HIGH PERFORMANCE SILVER POLYMER PASTES FOR SHJ CELLS

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OUTLINE

- IKTS: Paste Research Service (PRS) and Paste Vendor for Niche Markets (PVN)
- SHJ: Low Temperature Pastes
- Silver polymer paste
  - Experimental
  - Results and discussion
- Summary
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IKTS Group Thick Film Technology, Photovoltaics: Paste Research Service PRS
Paste Development, Manufacturing and Characterization

**Functional Requirements**
- Functional phase
- Glass
- Additives
- Organics (Binder, solvents...)

**Composition**

**Paste Characterization**
- Rheometry
- Shrinkage
- Thermal Analysis
- Particle Sizes

**Deposition**

**Firing**
- Thick Film (min ... h)
- Solar contact (sec)

**Film Characterization**
- Electrical
- Topography
- Microstructure, phase content

"Ready for Production"
200 kg per year worldwide

Paste Vendor for Niche Markets PVN: example AlN substrates

<table>
<thead>
<tr>
<th>Paste</th>
<th>Metal</th>
<th>R/mOhm/sq</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>FK 1205</td>
<td>AgPd</td>
<td>&lt; 25</td>
<td>R termination</td>
</tr>
<tr>
<td>FK 1220</td>
<td>AgPd</td>
<td>&lt; 25</td>
<td>Acid stable</td>
</tr>
<tr>
<td>FK 1164</td>
<td>AgPd</td>
<td>&lt; 25</td>
<td>Via paste</td>
</tr>
<tr>
<td>FK 1071</td>
<td>AgPt</td>
<td>&lt; 6</td>
<td>Low resistance</td>
</tr>
<tr>
<td>FK 1282</td>
<td>AgPt</td>
<td>&lt; 35</td>
<td>Dealloy stable</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Paste</th>
<th>Cond. Phase</th>
<th>R/Ohm/sq</th>
<th>TCR/ ppm/K</th>
</tr>
</thead>
<tbody>
<tr>
<td>FK 9821m</td>
<td>AgPd</td>
<td>0.1</td>
<td>± 100</td>
</tr>
<tr>
<td>FK 9831m</td>
<td>AgPd</td>
<td>1</td>
<td>± 100</td>
</tr>
<tr>
<td>FK 9611</td>
<td>RuO₂</td>
<td>10</td>
<td>± 100</td>
</tr>
<tr>
<td>FK 9615</td>
<td>RuO₂</td>
<td>50</td>
<td>± 100</td>
</tr>
<tr>
<td>FK 9621</td>
<td>RuO₂</td>
<td>100</td>
<td>± 100</td>
</tr>
<tr>
<td>FK 9631</td>
<td>RuO₂</td>
<td>1000</td>
<td>± 100</td>
</tr>
</tbody>
</table>
Future of crystalline silicon solar cell

- ITRPV roadmap 2015 predicts efficiencies for SHJ up to 25% and market share of 10% in the year 2025

BSF/PERC n-type mono Si
SHJ n-type mono Si
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Conventional pastes for front side metallization

800 °C, some seconds

Cool down

e.g.
Li et al., J. Appl. Physics 110, 074304 (2011)
SHJ cell concept

- Silver
- ITO
- Emitter: a-Si (p)
- Passivation: a-Si (i)
- Base: c-Si (n)

Maximum process temperature $\leq 200^\circ C$
Conductive phase Ag

glass $\Rightarrow$ crucial for adhesion, reactive contact formation, and interface/finger conductivity

Conductive phase Ag or LMPA

polymer $\Rightarrow$ crucial for adhesion and interface/finger conductivity

Low temperature thick film pastes for solar cell metallization
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Processing of low temperature pastes

Thermal (IR or convection; air or nitrogen, 2400 wafers/h, manufactured 2015 by REHM, Germany)
Low temperature thick film pastes for solar cell metallization

- Tuning of curable binder: polymer, solvent
- Conductive phases: Ag mono/polymodal Low Melting Point Alloys (LMPA)

\[ R_{sq} = 25 \text{ m\(\Omega\)/sq} \]
Experimental

- IKTS paste
- Commercial paste

• Comparison with reference

- Storage
  - Fridge 7 °C or RT
  - Freezer -20 °C

- Screen printing

- Characterization

- Convection

- Infrared

• 10 wafer per paste
• 74 fingers with 100 µm width

• 5 wafer per kind of heat transfer
• 15 min at 200°C

• GridTouch system
• Measured at Meyer Burger (Germany) AG
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Electrical performance

- IKTS pastes provide slightly lower $J_{sc}$
- Optimizing paste rheology will increase $J_{sc}$ due to optimized finger narrowing and decreasing shading
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Electrical performance

- Series resistances comparable for both pastes
- Infrared curing provides lower series resistances as well as a lower standard deviation
- Optimized heat transfer due to coupling of IR radiation
Efficiency level higher than 21.5 %
- CC commercial paste 22 % using IR curing → benefit against convection of 0.25 %
- CC IKTS paste 21.8 % using IR curing → benefit against convection of 0.1 %
Fill factor constant higher than 80 %
Presence and future of crystalline silicon solar cell

Efficiency reached today

Predicted efficiencies ITRPV
Performance forecast

![Graph showing performance forecast for Generations 01, 02, and 03. The graph plots Rs;q@25µm in mOhm/sq. against generations.]

- **Gen. 01**: High performance with a Rs;q@25µm value of approximately 25 mOhm/sq.
- **Gen. 02**: Moderate performance with a Rs;q@25µm value of approximately 20 mOhm/sq.
- **Gen. 03**: Low performance with a Rs;q@25µm value of approximately 5 mOhm/sq.

**Images**:
- **Ag composite with LMPA**: Showing a detailed microstructure of the composite material.
- **Polymodal Ag composite**: Demonstrating the multi-layered composition of the composite material.

**Notes**:
- The image on the left illustrates the microstructure of the composite material for each generation.
- The graph on the right provides a clear comparison of the performance across generations.
Summary

- 1st generation IKTS paste curable at 200°C for SHJ solar cells is introduced
- IR curing leads to better electrical performance of the reference paste as well as the own development, obviously due to improved microstructure formation
- Electrical performance on cell level is comparable to industrial standard
- Handling, storage and therewith processing of IKTS paste is much more easier than the commercial reference

- Further improvement announced with next generations:
  - low melting point alloys with reduced silver amount
  - polymodal silver powders for minimal finger resistances
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…and you for your attention!

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