Enabling 7,500wph Productivity by a Novel Screen Printing Process

Marco Galiazzo
R&D Lab Manager, Applied Materials Baccini
Metallization & Interconnection Workshop, Konstanz - May 13 2019
Forward-Looking Statements and Other Information

This presentation contains forward-looking statements, including those regarding industry outlooks, technology transitions, and other statements that are not historical facts. These statements are subject to risks and uncertainties that could cause actual results to differ materially from those expressed or implied by such statements and are not guarantees of future results or performance. Information concerning these risks and uncertainties is contained in Applied’s most recent Form 10-Q and other filings with the SEC. All forward-looking statements are based on management’s current estimates, projections and assumptions, and Applied assumes no obligation to update them.

Applied Materials, the Applied Materials logo, and other trademarks so designated as product names are trademarks of Applied Materials, Inc. Other names and brands are the property of third parties.
Outline

- Metallization roadmap
- 7,500wph: fundamental challenges
- New Tempo™ Presto
  - Architecture
  - Printing Process
- Paste Saving developments
Industry Roadmap: key drivers

- Throughput
  - 7,000wph in 2019 (progressive)

- Resolution

- Paste Saving

+500-800wph/yr
Industry Roadmap: key drivers

- **Throughput**
  - 7,000wph in 2019 (progressive)

- **Resolution**
  - 35-40um in 2019

- **Paste Saving**
  - 2um/yr
Industry Roadmap: key drivers

- **Throughput**
  - 7,000wph in 2019 (progressive)

- **Resolution**
  - 35-40um in 2019

- **Paste Saving**
  - 90mg Ag for p-type

---

**Graph Description**

- **Y-axis:** Amount of silver per cell [mg/cell]
- **X-axis:** Years (2018 to 2029)
- **Legend:**
  - monofacial p-type cell [mg/cell] (front + rear side)
  - bifacial p-type cell [mg/cell] (front + rear side)
  - HJT n-type cell [mg/cell] (front + rear side)
  - n-type cell (all cell types, without HTJ) [mg/cell] (front + rear side)

---

`-5mg/yr`
1sec Cycle Time with Rotary Table

- Cycle Time = Printing Time + Table Rotation
- Printing Time linearly decreasing with Printing Speed, Stroke Length
- Flood Time is masked if equal or lower than Table Rotation (flood speed >800mm/s)
- In order to get to 7,200wph Printing Speed has to go >430mm/s

[BCS Simulation Data]
1sec Cycle Time with Tempo Presto

- New Tempo™ Presto automation based on 2 Linear Shuttles
- Transfer time 0.32sec vs 0.4sec table rotation (+550wph)
- Flood Speed >1,200mm/s
Volo Flood Concept – Patent Pending

- Volo Flood = 2 paste rolls = Print and Flood back and forth
- Printing Speed: from 430mm/s to 350mm/s for 0.95 sec Cycle Time (7,500wph)
- Applies to all printing steps, including backside Aluminum

![BCS Simulation Data]
Better than 8um Precision

- Printing twice the same pattern shifted by a fixed offset
- Applies to bi-PERC, SE, FLDP cells

![Image of solar cell pattern with SE fiducial, SE finger, and Ag finger labels.](image_url)

### Print with Offset - Tempo Presto

- Offset X (mm): < ±8um
- Offset Y (mm): < ±8um
- Offset Theta (deg): < ±2.5mdeg
Double Printing Lab Results with Volo Flood

- Purpose: compare Print & Flood process and Volo Flood on Tempo™ Presto, with two different screens
- Under same conditions, comparable finger width is achieved by both systems
Fine Line Double Printing - Production Data

- Performed 3,000 wafers pilot run with Volo Flood
- Automatic printing direction management for improved printing control
- Improvement in screen pattern stability and Screen Lifetime due to Volo Flood

Print and Flood
New screen: 4,000 wafers
>8\text{um} deformation

Volo Flood
New screen: 2,600 wafers
No detectable deformation
Developments towards Ag Paste Saving

- **Shingling**
  - Overlap reduction, thin busbars

- **Front Process**

- **Heterojunction nano-Paste**

<table>
<thead>
<tr>
<th>simulation condition</th>
<th>finger height (mm)</th>
<th>busbar width (mm)</th>
<th>busbar height (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5bb DP</td>
<td>0.017</td>
<td>0.85</td>
<td>0.01</td>
</tr>
<tr>
<td>5bb DuP</td>
<td>0.017</td>
<td>0.85</td>
<td>0.005</td>
</tr>
<tr>
<td>12bb MW</td>
<td>0.01</td>
<td>0.3</td>
<td>0.01</td>
</tr>
<tr>
<td>5bb SHG 1mm</td>
<td>0.017</td>
<td>0.6</td>
<td>0.01</td>
</tr>
<tr>
<td>5bb SHG 0.6mm</td>
<td>0.017</td>
<td>0.35</td>
<td>0.01</td>
</tr>
</tbody>
</table>

100 fingers, 40um finger width for all conditions
Developments towards Ag Paste Saving

- Shingling
  - Overlap reduction, thin busbars

- Front Process
  - Double and Dual Printing

- Heterojunction nano-Paste

[Image: Diagram comparing Single Print vs Dual Print vs Double Print]

[Enabling higher efficiency through metallization improvements and breakthroughs | Dr. Weiming Zhang | Heraeus Photovoltaics, PVCelltech, Penang, Mar 2019]
Developments towards Ag Paste Saving

- **Shingling**
  - Overlap reduction, thin busbars

- **Front Process**
  - Double and Dual Printing

- **Heterojunction nano-Paste**
  - Increased conductivity

### New HJT paste

- **Main advantages**
  - Medium Viscosity → Increase the Printing Speed
  - High Conductivity → Paste Cost Saving
  - Low Particle Size → Increase CE, Fine Line Printing

- **Technical Achievement at R&D level**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Printing Speed</td>
<td>Up to 500 mm/sec</td>
</tr>
<tr>
<td>Conductivity</td>
<td>Up to 50% Ag bulk</td>
</tr>
<tr>
<td>Fine Line Printing</td>
<td>Proven down to 20 μm, Avg. Linewidth 50-55 μm</td>
</tr>
<tr>
<td>CE (%)</td>
<td>~ Same range as baseline</td>
</tr>
<tr>
<td>Paste Laydown</td>
<td>Almost 45% reduction*</td>
</tr>
<tr>
<td>Adhesion/Solder</td>
<td>Yes / Tests ongoing</td>
</tr>
<tr>
<td>Contact Resistance</td>
<td>~ Same range as baseline</td>
</tr>
</tbody>
</table>

### Process Parameters

- **Drying Time**: 2-3 minutes
- **Drying Temperature**: 130°C
- **Curing Time**: 20 minutes
- **Curing Temperature**: 200°C
Fine Printing Process Development

- Fingers printing at 25µm x 5µm – influence of substrate
Conclusions

- Tempo™ Presto shuttle architecture allowing fastest handling at 0.32sec
- Volo Flood printing process enabling 7,500 wph at 350mm/s printing and flooding speed
- BCS continuous improvements:
  - Tool precision ±8um
  - Process development for paste saving

Thanks for your attention!