# 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**

**Composition**
- Functional phase
- Glass
- Additives
- Organics (Binder, solvents…)

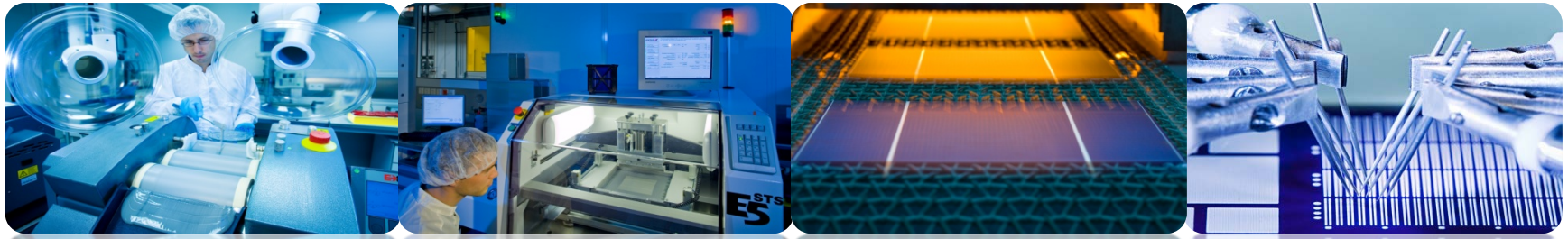
**Paste Characterization**
- Rheometry
- Shrinkage
- Thermal Analysis
- Particle Sizes

**Deposition**
- Screen/ stencil
- Micro dispensing
- Gravure
- Aerosol

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

**Film Characterization**
- Electrical
- Topography
- Micro structure, phase content

**„Ready for Production“**





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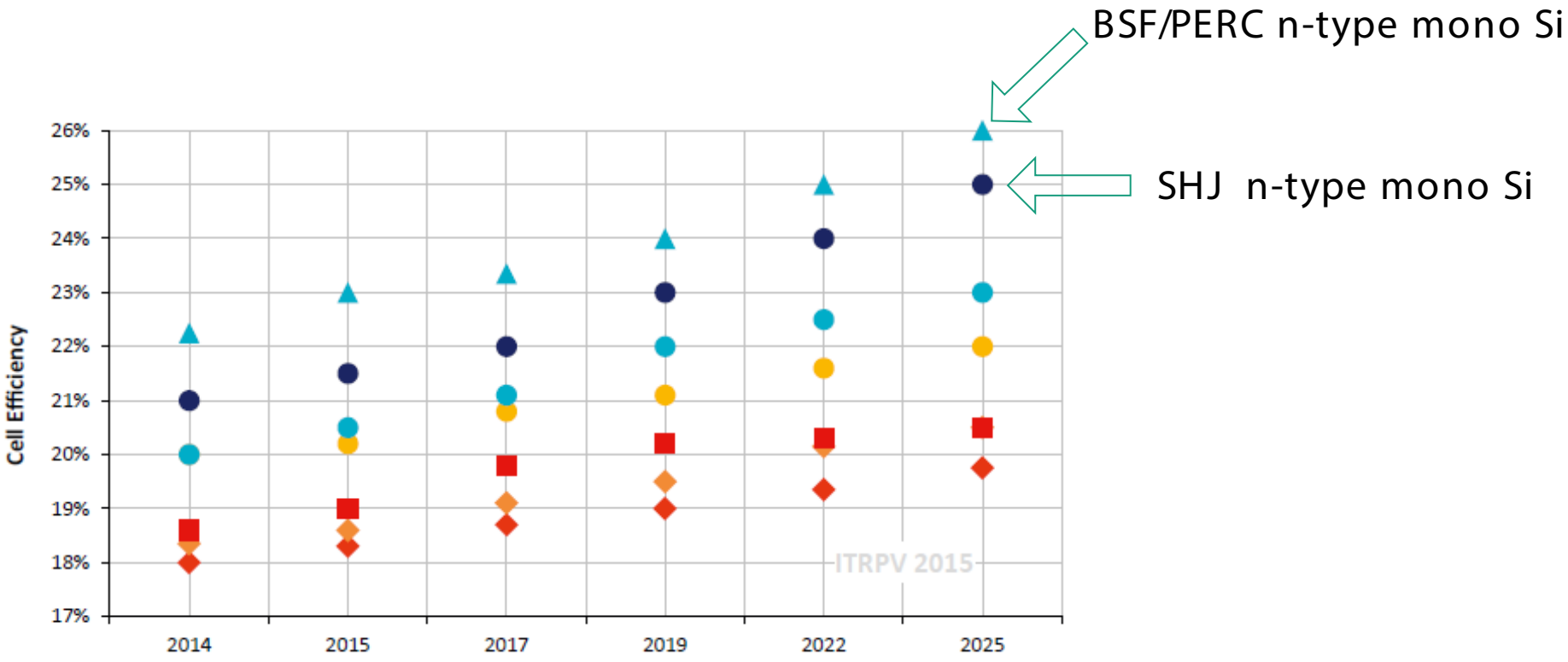
# Paste Vendor for Niche Markets PVN: example AlN substrates


