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# Advanced Metallization with Low Silver Consumption for Silicon Heterojunction Solar Cells

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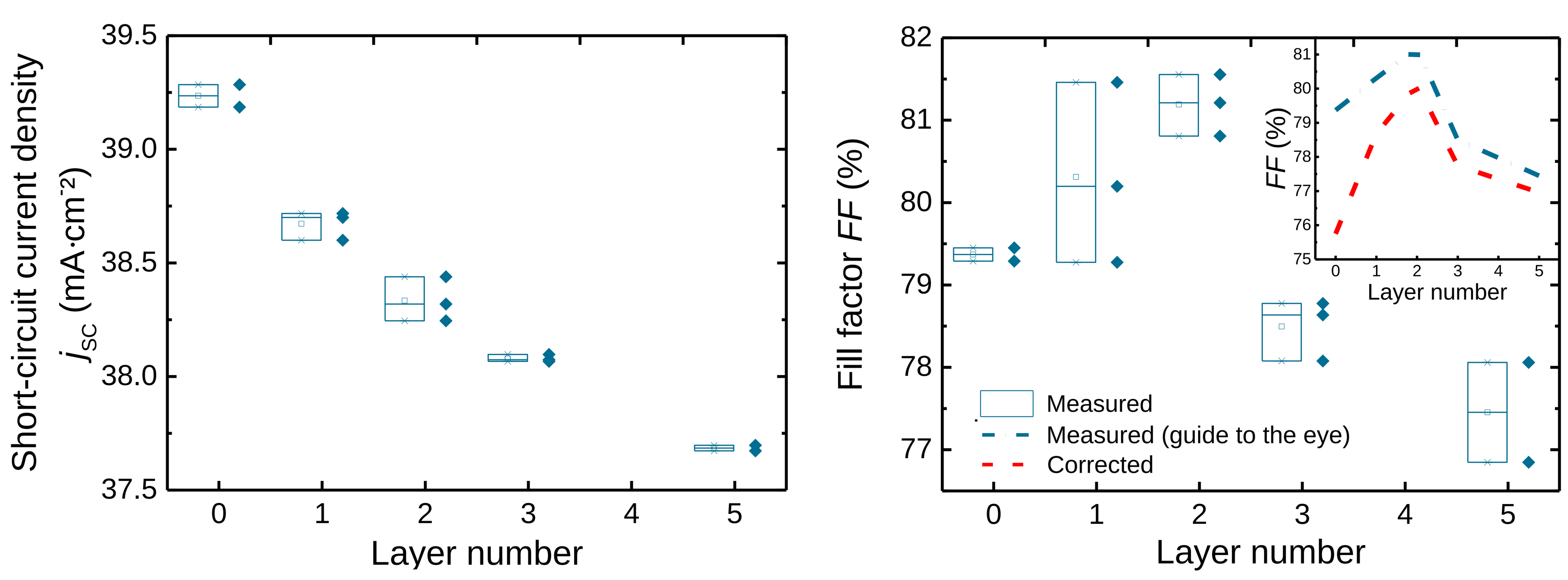
## Introduction

- Ag is a main cost driver in photovoltaics production [1]
- Metallization with Ag reduction potential for Silicon Heterojunction (SHJ) solar cells investigated
  - **Screen-printing** of Ag-coated copper paste [2] ➔ Pot. 30% Ag reduction
  - **Inkjet-printing** of Ag nanoparticle ink [3] ➔ > 90% Ag reduction
  - **FlexTrail-printing** of Ag nanoparticle ink ➔ > 90% Ag reduction

## Inkjet-Printing of Ag Nanoparticle Ink

**Dependence on the printed layer number per finger**

- Busbarless SHJ solar cells
  ➔ Correction of PCB Touch [4] measurement necessary (see also Ref. [5])
- The lower the layer number the higher the $j_{SC}$
- Highest *FF* with one/two printed layers (see explanation below)




$j_{SC}$ and *FF* of SHJ solar cells with inkjet-printed front grids.

