6th Workshop on Metallization & Interconnection for Crystalline Silicon Solar Cells

Transition to 4 and 5 BB designs for Ni/Cu/Ag plated cells


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Overview

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• Simulation
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• Comparison of simulation and experimental results
• Finger and solder adhesion
• Total cost of ownership
• Conclusion
Motivation

- **Advantages of more busbars**
  - Shorter effective finger length – reduced Rs
  - Potential metal reduction

- **Advantages of an electroplated grid**
  - Narrow finger width achievable
  - Copper substitutes silver – reduced material costs

ITRPV 2016
3 busbars
4 busbars
5 busbars
busbarless
Process sequence

Process Sequence
- Laser contact opening (LCO) of SiNx; UV pico sec
- Single side inline processing
  - Pretreat (to remove native oxide)
  - Ni LIP (contact layer and diffusion barrier)
  - Cu LIP (conducting layer)
  - Im Ag (solderable layer)
- Thermal anneal

Front side layout
- 150 finger, BB layout to keep shading similar
  - 3x 1.5mm
  - 4x 1 mm
  - 5x 0.9 mm

Material
- Cz-Al BSF solar cells with 120 Ohm emitter
  - Reduced surface concentration
  - Deeper diffusion

Emitter used for these experiments processed by Trina solar
Simulation

- Gridsim\(^1\) simulations
- Assumptions:
  - Variation just in finger length
  - All busbar parameters assumed as constant: width, height, conductivity
- Grid was optimized to a minimal power loss for a 3 busbar design
- \(R_{s,\text{total}} = 0.36\ \Omega \text{ cm}^2\) fixed as goal parameter for all busbar designs
- Finger height (cross section) for 4 and 5 BB was varied to match \(R_s\)

1) A. Mette 2007
Optimal metal mass

- A level for the FF of 80.2% is considered to be sufficiently metallised
- A 30% metal reduction can be achieved with 5 BBs
- Results from simulation and experiment differ

<table>
<thead>
<tr>
<th>BB</th>
<th>Metal deposition /mg</th>
<th>Metal reduction / %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Simulation</td>
<td>Experimental</td>
</tr>
<tr>
<td>3</td>
<td>130</td>
<td>75-90</td>
</tr>
<tr>
<td>4</td>
<td>65</td>
<td>60-72</td>
</tr>
<tr>
<td>5</td>
<td>46</td>
<td>50-65</td>
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Efficiency

- Lower metal mass
- Above 0.15% efficiency gain is achieved with more busbars
- 4 busbar cells have a reduced shaded area compared to 3,5 busbar cells
- Best cells Eta = 19.5%
Comparison of simulation and experimental results

- There is a significant deviation from simulation to experiment
  - Finger width varies across cell
  - Finger roughness
  - Metal mass is not uniformly deposited on BB and fingers
Finger adhesion is tested with a tape test that is close to IPC-TM-650 (printed circuit boards).

Finger adhesion seems to be influenced by metal mass.

This could be related to mechanical stress in the metal stack.

Or geometric, broader fingers have more surface for the adhesive tape to attach to.
Finger adhesion

Shear test

- No difference between the groups
- More investigation necessary

Pragmatic approach: finger adhesion is on a good level and having narrower fingers is certainly not a disadvantage
Solder adhesion

- 90° peel test
- Force per busbar area is approximately the same
- Peel forces are mostly above 1 N/mm
- Low values can partly be explained by manual assembly
- Adhesion is good enough to cause wafer fracture in peel test
Total cost of ownership
Three busbars

Plating
- Lower consumable costs
- Higher tool costs
- TCoO=9.0 €ct/wafer

Screen printing
- Ag price 480 €/kg (March 2016)
- Double print 90mg paste
- Lower tool costs
- TCoO=12.4 €ct/wafer

Others: labour, facility, waste treatment, etc.
Savings in TCoO for plating

- Transition from 3 to 5 BB:
  - Cost reduction consumables ~ 75%
  - Shorter plating bath ~25%
  - equals ~35 mg Ag paste deposition
  - Efficiency gain not accounted for

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<th>BB</th>
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<th>Experimental</th>
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<tbody>
<tr>
<td>3 to 4</td>
<td>6 %</td>
<td>3 %</td>
</tr>
<tr>
<td>3 to 5</td>
<td>8 %</td>
<td>4 %</td>
</tr>
</tbody>
</table>

![Graph showing TCoO (€ct/wafer) for different busbars: Experiment vs Simulation for BB 3, 4, and 5.](image)
Conclusion

- Transition from 3 to 4 or 5 busbars is on its way
- 4, 5 BB cells were processed with electroplated NiCuAg grid that
  - Need less metal deposit
  - Show better finger adhesion
  - Comparable solder adhesion to 3 BB cells
- CoO for plated cells is improved by
  - Lower consumption
  - Smaller production tool
Thank you for your attention

Although not everyone will agree that having less metal is a good thing

Mike Judge