»ROCK-STAR« – HIGH-SPEED ROTARY PRINTING FOR SOLAR CELL METALLIZATION: FROM VISION TO REALITY

A. Lorenz, J. Röth, M. Klawitter, K. Zengerle, M. Linse, S. Tepner, N.Wirth, R. Greutmann, M. Lehner, A. Senne, D. Reukauf, A. Mette, F. Hage, M. Drews, S. Gombert, H. Brocker, J. Rohde, E. Dörsam, F. Clement and R. Preu

9th Metallization & Interconnection Workshop

High-Speed Rotary Printing for Solar Cell Metallization: From Vision to Reality

Fraunhofer Institut für Solare Energiesysteme

Freiburg, 06.10.2020

Fraunhofer ISE

„Rock-Star“
Agenda

1. Rotary Printing for Solar Cell Metallization

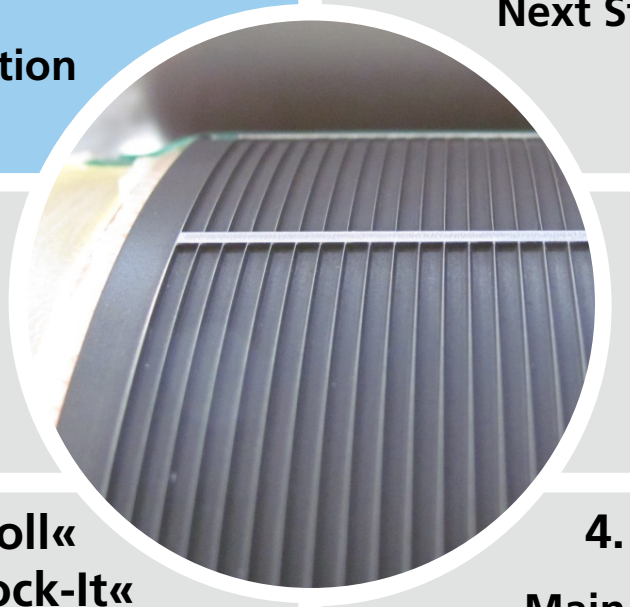
Background and Motivation

2. Technology

Flexography and Rotary Screen Printing

3. Projects »Rock‘n‘Roll« »Rock-Star« and »Rock-It«

A Brief Review



4. Project »Rock-Star«

Main Results and Achievements of the Project

5. The »Rock-Star« Demonstrator

Concept and Highlights

6. Summary and Outlook

Next Steps - Project »Rock-It«

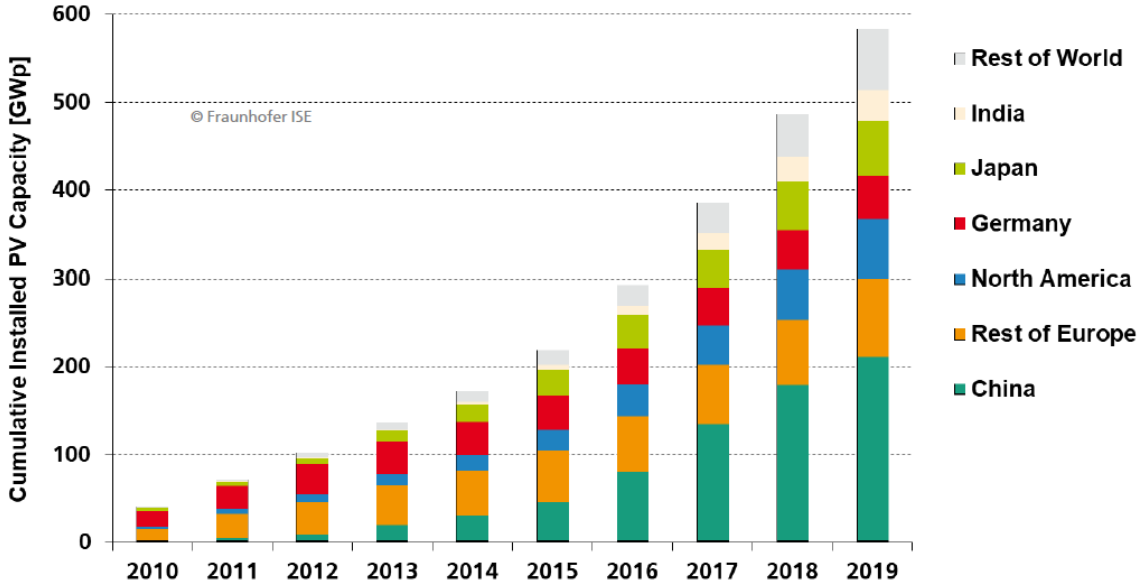
Rotary Printing for Solar Cell Metallization

Background and Motivation

- Globally installed PV capacity rapidly approaches **terawatt-scale**:

  → Decrease costs of cell and module production

  → Increase throughput of production lines



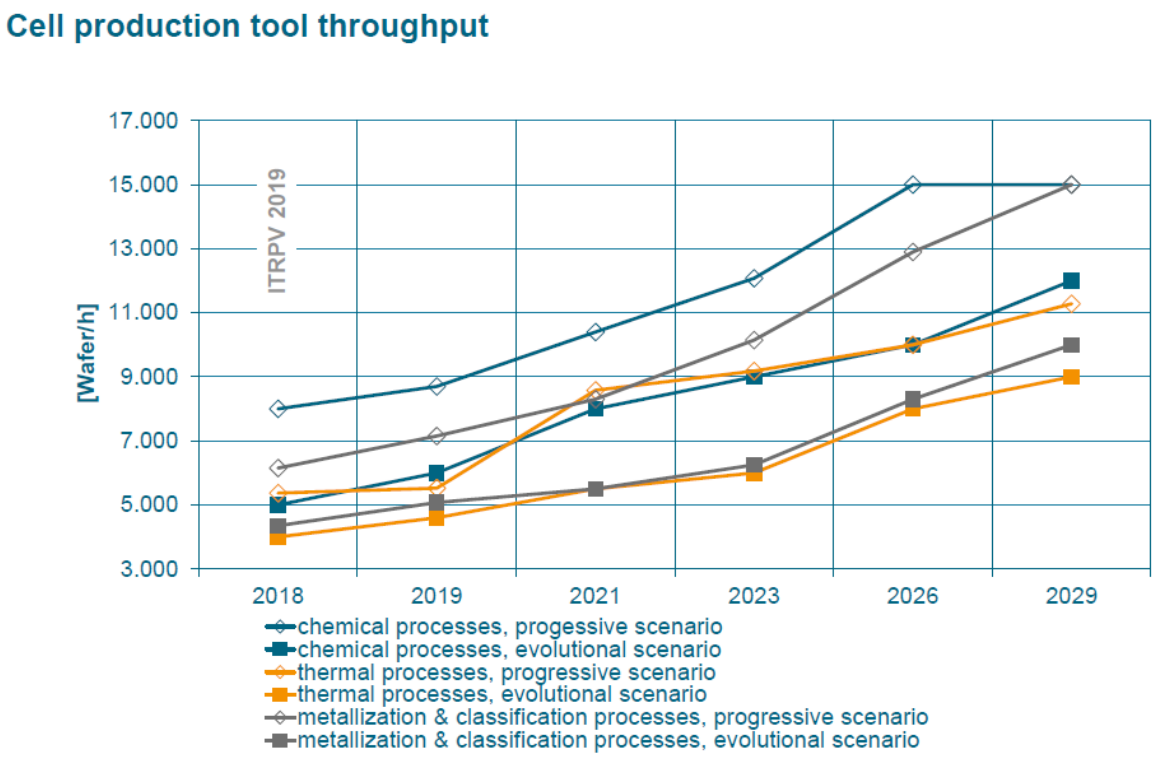
Cumulative installed global PV capacity from 2010 to 2019 (Source: PSE Projects GmbH, taken from Fraunhofer ISE Photovoltaics Reports 2020)

[1] International Technology Roadmap for Photovoltaic (ITRPV): 2018 Results. 10th Ed. (2019).