**200 kg per year worldwide**

| Paste | Metal | R/ mOhm/sq | Application |
|---|---|---|---|
| FK 1205 | AgPd | < 25 | R termination |
| FK 1220 | AgPd | < 25 | Acid stable |
| FK 1164 | AgPd | < 25 | Via paste |
| FK 1071 | AgPt | < 6 | Low resistance |
| FK 1282 | AgPt | < 35 | Dealloy stable |

| Paste | Cond. Phase | R/ Ohm/sq | TCR/ ppm/K |
|---|---|---|---|
| FK 9821m | AgPd | 0.1 | ± 100 |
| FK 9831m | AgPd | 1 | ± 100 |
| FK9611 | $RuO_2$ | 10 | ± 100 |
| FK9615 | $RuO_2$ | 50 | ± 100 |
| FK9621 | $RuO_2$ | 100 | ± 100 |
| FK9631 | $RuO_2$ | 1000 | ± 100 |

# 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

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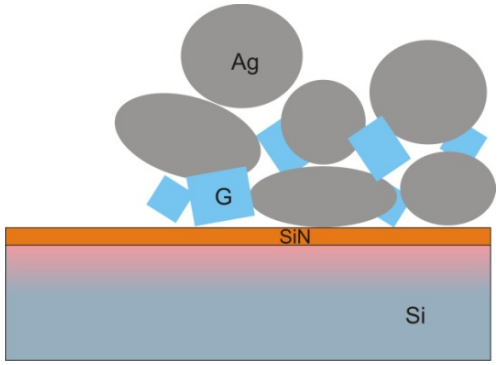
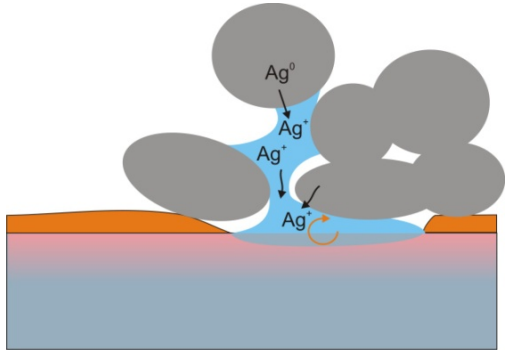
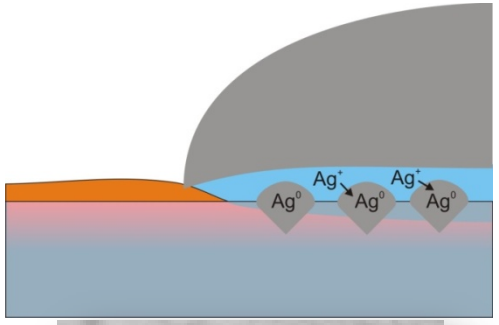
# Conventional pastes for front side metallization

