STATUS AND PERSPECTIVES OF METALLIZATION TECHNOLOGIES FOR HVM

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Agenda

- c-Si Technology Roadmap
- BCS Metallization Roadmap
- Advanced Line Configuration
  - Bi-PERC+SE
  - DP/Knotless
  - Shingling
- Conclusion
c-Si Technology Roadmap

Unique enabling Baccini technologies

- Esatto AOI, FLDP, metrology, Industry 4.0
- Esatto SEM, Selective BSF, LED Flasher
- Custom Esatto, Custom automation
- Print, Dry and cure
- Full custom solutions

Tool extendibility requirements

- p-multi BSF, up to 20.5% CE
- p-multi PERC, up to 21.5% CE
- p-mono BSF, up to 21.5% CE
- n-PERT/PERL, up to 23% CE
- p-mono PERC, up to 22.5% CE
- Heterojunction, up to 24.5% CE
- IBC, up to 25% CE

Metallization technology key to control performances
FLDP Metallization Roadmap

FLDP at least -5um over SP in mass production, Aspect Ratio >0.5

Screen images courtesy of Murakami

Ref: itrpv.net/Reports/Downloads
## FLDP Mass Production Data - Jinergy

### Processing conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell type</td>
<td>Cz-Si PERC</td>
</tr>
<tr>
<td>Screen opening</td>
<td>22 + 22 um</td>
</tr>
<tr>
<td>Mesh type</td>
<td>380-14</td>
</tr>
<tr>
<td>Finger width</td>
<td>35-38 um</td>
</tr>
<tr>
<td>Paste type</td>
<td>A + A</td>
</tr>
<tr>
<td>Printing speed</td>
<td>300 mm/s</td>
</tr>
<tr>
<td>Flooding speed</td>
<td>800 mm/s</td>
</tr>
<tr>
<td>Electroluminescence</td>
<td>&lt;5 interruptions</td>
</tr>
</tbody>
</table>

Data used with customer permission

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FLDP providing <40 um finger width in mass production, no EL defects
Advanced Metallization Line Configuration

- **Metal**:
  - Back Ag
  - Back Al
  - Front 1st
  - Front 2nd

- **Process**:
  - Bi-PERC
  - SE
  - FLDP/DuP

- **Alignm.**:
  - Edge ±25 µm
  - Pattern ±12.5 µm
  - Pattern ±12.5 µm
  - Pattern ±12.5 µm

4 items configuration commonly adopted, requirement for high precision for all steps
Shingled Modules – Value Drivers

- Full area utilization
- Improved reliability
- No ohmic losses
- Lower operating temperature means better performance ratio
- Work with bifacial modules
- Up +10% power from same module size
- Fully compatible with all cell technologies
- No residual stress between metal and Si
- Premium for residential applications
- Better aesthetics

Wöhrle, N. et al., Photovoltaics International 36, 2017
Alignment for Shingling - Print

Shingling needs precise edge alignment for both front and rear metallization along print direction!
Alignment for Bifacial PERC – Print

Bi-PERC advantages:
- 60-70% bifaciality
- Low Al consumption (<0.5g/cell)

Disadvantages:
- Decrease front efficiency


Bi-PERC requires pattern alignment on laser lines, reducing cell cost and increasing module yield
Alignment for Selective Emitter - Print

Misalignment Issue
- OM Image
- SE pattern (heavy emitter)
- SP pattern (Ag finger)
- High Rs Issue
- Misalignment between SE and SP patterns causes high Rs and low efficiency.

Edge vs. Fiducial Alignment
- In-line EL monitoring
- Fiducial Alignment:
  - Efficiency distribution moves to higher efficiency and becomes narrower.
  - No low efficiency tail due to misalignment between SE and screen patterns.

<table>
<thead>
<tr>
<th>% of cells with CE &lt;21%</th>
<th>Edge align</th>
<th>Pattern align</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.36%</td>
<td>0.08%</td>
<td></td>
</tr>
<tr>
<td>% of cells with CE &lt;20.8%</td>
<td>1.59%</td>
<td>0 %</td>
</tr>
<tr>
<td>% of cells with CE &lt;20.5%</td>
<td>0.28%</td>
<td>0 %</td>
</tr>
</tbody>
</table>

Pattern alignment allowing 0.1% CE gain over edge, no low efficiency cells tail
High A/R fingers achieved in FLDP needed for shingling layout to reduce resistive losses
Knotless Dual Printing - Print

Knotless is a promising approach (in DuP) some concerns exist on EL and image deformation.
Advanced Line Results

Test results
- 60 cells equivalent modules
- Reference PERC 290W
- Average power for shingling 314W, max 323W

Advanced Line can deliver 325W shingled modules, TC800 reliability ok
Conclusion

- Cell technology is constantly evolving: PERC, bi-PERC, SE+DP, knotless being introduced to increase efficiency
- FLDP targeting <35um lines in mass production next year
- Module technology is (finally) evolving, bringing in new requirements
- Metallization process is becoming more critical for all technologies
  - Precise edge alignment front/rear
  - Pattern alignment for bi-PERC and SE (fiducial, laser lines)
  - FLDP for high A/R in shingling

- Screen printing is still mainstream process...and has a long and bright future!

Thank you!