Fraunhofer ISE

Rotary Printing for Solar Cell Metallization
Background and Motivation

- Globally installed PV capacity rapidly approaches **terawatt-scale**:
  - → Decrease costs of cell and module production
  - → Increase throughput of production lines
  - → Backend: Metallization & Classification:
    ITRPV Prediction 2026: **8.500 – 13.000 Wafer/h**[1]



Actual forecast of the International Technology Roadmap for Photovoltaics (ITRPV) regarding the expected through-put of PV production lines[2]

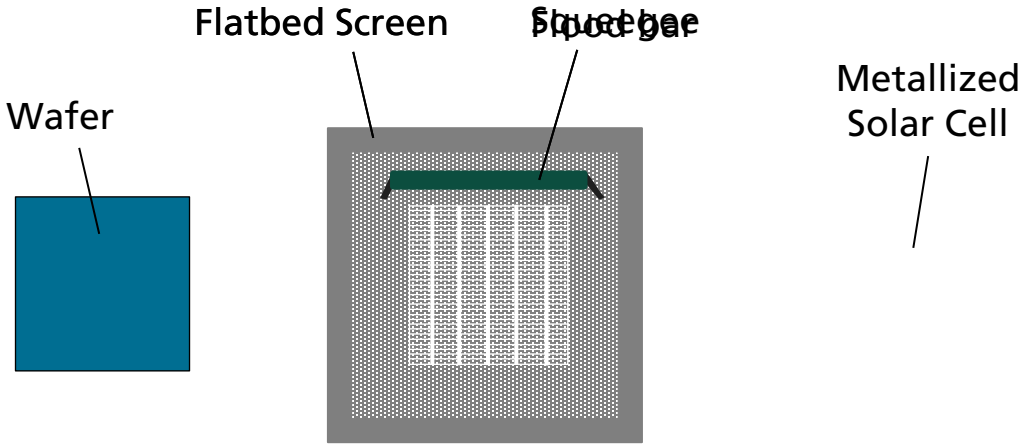
[1] International Technology Roadmap for Photovoltaic (ITRPV): 2018 Results. 10th Ed. (2019).

Fraunhofer ISE

Rotary Printing for Solar Cell Metallization

Background and Motivation

- Globally installed PV capacity rapidly approaches **terawatt-scale**:
  - → Decrease costs of cell and module production
  - → Increase throughput of production lines
  - → Backend: Metallization & Classification:
    ITRPV Prediction 2026: **8.500 – 13.000 Wafer/h**[1]
  - → Flatbed screen printing:
    Reduction of cycle time below **t ≈ 1 s**
    difficult or impossible



[1] International Technology Roadmap for Photovoltaic (ITRPV): 2018 Results. 10th Ed. (2019).

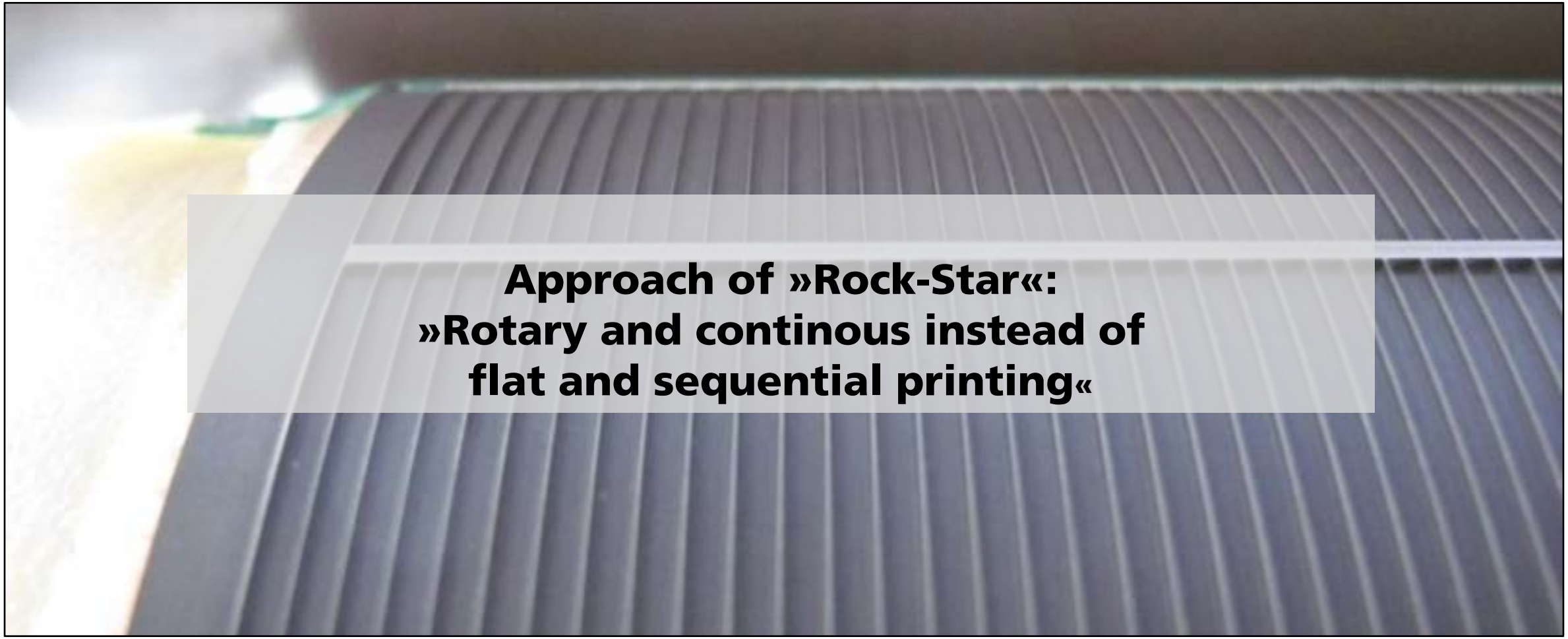
Fraunhofer ISE

Rotary Printing for Solar Cell Metallization
Challenge

The Challenge:
»Boosting throughput of metallization by maintaining the same quality level«