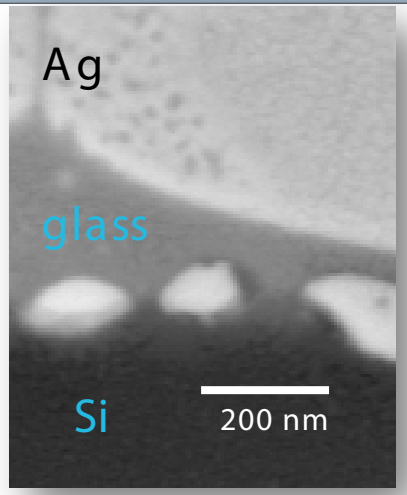



800 °C, some seconds




Cool down




e.g.

K.-K. Hong, S.-B. Cho, J.S. You, J.-W. Jeong, S.-M. Bea, J.-Y. Huh; Mechanism for the formation of Ag crystallites in the Ag thick-film contacts of crystalline Si solar cells, Solar Energy Materials & Solar Cells 93 (2009) 898–90

Li et al., J. Appl. Physics 110, 074304 (2011)

Kulushich, G., B. Bazer-Bachi, et al. (2012 April 03-05). Contact formation on 100 Ω/sq emitter by screen printed silver paste. SiliconPV, Leuven, Belgium.



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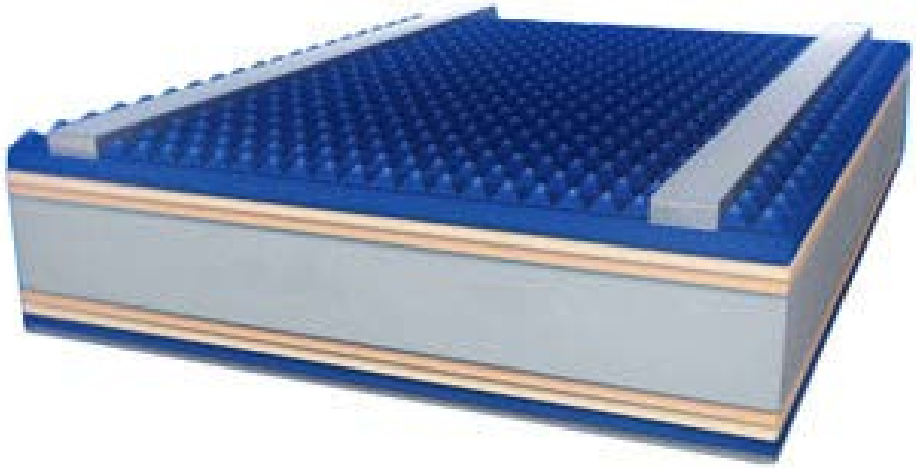
# SHJ cell concept



silver

ITO

emitter: a-Si (p)

passivation: a-Si (i)

base: c-Si (n)

