow$ less recombination $\rightarrow$ higher Voc
  - Lower probability of shunting caused by laser damage

- **Interconnection**
  - Traditional soldered interconnection can be applied
  - Alternative to new, emergent but as of yet unproven interconnection technologies
### p-type PERC cells with plated fingers

**p-Cz (Ga), 156mm-sq, 180um, 1.8 Ohm-cm**

<table>
<thead>
<tr>
<th>Step</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Texturing front and polishing rear</strong></td>
</tr>
<tr>
<td><strong>POCl\textsubscript{3}</strong> target 130-140 Ohm/sq emitter + junction isolation</td>
</tr>
<tr>
<td><strong>Clean and oxidation</strong> (target 120 Ohm/sq)</td>
</tr>
<tr>
<td><strong>PECVD SiNx on the front + PECVD stack on the rear</strong></td>
</tr>
<tr>
<td><strong>Rear laser ablation, Al sputtering and co-firing</strong></td>
</tr>
<tr>
<td><strong>Front laser ablation fingers and BB</strong></td>
</tr>
<tr>
<td><strong>LIP Ni-LIP Cu-LIP Ag plating</strong></td>
</tr>
<tr>
<td><strong>Cu BB Printing</strong></td>
</tr>
<tr>
<td><strong>Full stack sintering</strong></td>
</tr>
</tbody>
</table>
Nett performance increase with Cu paste busbar

- 6 mV higher Voc thanks to floating busbar
- 0.4 % rel. decrease. Due to bleeding?
- 0.8 % abs. higher FF thanks to higher Rshunt
- 0.1 % abs. higher efficiency. All cells with Cu paste BB have eff. > 20.2 %
n-PERT cells with plated fingers

Integration flow- front -end
- TMAH SDR/polishing
- Boron diffusion- emitter
- BSG removal +Wet oxidation
- Front oxide removal
- TMAH texturing
- POCl₃ diffusion - FSF
- PSG removal +Dry oxidation
- ARC front-PECVD SiNx
- Rear PECVD SiOx

Integration flow- back-end
- Laser ablation - rear
- AISi PVD
- FG-anneal- contact formation
- Front Laser: fingers and BBs
- Front Laser: fingers only
- Ni/Cu/Ag plating
- Cu BB printing
- Contact co-sintering

n-Cz (P), 156mm-sq, 180um, 3.5 Ohm-cm
**N-PERT cells with Cu paste busbar: cell results**

### Std structure- 3BB PLATED

<table>
<thead>
<tr>
<th></th>
<th>( J_{sc} ) (mA/cm(^2))</th>
<th>( V_{oc} ) (mV)</th>
<th>FF (%)</th>
<th>Efficiency (%)</th>
<th>( J_{sc} ) (mA/cm(^2))</th>
<th>( V_{oc} ) (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>39.2 ± 0.1</td>
<td>663.3 ± 1.1</td>
<td>79.5 ± 0.4</td>
<td>20.7 ± 0.2</td>
<td>666.5 ± 1.0</td>
<td>83.4 ± 0.1</td>
</tr>
<tr>
<td>Best</td>
<td>39.2</td>
<td>664.9</td>
<td>80.1</td>
<td>20.9</td>
<td>668.0</td>
<td>83.4</td>
</tr>
</tbody>
</table>

### Floating BB

<table>
<thead>
<tr>
<th></th>
<th>( J_{sc} ) (mA/cm(^2))</th>
<th>( V_{oc} ) (mV)</th>
<th>FF (%)</th>
<th>Efficiency (%)</th>
<th>( J_{sc} ) (mA/cm(^2))</th>
<th>( V_{oc} ) (mV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>38.9 ± 0.1</td>
<td>668.2 ± 1</td>
<td>79.4 ± 0.5</td>
<td>20.7 ± 0.2</td>
<td>670.1 ± 1.1</td>
<td>82.9 ± 0.6</td>
</tr>
<tr>
<td>Best</td>
<td>39.0</td>
<td>667.9</td>
<td>80.1</td>
<td>20.9</td>
<td>671.7</td>
<td>83.5</td>
</tr>
</tbody>
</table>

\( \Delta \) 5mV average gain for floating BB

Drop in \( J_{sc} \) leads to same efficiency
Suspected reason for lower $J_{sc}$: bleeding

Printed Busbar

Plated fingers (LIP)

Shaded region

Unaffected region
Bleeding : a closer look

- Wider regions between pyramids in **carbon shaded region** vs **unaffected region**
- Small copper particles present at the base of the pyramids, carried by solvent
- Both copper and carbon cause shading loss
- Bleeding issue has been addressed in subsequent formulations and does not appear a fundamental problem
Summary

• A low-temperature screen printing paste based on Cu particles was developed

• The Cu paste was applied to front busbars in PERC and n-PERT solar cells with Ni/Cu-plated fingers

• Consistent $V_{oc}$ increase thanks to lower recombination under busbars

• Efficiencies up to 20.5 % (PERC) and 20.9 % (n-PERT) have been obtained for 156 mm Cz wafers

• Cu paste busbar process results in solderable and easily measurable cells

• Good control of bleeding desired to make use of full efficiency increase potential