Fraunhofer ISE

Rotary Printing for Solar Cell Metallization
»Rock-Star« Approach



Fraunhofer ISE

„Rock-Star“
Agenda

1. Rotary Printing for Solar Cell Metallization

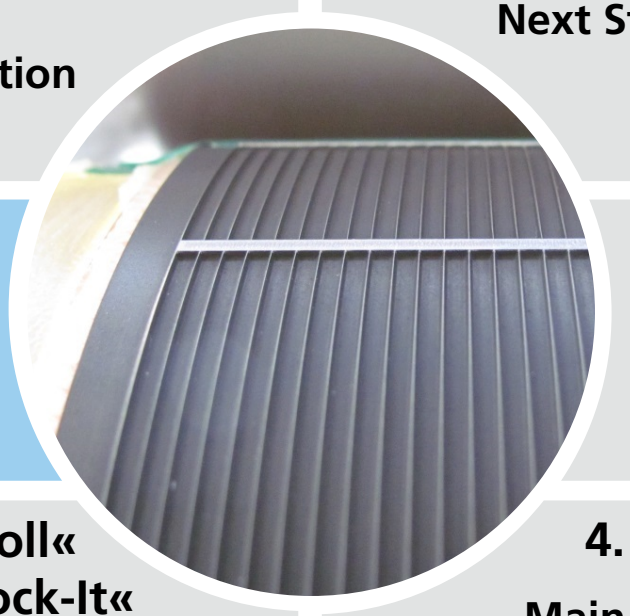
Background and Motivation

2. Technology

Flexography and Rotary Screen Printing

3. Projects »Rock‘n‘Roll« »Rock-Star« and »Rock-It«

A Brief Review



4. Project »Rock-Star«

Main Results and Achievements of the Project

5. The »Rock-Star« Demonstrator

Concept and Highlights

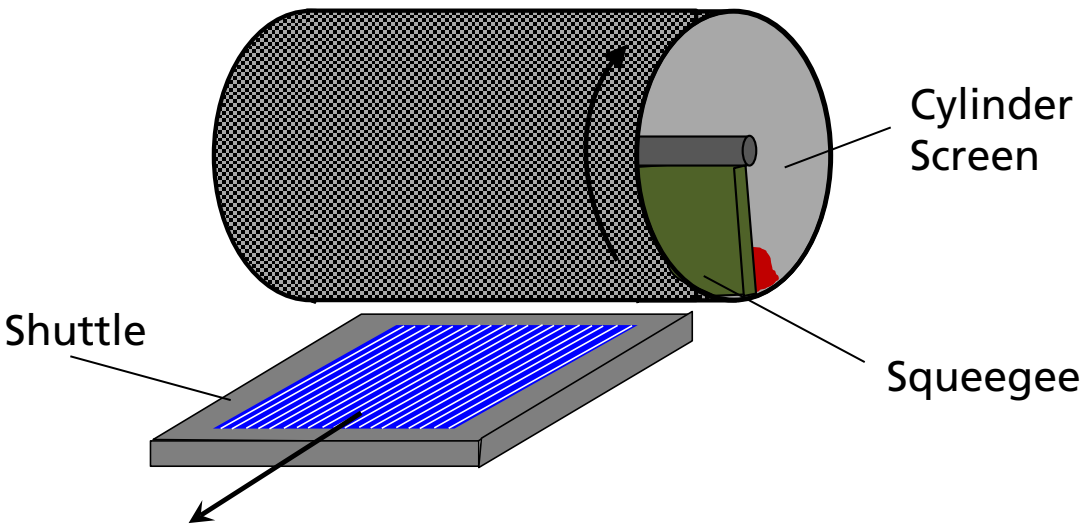
6. Summary and Outlook

Next Steps - Project »Rock-It«

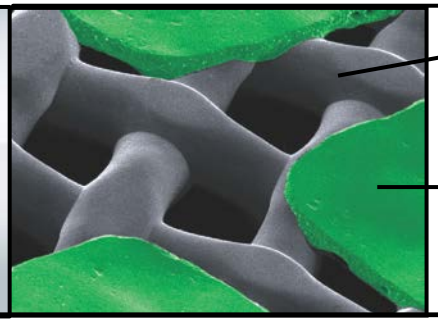
Rotary Printing for Solar Cell Metallization

Technical Background – Rotary Screen Printing and Flexographic Printing

Rotary Screen Printing:



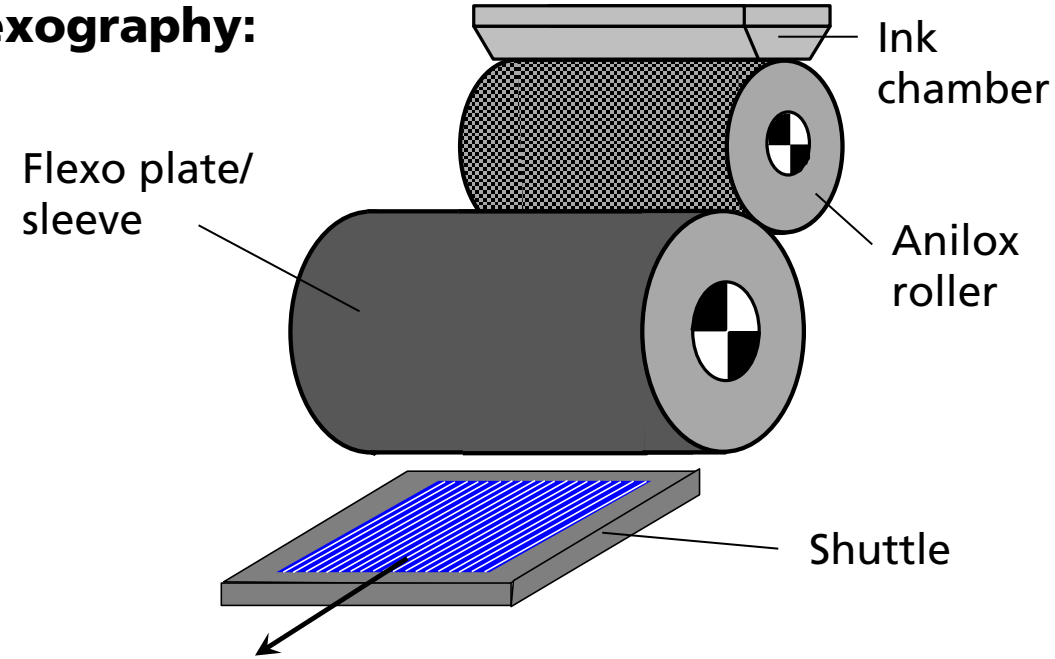
Source: Gallus Ferd. Rüesch AG

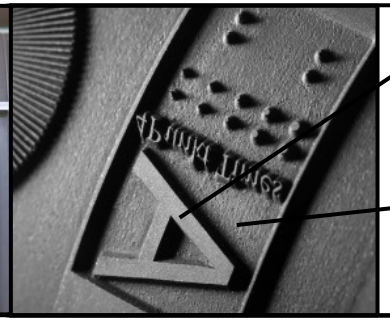


Open mesh
→ Printing

Emulsion
→ Non-printing

Flexography:





Elevated areas
→ Printing

Recessed areas
→ non-printing

Fraunhofer ISE

„Rock-Star“
Agenda

1. Rotary Printing for Solar Cell Metallization

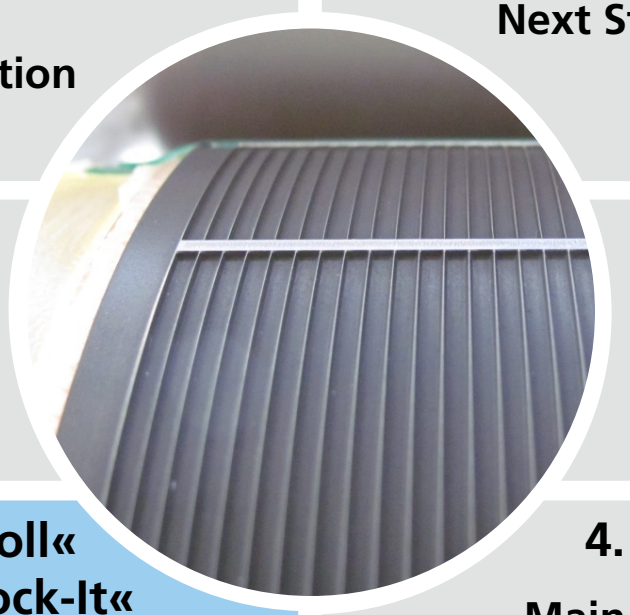
Background and Motivation

2. Technology

Flexography and Rotary Screen Printing

3. Projects »Rock‘n‘Roll« »Rock-Star« and »Rock-It«

A Brief Review



4. Project »Rock-Star«

Main Results and Achievements of the Project

5. The »Rock-Star« Demonstrator

Concept and Highlights

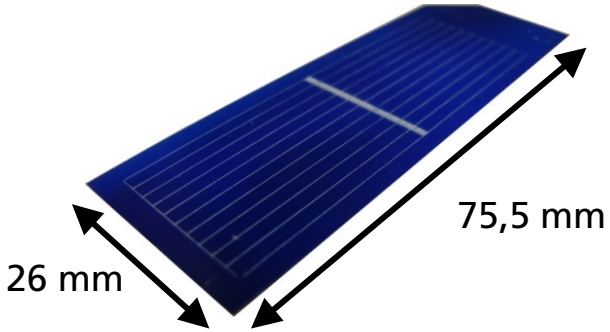
6. Summary and Outlook

Next Steps - Project »Rock-It«

Joint Projects „Rock-Star“ and „Rock-It“

Projects „Rock‘n‘Roll“, „Rock-Star“ and „Rock-It“ – A Review

2010: First results on small-size Si samples using IGT test device[1,2]



[1] Frey, Master Thesis (2010) [2] Frey et al., Energy Proc. 8 (2011)

Fraunhofer ISE

Joint Projects „Rock-Star“ and „Rock-It“

Projects „Rock‘n‘Roll“, „Rock-Star“ and „Rock-It“ – A Review

2010: First results on small-size Si samples using IGT test device[1,2]

2012 - 2014 Fraunhofer-internal research project “Rock’n’Roll”
→ Upscaling of tests on full wafer size[3]

Flexographic Printing on Cz-Si wafers (156 mm x 156 mm) using a laboratory flexo printing machine at DFTA-TZ in Stuttgart

[1] Frey, Master Thesis (2010) [2] Frey et al., Energy Proc. 8 (2011)
[3] Lorenz et al., Proc. 28th EUPVSEC (2013)

Fraunhofer ISE

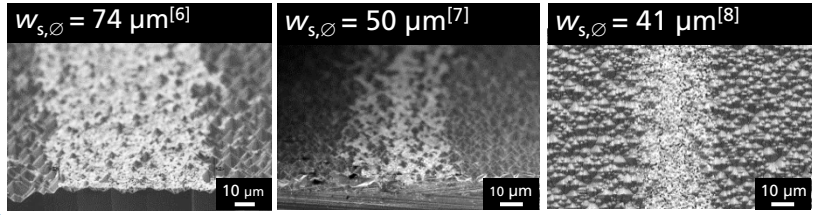
Joint Projects „Rock-Star“ and „Rock-It“

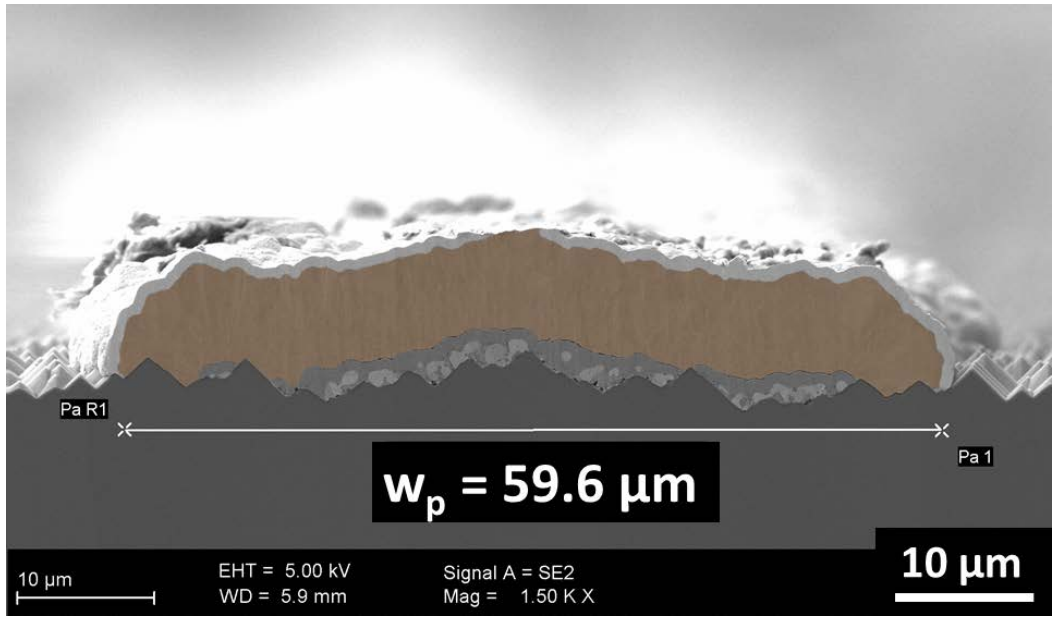
Projects „Rock‘n‘Roll“, „Rock-Star“ and „Rock-It“ – A Review

2010: First results on small-size Si samples using IGT test device[1,2]

2012 - 2014 Fraunhofer-internal research project “Rock’n’Roll”
→ Upscaling of tests on full wafer size[3]
→ Focus on flexo seed & plate approach[4]

Flexo-printed seed layer contacts





SEM image of contact finger with flexo printed seed layer metallization and Ni/Cu/Ag-plating

[1] Frey, Master Thesis (2010) [2] Frey et al., Energy Proc. 8 (2011)
[3] Lorenz et al., Proc. 28th EUPVSEC (2013) [4] Lorenz et al., Proc. 30th EUPVSEC (2015)