Maximum process temperature ≤ 200°C



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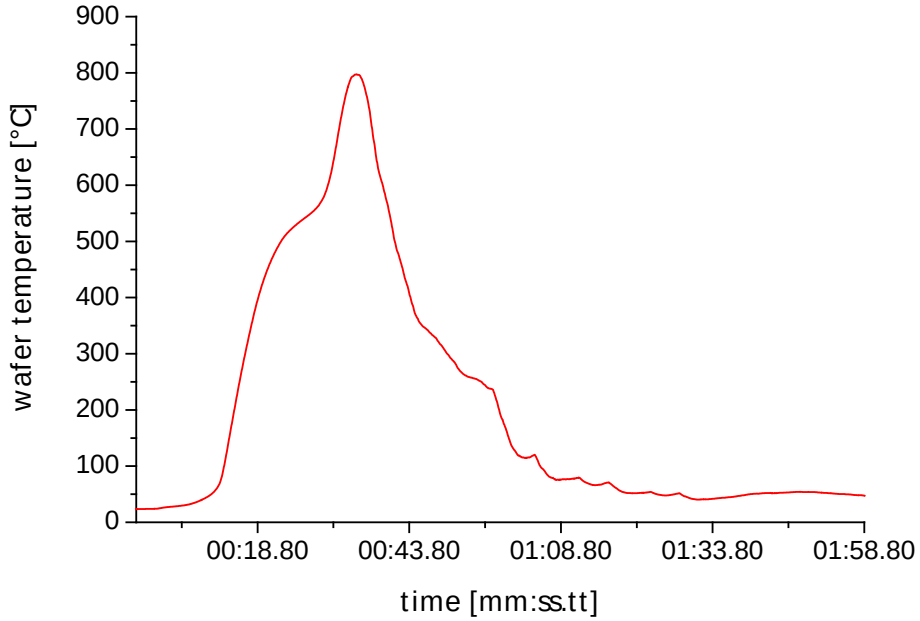
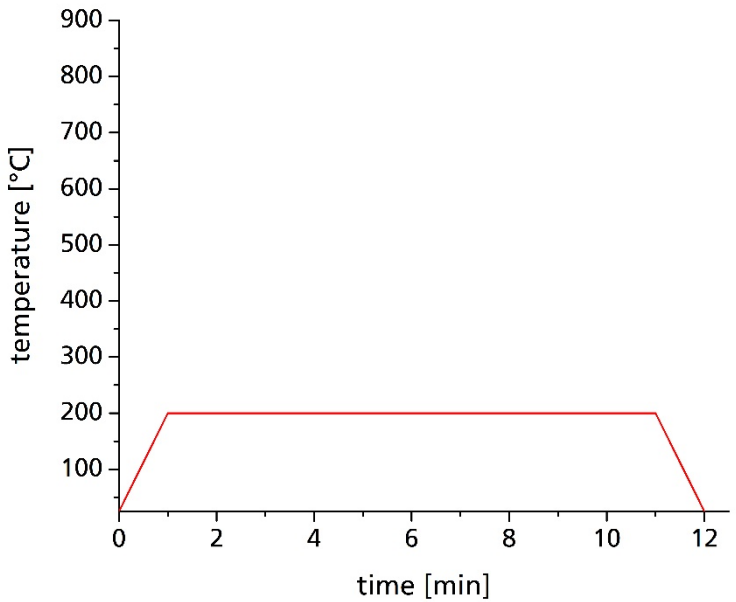
# Low temperature thick film pastes for solar cell metallization




Conductive phase Ag

glass ➔ crucial for adhesion, reactive contact formation, and interface/finger conductivty