**Contacting extreme thin fingers with PCB Touch**

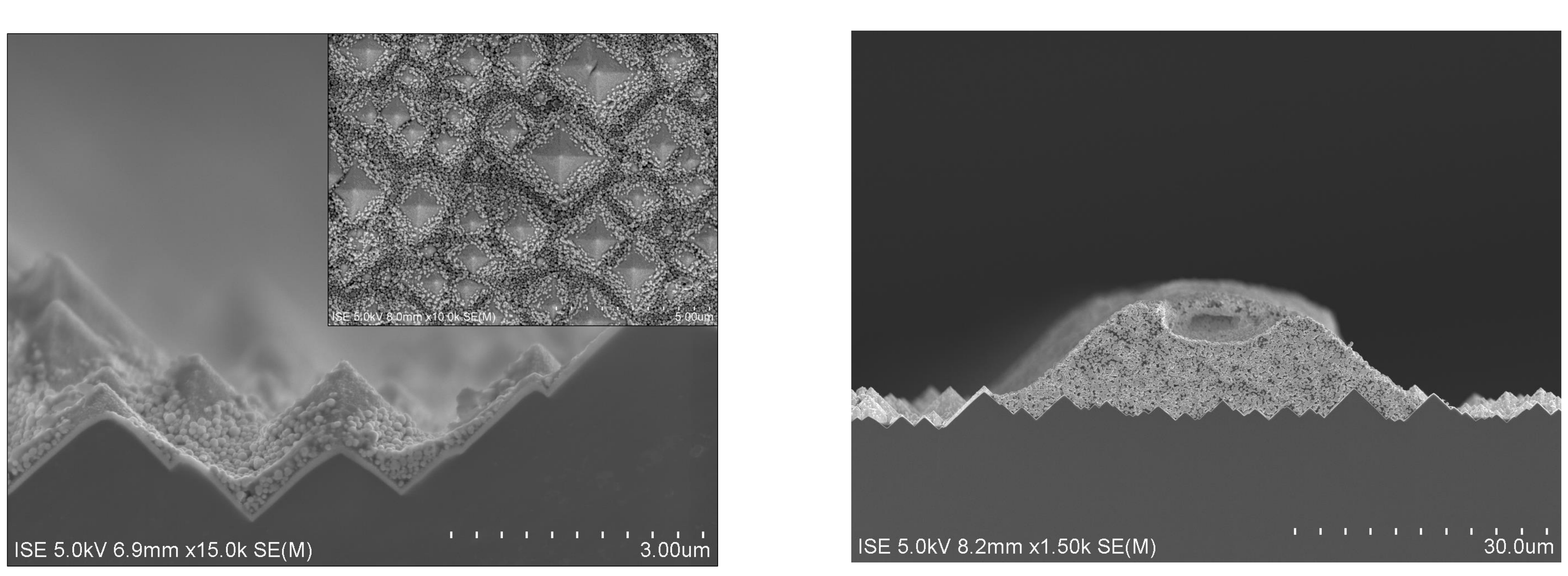
| Printing technique | $V_{OC}$ (mV) | $j_{SC}$ (mA/cm²) | *FF* (%) | $\eta$ (%) |
|---|---|---|---|---|
| Inkjet-printing (one layer) | 733.8 | 38.7 | 81.6 | 23.1 |
| Screen-printing | 736.8 | 37.9 | 80.1 | 22.4 |

*IV*-data (median values) of busbarless SHJ solar cells with comparable grid layouts.

- $R_f$ (screen-printing) << $R_f$ (inkjet-printing)
- *FF* (screen-printing) < *FF* (inkjet-printing)

} Includes contacting by means of PCB Touch!

➔ *High fingers (e.g. screen-printing):* ***PCB Touch contacts fingers only.***
➔ *Thin fingers (e.g. inkjet-printing):* ***PCB Touch contacts fingers and ITO.***




SEM images of an inkjet-printed one-layer-finger's (left) and a screen-printed finger's (right) cross-section.