Fraunhofer ISE

Joint Projects „Rock-Star“ and „Rock-It“

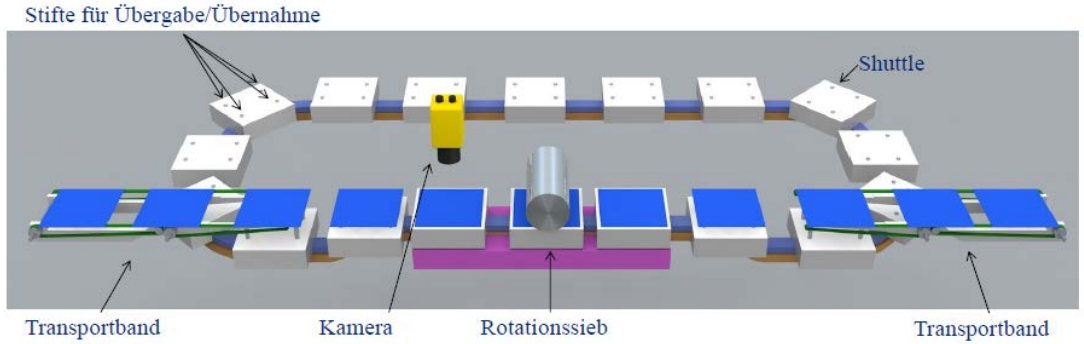
Projects „Rock‘n‘Roll“, „Rock-Star“ and „Rock-It“ – A Review

2010: First results on small-size Si samples using IGT test device[1,2]

2012 - 2014 Fraunhofer-internal research project “Rock’n’Roll”
→ Upscaling of tests on full wafer size[3]
→ Focus on flexo seed & plate approach[4]

2015 Start of funded joint project “Rock-Star” with 9 industry partners
→ Comprehensive evaluation of flexo and rotary screen printing[5-7]

2016 – 2019 Concept, fabrication and testing/hook-up of the “Rock-Star” demonstrator machine



Fraunhofer ISE

Joint Projects „Rock-Star“ and „Rock-It“

Projects „Rock‘n‘Roll“, „Rock-Star“ and „Rock-It“ – A Review

2010: First results on small-size Si samples using IGT test device[1,2]

2012 - 2014 Fraunhofer-internal research project “Rock’n’Roll”
→ Upscaling of tests on full wafer size[3]
→ Focus on flexo seed & plate approach[4]

2015 Start of funded joint project “Rock-Star” with 9 industry partners
→ Comprehensive evaluation of flexo and rotary screen printing[5-7]

2016 – 2019 Concept, fabrication and testing/hook-up of the “Rock-Star” demonstrator machine

2019 Start of follow-up project “Rock-It” , End of project “Rock-Star”

Continental ASYS SOLAR Fraunhofer ISE
gallus Heraeus NAMICS
FMP TECHNOLOGY GmbH HIGHLINE TECHNOLOGY

Gefördert von
Bundesministerium für Bildung und Forschung
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

Joint Projects „Rock-Star“ and „Rock-It“

Projects „Rock‘n‘Roll“, „Rock-Star“ and „Rock-It“ – A Review

2010: First results on small-size Si samples using IGT test device[1,2]

2012 - 2014 Fraunhofer-internal research project “Rock’n’Roll”
→ Upscaling of tests on full wafer size[3]
→ Focus on flexo seed & plate approach[4]

2015 Start of funded joint project “Rock-Star” with 9 industry partners
→ Comprehensive evaluation of flexo and rotary screen printing[5-7]

2016 – 2019 Concept, fabrication and testing/hook-up of the “Rock-Star” demonstrator machine

2019 Start of follow-up project “Rock-It”, End of project “Rock-Star”

2020 Demonstrator launched at ISE PVTEC[8]

„Rock-Star“ Demonstrator machine at Fraunhofer ISE PVTEC

[8] Abschlußbericht Projekt „Rock-Star“ (Final Report), to be published (2020)

Fraunhofer ISE

„Rock-Star“
Agenda

1. Rotary Printing for Solar Cell Metallization

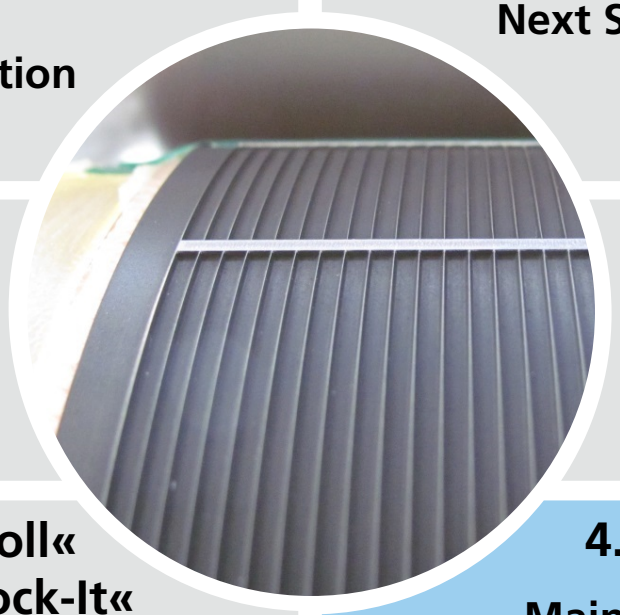
Background and Motivation

2. Technology

Flexography and Rotary Screen Printing

3. Projects »Rock‘n‘Roll« »Rock-Star« and »Rock-It«

A Brief Review



4. Project »Rock-Star«

Main Results and Achievements of the Project

5. The »Rock-Star« Demonstrator

Concept and Highlights

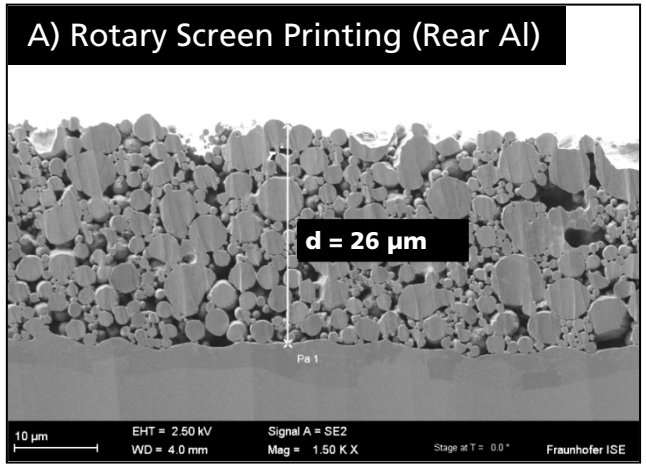
6. Summary and Outlook

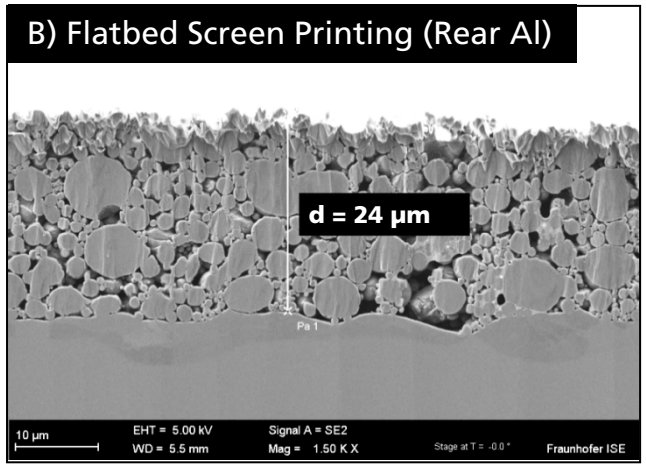
Next Steps - Project »Rock-It«

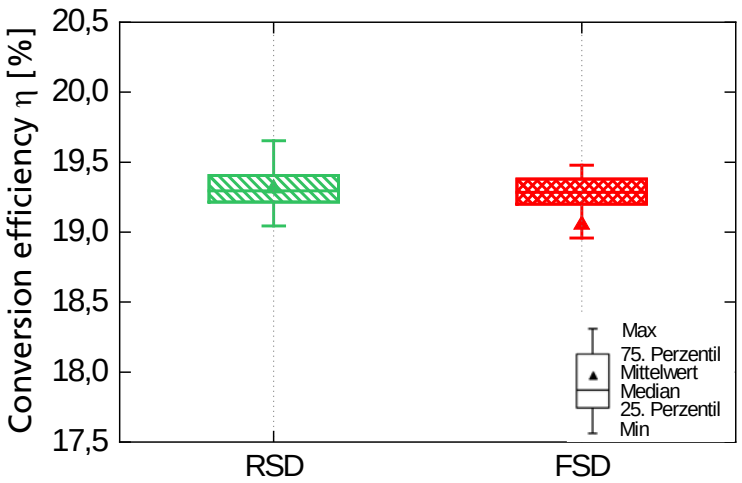
Project »Rock-Star«
Technological Highlights and Achievements