Conductive phase Ag or LMPA

polymer → crucial for adhesion and interface/finger conductivity

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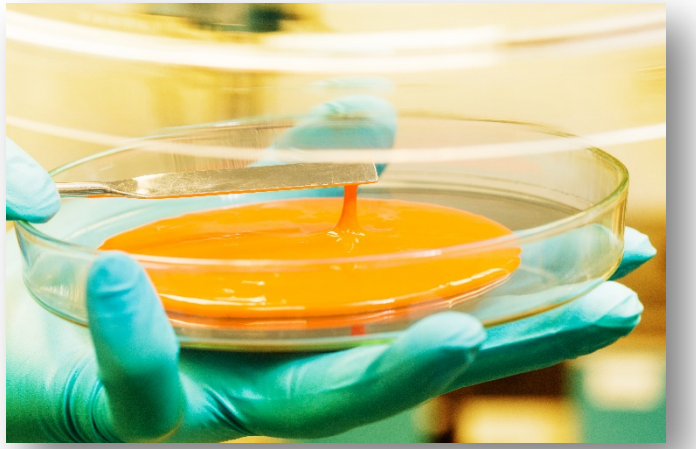
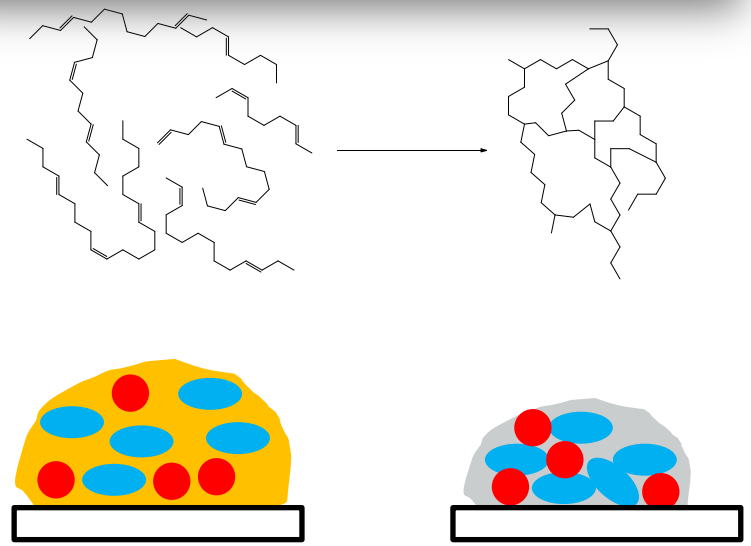
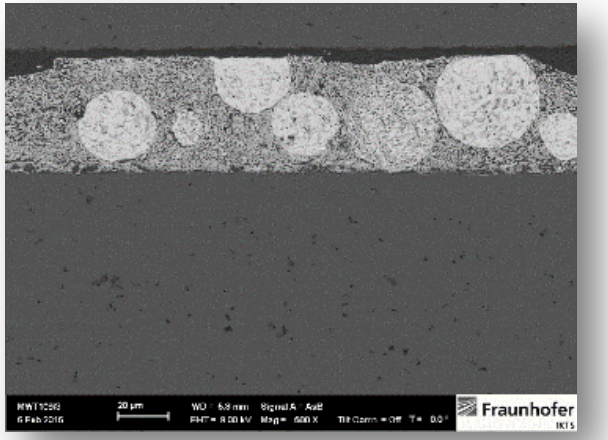
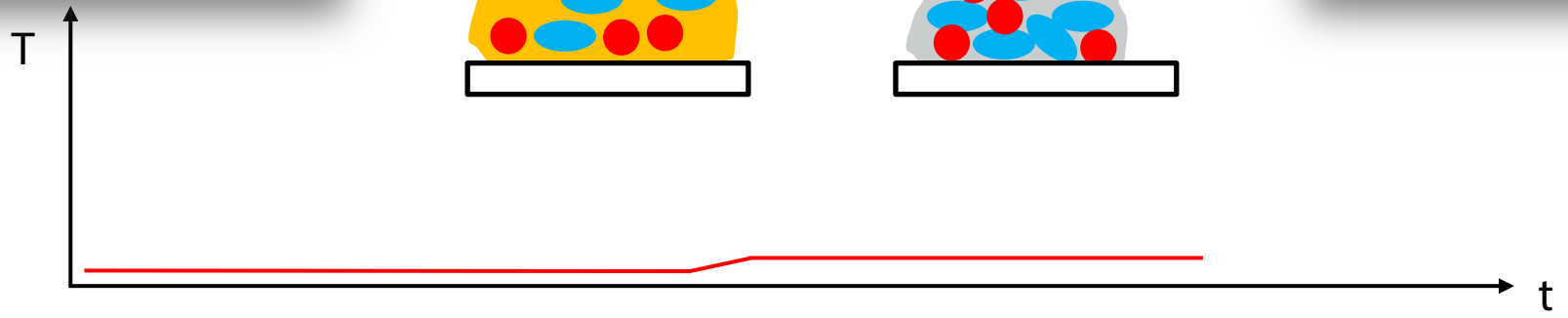
# Processing of low temperature pastes

Thermal (IR or convection; air or nitrogen, 2400 wafers / h, manufactured 2015 by REHM, Germany)