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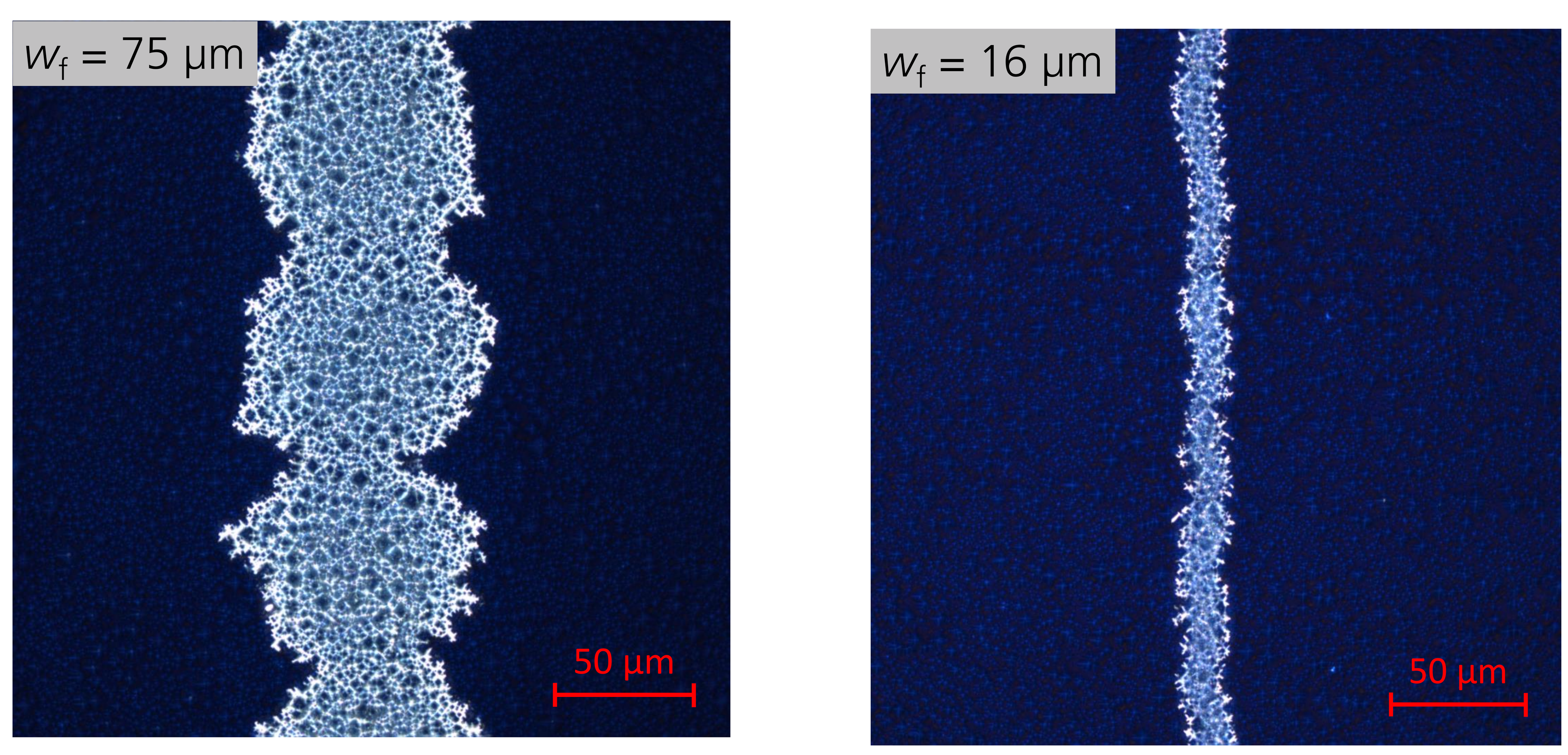
[1] ITRPV consortium, *ITRPV*, 2018
[2] K. Nakamura et al., *35th EU PVSEC*, 2018
[3] J. Hermans et al., *SNEC PV Power Expo.*, 2015
[4] N. Bassi et al., *29th EU PVSEC*, 2014
[5] M. Rauer et al., *8th metallization workshop*, 2019, tbp.