Rotary Screen Printing:

- Rear side metallization of Cz-Si PERC solar cells successfully shown[1]







[1] Lorenz et al., Energy Proc. 124 (2017)

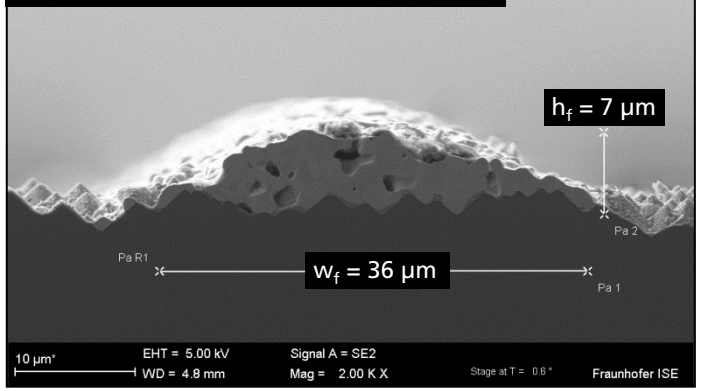
Fraunhofer ISE

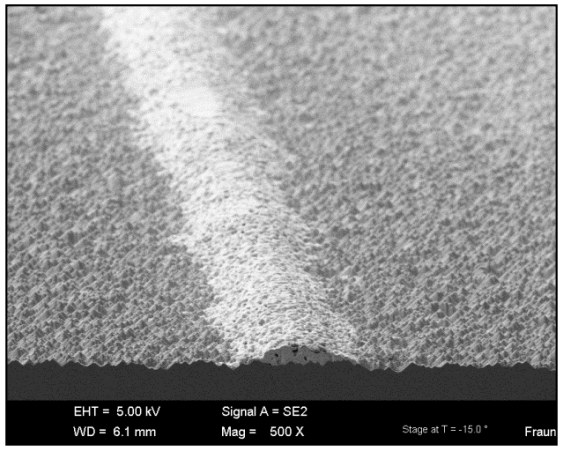
Project »Rock-Star«
Technological Highlights and Achievements

Rotary Screen Printing:

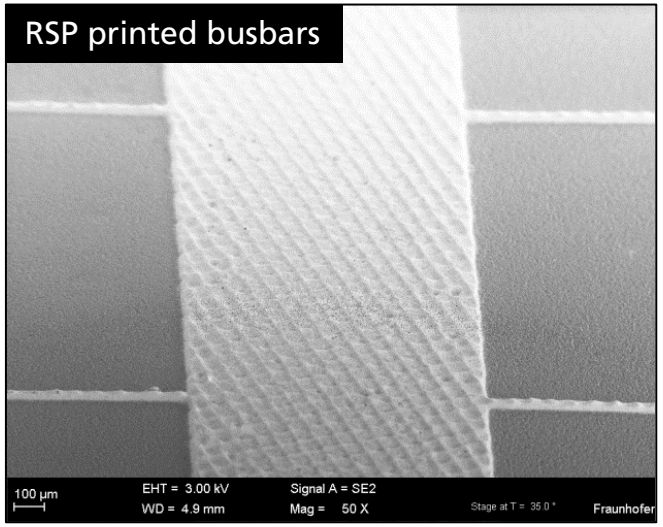
- Rear side metallization of Cz-Si PERC solar cells successfully shown[1]
- Front side metallization with finger width down to $w_f \approx$ 40 µm[2]

RSP printed front side contacts





RSP printed busbars



[1] Lorenz et al., Energy Proc. 124 (2017)
[2] Lorenz et al., PhD Thesis (2018)

Fraunhofer ISE

Project »Rock-Star«
Technological Highlights and Achievements

Rotary Screen Printing:

- Rear side metallization of Cz-Si PERC solar cells successfully shown[1]
- Front side metallization with finger width down to $w_f \approx$ 40 µm[2]
- Demonstrator module (9 mc-Si PERC cells, SWCT interconnection):
  - RSP rear side metallization
  - Module efficiency: $\eta_{mod,n}$ = 17.7 %[3] ($\eta_{mod,n}$ normalized on total cell area)

Demonstrator module: 9 mc-Si PERC solar cells with rotary screen printed rear side metallization and SWCT interconnection

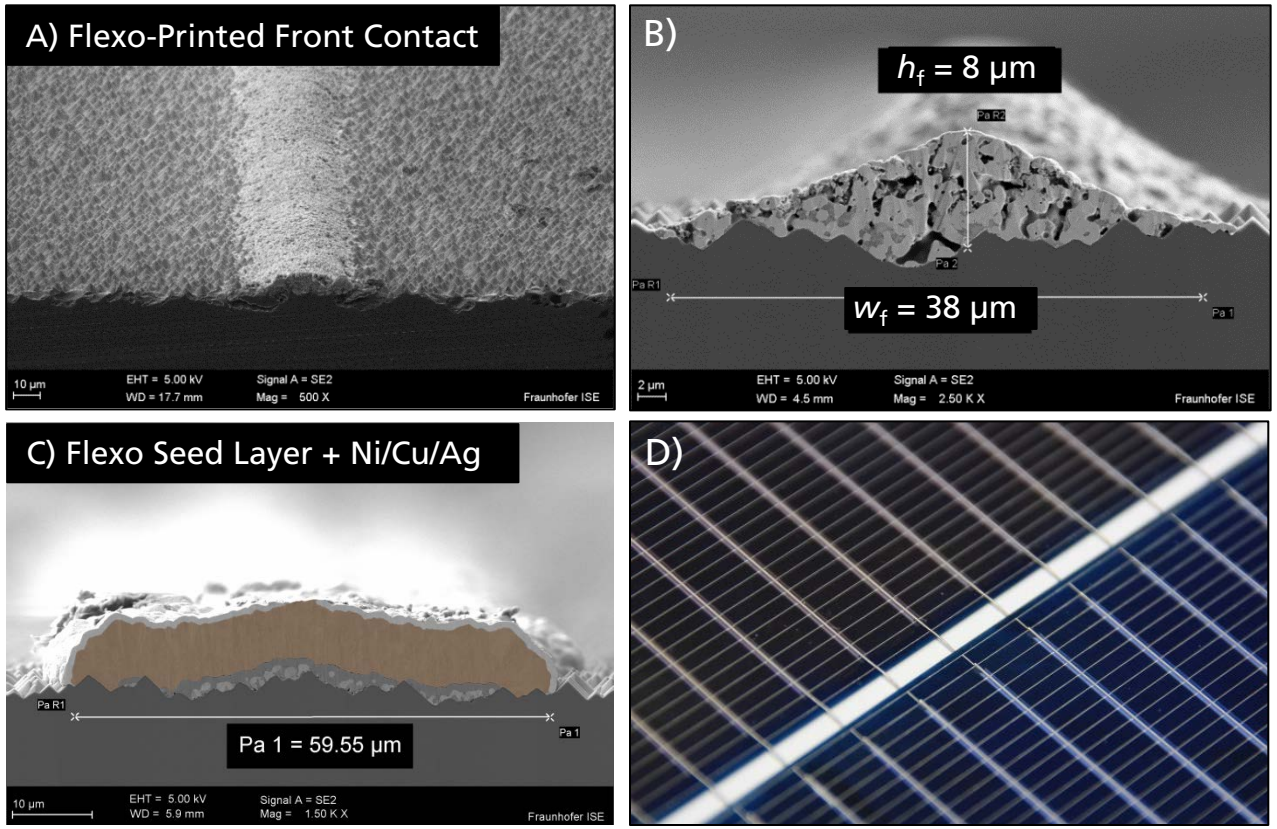
[1] Lorenz et al., Energy Proc. 124 (2017)
[2] Lorenz et al., PhD Thesis (2018) [3] Lorenz et al., Proc. 37th EUPVSEC (2020)