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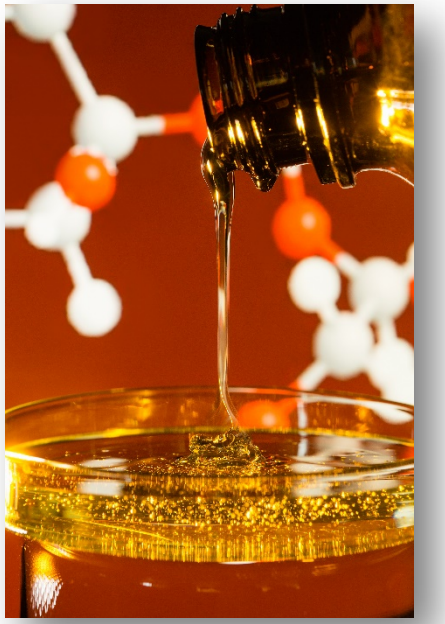
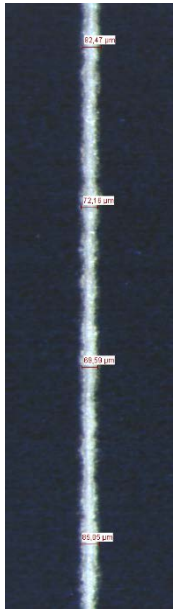
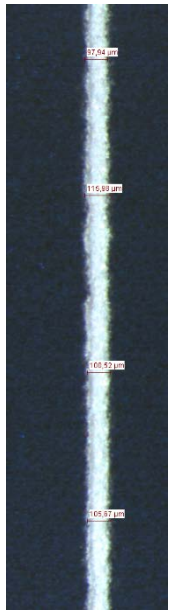
# Low temperature thick film pastes for solar cell metallization

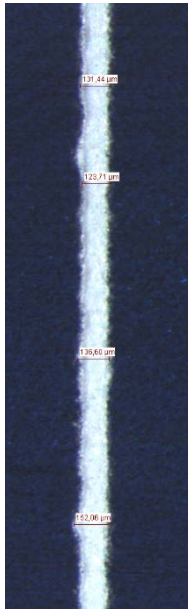




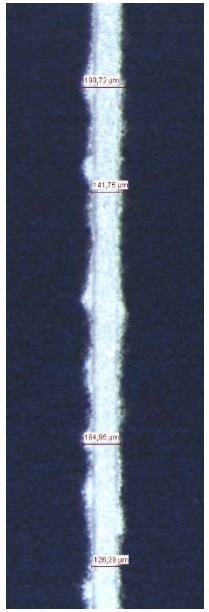
40 µm



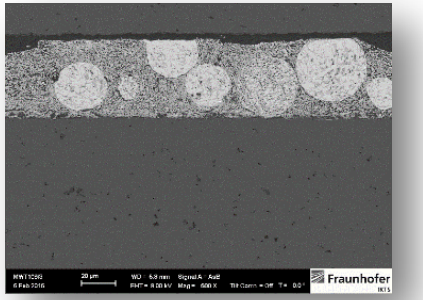
60 µm

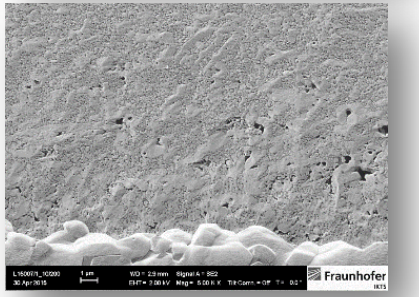


80µm



100 µm




- tuning of curable binder: polymer, solvent

$R_{sq} = 25\ m\Omega/sq$

- conductive phases: Ag mono/polymodal Low Melting Point Alloys (LMPA)



