Ag-paste based ultra-fine line metallization by pattern transfer printing (PTP™)

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Why to reduce Silver?

- Assuming a 25% annual growth, PV industry soon might become the largest consumer of Ag
- Further growth of PV can be limited by growth of Ag-Production
- Sustainability and costs in thread

From Pierre Verlinden, Moving to Terawatt levels of annual solar cell production: aligning research, technology & production roadmaps
PV CellTech 2018, Penang 13-14 March, 2018
ITRPV Roadmap

• Ag will remain main metallization material in c-Si technology for the next years

• Ag price accounts for a significant part of cell conversion costs (~30%)

• However, ITRPV predicts only a moderate decrease of Ag consumption

From Markus Fischer, ITRPV 9th edition 2018 - report release and key findings
PV CellTech 2018, Penang
**Optimum finger width**

Which finger width would give the highest efficiency?

- Answer depends on the number of BB and on the achievable aspect ratio (AR)
- With more BBs and higher AR finer fingers are favorable
- For 6BB and AR 0.5 the optimum fingers width is below 20µm

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Simulation for 6BB PERC cell

Griddler 2.5 Pro Simulation

Input Parameter:
- IV and recombination parameters of 6BB PERC cell
- Assumption of fixed finger sheet res.
- Finger width: 15 … 35 µm
- Finger #: 100 … 150 fingers

Results:
- Significant eta increase possible
- Optimum shifts for smaller finger width to a higher number of fingers
- But, the shaded area of fingers still is reduced, $J_{sc}$ and $V_{oc}$ are increased
Pattern Transfer Printing

Working principle

1. Creation of a negative image of the desired pattern into a polymer substrate (e.g. deep trenches)
2. Filling of the trenches with standard Ag paste
3. Transfer of pattern by laser irradiation (in one piece/shot) to the wafer
Pattern Transfer Printing

Sequence of pattern transfer printing

- Trenches in tape are filled with Ag paste
- The tape is positioned in proximity to the wafer
- Irradiation of laser light through the transparent tape
- Evaporation of solvent at the interface
- Overpressure accelerates paste towards wafer
- As a laser with a very high scanning speed of 200 m/s is used, a complete finger is deposited in “one piece”
Pattern Transfer printing
Experimental
- PERC precursors from pilot line of Hanwha Q Cells in Germany
- SP reference with 30 µm opening, 380/14 mesh
- Paste: two modification of Heraeus 9651B

Finger geometry
- No mesh marks with PTP
- Line width ~ 25 µm
- Height ~ 10 µm
- AR 0.4 – 0.5
- $R_L$ ~ 1.15 Ω/cm
Printing experiment 30µm trench

IV Data

- Reduced shading results +0.2 mA Jsc gain for both pastes
- Small lost in FF, small gain in Voc
- Efficiency gain of ~ 0.1%
Experimental
- PERC precursors from pilot line of Hanwha Q Cells in Germany
- Paste: modification of Heraeus 9651B with adjusted glass chemistry
- Printing from two tapes (20 µm trench, 30 µm trench) performed at ISC Konstanz

Finger geometry (analyzed by laser scanning microscope):

- For 20 µm trench: fingers < 25 µm width with aspect ratio > 0.5
- For this paste, the specific **contact resistance rhoC reduces with smaller line width**
  (→ a detailed analysis of contact formation is presented by D. Rudolph at IEEE, Hawaii: “Influence of the paste volume on the contact formation in fine line metallization”)

- Increased Line Resistance RL is in good agreement with reduced cross section

- Paste laydown:  *< 30 mg for PTP with 20µm trench and 112 fingers*
Printing experiment 20µm trench

IV Data

- Reduced shading results in +0.4 mA Jsc gain
- Loss in FF, small gain in Voc
- **Efficiency gain of ~0.15% for PTP printing from 20 µm trench**
Summary

- High Ag consumption could threaten sustainability of PV growth

- Simulation predicts efficiency gain for further line width reduction

- The contactless Pattern Transfer Printing (PTP) technology enables printing of very fine finger lines:
  - Line width < 25 µm, AR ~ 0.5
  - Laydown for 112 fingers < 30 mg

- Efficiency gain of 0.1% / 0.15% demonstrated for 30 µm / 20 µm trench geometry on high efficient PERC cells
Conclusion comparing ITRPV

- PTP technology can bring you significantly ahead of the ITRPV roadmap
- Samplings are possible at ISC Konstanz e.V.

From Markus Fischer, ITRPV 9th edition 2018 - report release and key findings
PV CellTech 2018, Penang
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Thank you for your attention