Fraunhofer ISE

Project »Rock-Star«
Technological Highlights and Achievements

Flexo Printing:

- Flexo printed front side metallization successfully demonstrated using
  - Seed and Plate approach with Ni/Cu/Ag Plating (Fig. C)[1,2]
  - Direct metallization down to $w_f \approx 30$ µm finger width[3]
- Mini module with flexo printed Al BSF solar cells and SmartWire interconnection[4]



Flexo printed contact finger with A,B) direct metallization, C) seed layer and Ni/Cu/Ag plating, D) interconnected cells with SmartWire

[1] Lorenz et al., Proc. 28th EUPVSEC (2013)
[2] Lorenz et al., Proc. 30th EUPVSEC (2015)
[3] Lorenz et al., PhD Thesis (2018)
[4] Lorenz et al., SolMat 157 (2016)

Fraunhofer ISE

„Rock-Star“
Agenda

1. Rotary Printing for Solar Cell Metallization

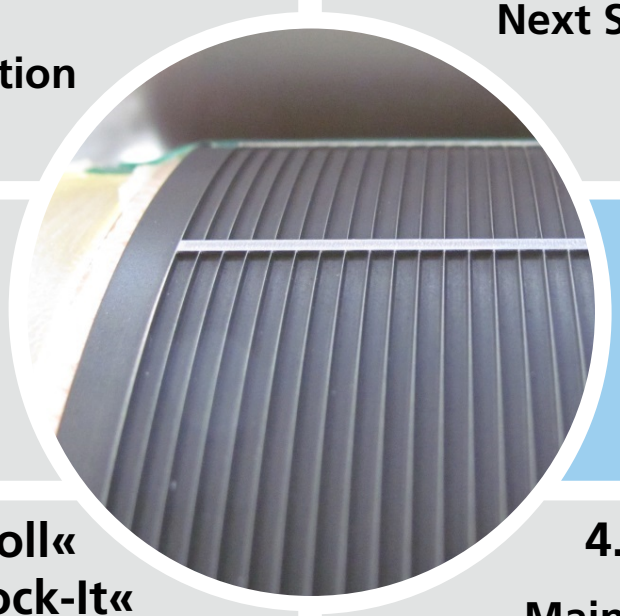
Background and Motivation

2. Technology

Flexography and Rotary Screen Printing

3. Projects »Rock‘n‘Roll« »Rock-Star« and »Rock-It«

A Brief Review



4. Project »Rock-Star«

Main Results and Achievements of the Project

5. The »Rock-Star« Demonstrator

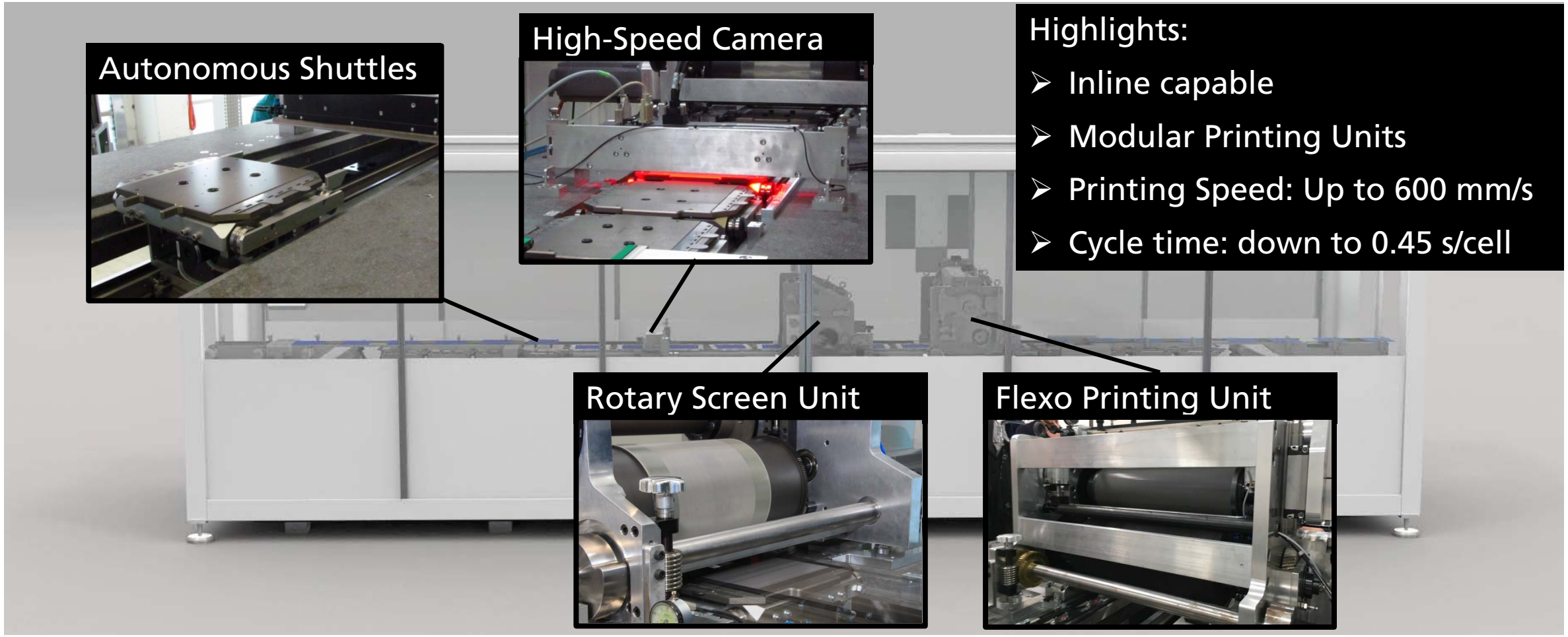
Concept and Highlights

6. Summary and Outlook

Next Steps - Project »Rock-It«

»Rock-Star« Demonstrator

Concept and Innovation of the »Rock-Star« Demonstrator



Highlights:

- Inline capable
- Modular Printing Units
- Printing Speed: Up to 600 mm/s
- Cycle time: down to 0.45 s/cell

Fraunhofer ISE

„Rock-Star“
Agenda

1. Rotary Printing for Solar Cell Metallization

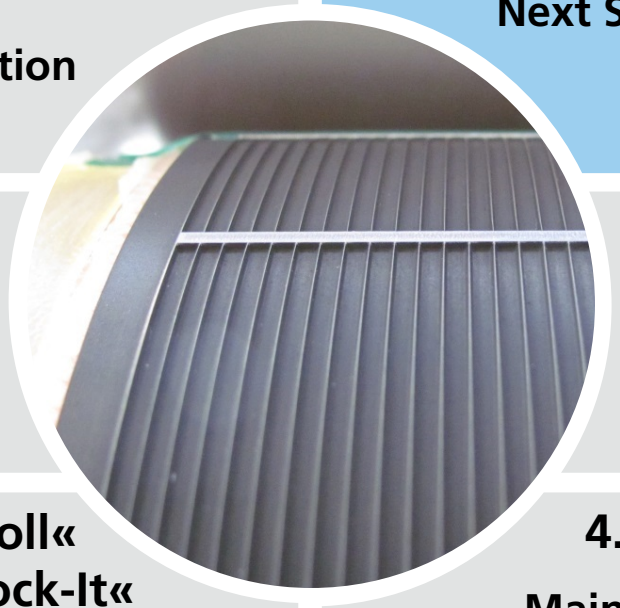
Background and Motivation

2. Technology

Flexography and Rotary Screen Printing

3. Projects »Rock‘n‘Roll« »Rock-Star« and »Rock-It«

A Brief Review



4. Project »Rock-Star«

Main Results and Achievements of the Project

5. The »Rock-Star« Demonstrator

Concept and Highlights

6. Summary and Outlook

Next Steps - Project »Rock-It«

Summary and Outlook

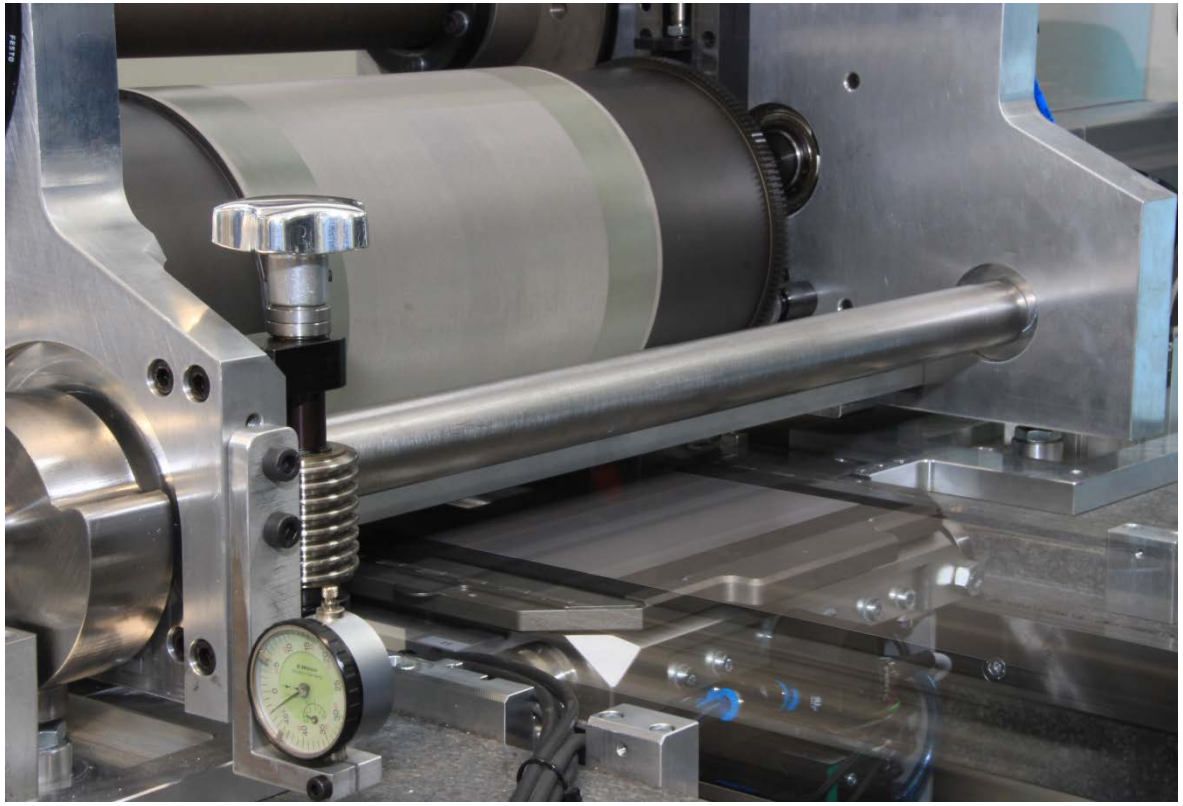
Next Steps – Project „Rock-It“

Summary:

- Successfull demonstration of front and rear side metallization using flexography / rotary screen printing
- Development and launch of high-throughput demonstrator platform

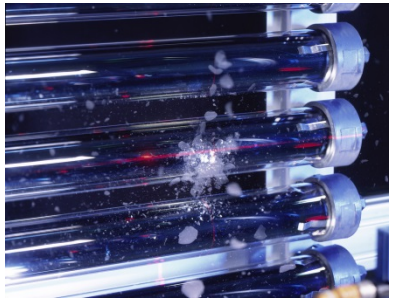
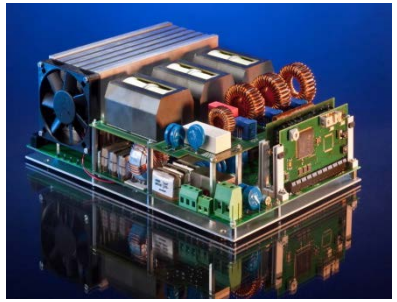
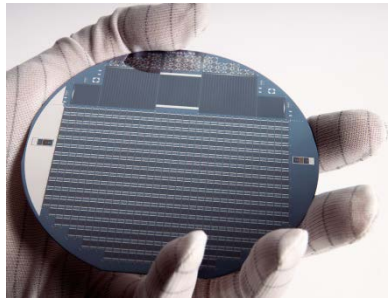
Outlook „Rock-It“:

- Evaluation of demonstrator platform
- Optimization of rotary printed metallization
- Fabrication of fully rotary printed PERC and HJT solar cells
- Feasibility studies for other applications (fuel cells, sensors, PCB…)



Thank you for your attention!




Fraunhofer-Institut for Solar Energy Systems ISE

Dr. Andreas Lorenz
Andreas.Lorenz@ise.fraunhofer.de
www.ise.fraunhofer.de

Gefördert von

Bundesministerium für Bildung und Forschung

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

Gefördert von

Bundesministerium für Bildung und Forschung

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

Fraunhofer ISE