## Conclusion

- 21.6% median efficiency of bifacial five busbar SHJ solar cells achieved with **screen-printed** Ag-coated copper paste and silver paste
- 23.3% maximum efficiency of a busbarless bifacial SHJ solar cell utilizing a **inkjet-printed** front grid achieved
- **FlexTrail-printing** allows for 23.7% maximum efficiency of a busbarless bifacial SHJ solar cell

## FlexTrail-Printing of Ag Nanoparticle Ink

- FlexTrail is established at Fraunhofer ISE as a novel printing technology
- Printing of commercially available Ag nanoparticle ink
- FlexTrail's arguments
  - Printing of ultra-fine lines, flexible layouts
  - Large process window, simple handling
  - Higher process stability compared with inkjet-printing (e.g. clogging)



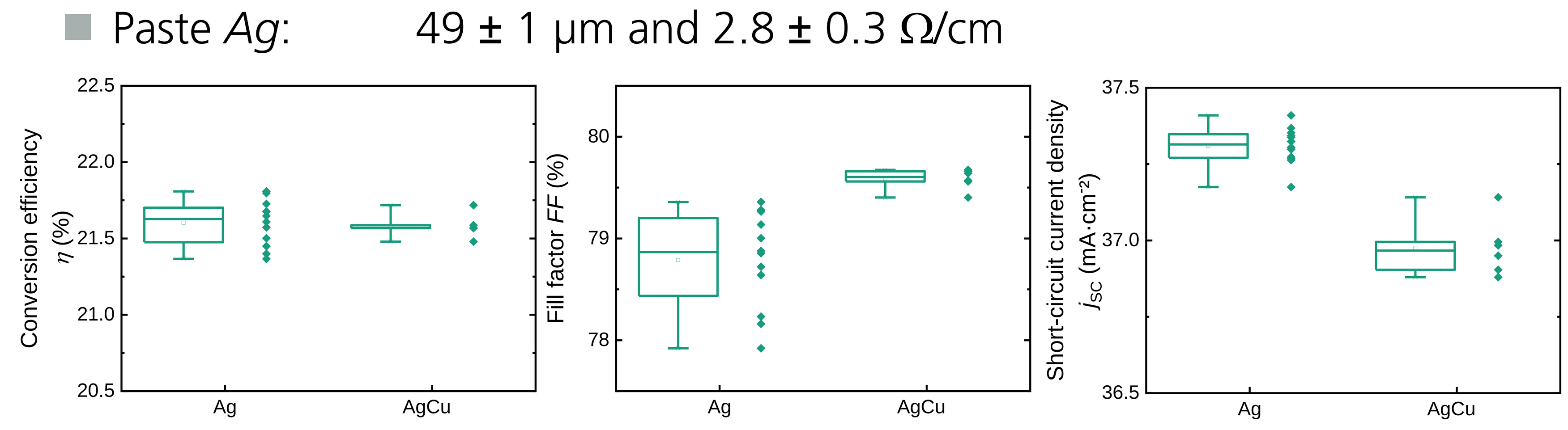

Microscopy images at a magnification of 50 of an inkjet-printed finger (one layer) (left) and a FlexTrail-printed finger (right) on alkaline textured SHJ solar cells.

| Printing technique | $V_{OC}$ (mV) | $j_{SC}$ (mA/cm²) | *FF* (%) | $\eta$ (%) |
|---|---|---|---|---|
| Inkjet-printing | 736.7 | 38.7 | 81.5 | 23.2 |
| FlexTrail-printing | 737.4 | 39.2 | 82.1 | 23.7 |

*IV*-data of busbarless SHJ solar cells with inkjet- and FlexTrail-printed front grids (80 fingers) measured by means of PCB Touch, each one exhibiting the highest $\eta$.

## Screen-Printing of Silver-Coated Copper Paste

- 21.6% median efficiency achieved with pure Ag and Ag-coated copper
- $V_{OC}$ on similar level for both groups (mean value is 734.4 ± 1.0 mV)
- Finger widths and finger resistances (40 µm screen openings)
  - Paste *AgCu*: 60 ± 2 µm and 2.1 ± 0.1 Ω/cm
  - Paste *Ag*: 49 ± 1 µm and 2.8 ± 0.3 Ω/cm




$\eta$, *FF*, and $j_{SC}$ of SHJ solar cells with five busbars (at least 6 samples per group).

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