DISPENSING TECHNOLOGY ON THE ROUTE TO AN INDUSTRIAL METALLIZATION PROCESS

Latest developments and results of the research project „GECKO“


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5th Workshop on Metallization
Constance, Tue, 21th October 2014
Front Side Metallization
Process Requirements

- Robust contact formation

- High conductivity
  - Finger cross-section area $A_f$

- Less shading losses
  - Small finger width $w_0$

- Little (Ag-) paste consumption
  - Efficient silver usage

Screen Printing

... as Industrial Standard Metallization Process

- Established, reliable single step metallization approach
- Robust contact formation
- Throughput rates
  1600 – 1800 Wafer/h

- Finger homogeneity
  (meshmarks and paste spreading)
- Low aspect ratio (= height : width)
- Screen wear
- Mechanical load on wafer

Source: M. Pospischil et al., Energy Procedia 55, 693 (2014)
Dispensing Technology for Front Side Metallization

Opportunities

- Non-impact, single step process
- High resolution, high aspect ratio using similar Ag-pastes
- Improvement of cell-efficiencies
  \[ \Delta \eta = 2 - 3\%_{\text{rel.}} \] \( ^{(1)} \) \( \Rightarrow \eta_{\text{max}} = 20.6\% \) \( ^{(2)} \)

* Sources: (1) Specht et al., EUPVSEC 2010, (2) Lohmüller et al., IEEE Electron, 2011

Source: M. Pospischil et al., Energy Procedia 55, 693 (2014)
Dispensing Technology for Front Side Metallization

Challenges

- Process stability & accuracy
- Throughput
- Economic Boundaries
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→ Parallelization
Developing an Industrial Metallisation Process
Interacting Fields of Research and Engineering

- Integration into new developed dispensing platform
- Development of advanced dispensing pastes
- Cell Processing and Characterization

- Rheology
- Paste Development (external)
- Process Development
- Contact Formation
- Technology & Material Evaluation
- Hardware Design & Construction
- CFD - Simulation
- Integration in PV Production Process
Multi Nozzle Print Head
Integrated in Industrial Dispensing Platform

- Multi Nozzle Print Head
- Printing speed > 700 mm/s
- Nozzle Plates with ten nozzles
  → Pitch 1.55mm, N = 100
- Advanced valve technology in development

Platform
- Inline feasible dispensing platform
- Future scalability

Multi-nozzle print head, mounted in industrial dispensing platform at Fraunhofer ISE’s PV-TEC
Design of Production Line
Dispenser as Drop-In-Replacement

- Single Print Approach
- Dual Print Approach
- Dispensing Approach

SP-Front: Busbars + Grid

SP-Front: Busbars

SP-Front: Finger Grid

Dispenser: Finger Grid

Drying

Drying + FFO

SP-Back: Ag Pads

Drying

SP-Back: Printed Al

Drying

Drying

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Resulting Finger Geometries of Dispensed Contacts
Influence of Paste Rheology

- Pastes designed for screen printing gives increased homogeneity at medium aspect ratios (AR).

→ Evaluation of pastes possible prior to rheological adaption!

**Resulting Finger Geometries of Printed Contacts**

**Finger Widths and Cross Section**

- **Stable processing of homogeneous dispensed contact grid with finger widths < 40μm**

- **Cross section area $A_f$ in the range of screen printed references at Nozzle openings of $D < 60μm$**
Resulting Finger Geometries of Printed Contacts
Improved Finger Homogeneity

- Visualization of mesh marks (SP)
- Improved finger homogeneity for all dispensed samples

Cross section area $A_f$ in the range of screen printed references at Nozzle openings of $D < 60\mu m$
Resulting Finger Geometries of Printed Contacts
Improved Effective Silver utilization

- Relatively higher impact of inhomogeneities with decreasing finger width
- Significantly improved finger homogeneity increases effective silver utilization by 20%
Characterization of Finger Geometries
Effective Widths by SR-LBIC

- SR-LBIC maps of EQE (Beutel et al.*)
- Extraction of finger contribution to $j_{sc}$ possible without special sample preparation

$\rightarrow$ Effective finger width (EW)**


Source: Woehl et al.**
Determination of Effective Finger Widths
Relative Values

- Relative comparison with geom. width
- High aspect ratio dispensing technology:
  - $E_{W_{rel}} \approx 73\%$ on cell level!
  - $E_{W_{rel}} \approx 48\%$ on module level!
- $E_{W_{SP}}: \ 72\% \times 45\mu m = 32.4\mu m$
- $E_{W_{DSP}}: \ 48\% \times 35\mu m = 16.8\mu m$
Conversion Efficiencies on Standard Al-BSF Cell Batch on Industrial Precursor Material

- Cz p-type Si, Emitter: $R_{sh} \approx 90\Omega/$sq.
- $V_{oc}$: +3mV due to floating Busbar
- $J_{sc}$: +0.5mA compared to single SP
- $\Delta \eta$: **+0.4%abs.** of best cell compared to single SP
- With dual/double SP (2x): $\Delta \eta$: + **0.3%abs.**

→ **Expected advantages due to advanced finger geometry demonstrated**
Recent Cell Results on PERC Samples
Cell Batch on Industrial Precursor Material

- Cz p-type Si
- All groups with floating BB
- FF on high level
- $J_{sc}$: +0.35 mA/cm²
- $\Delta \eta$: +0.4% abs. of best cell compared to dual SP (2x)
- With dual + double SP (3x): $\Delta \eta$: + 0.2% abs.
- $\rightarrow$ Max. $\eta = 20.5\%$ with Dispensing
Summary and Outlook
... on the Route to an Industrial Metallization Process

- Advanced Parallel Dispensing Print Head developed and integrated into inline feasible Dispensing Platform at Fraunhofer ISE’s PV-TEC

- Substantially improved dispensing pastes allow for
  - Stable processing of < 40μm fingers at ~95mg paste consumption
  - Similar contacting behaviour as screen printing pastes

→ linked development with fast emerging screen printing pastes

- High aspect ratio and lower effective width allow for substantially increased cell efficiencies compared to screen printing
  - 19.4% vs. 19.0% on industrial Al-BSF
  - 20.5% vs. 20.1% on industrial PERC
Thank you for your attention!

... and all Co-authors and Co-workers within the Dispensing Project
... as well as our industry partners:

This work was supported by the German Federal Ministry for Economic Affairs and Energy within the research project “GECKO” under contract number 0325404.

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