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# Experimental

storage

IKTS paste → fridge 7 °C or RT

commercial paste → freezer -20 °C

→ screen printing

→ convection / infrared

→ characterization

- comparison with reference

- 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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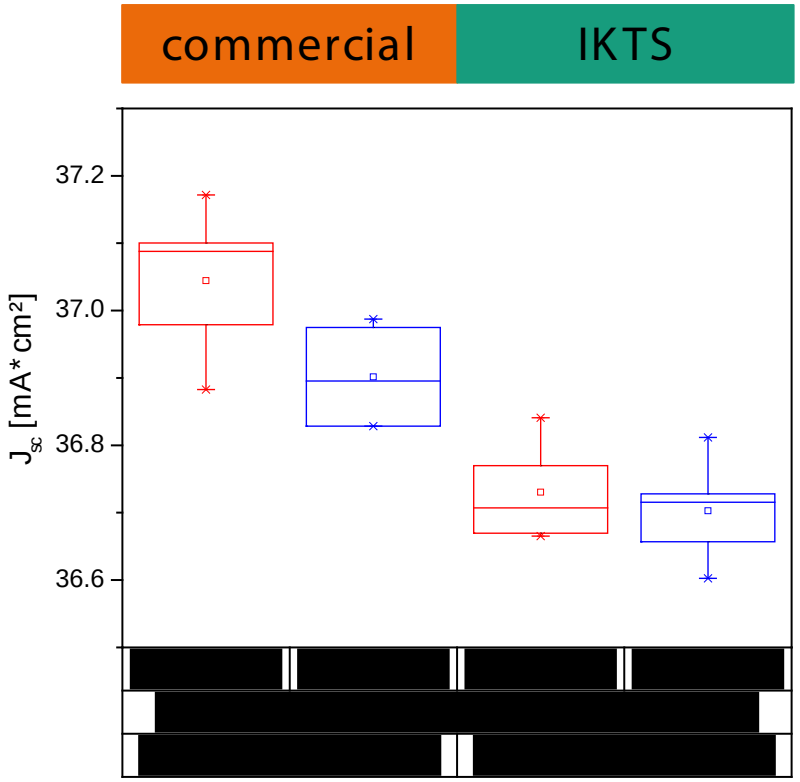
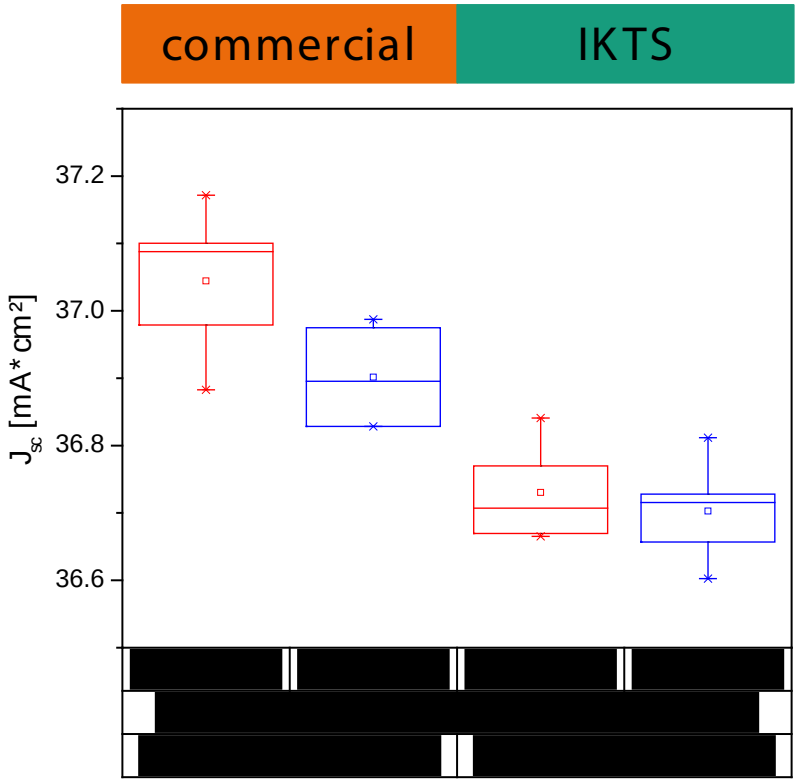
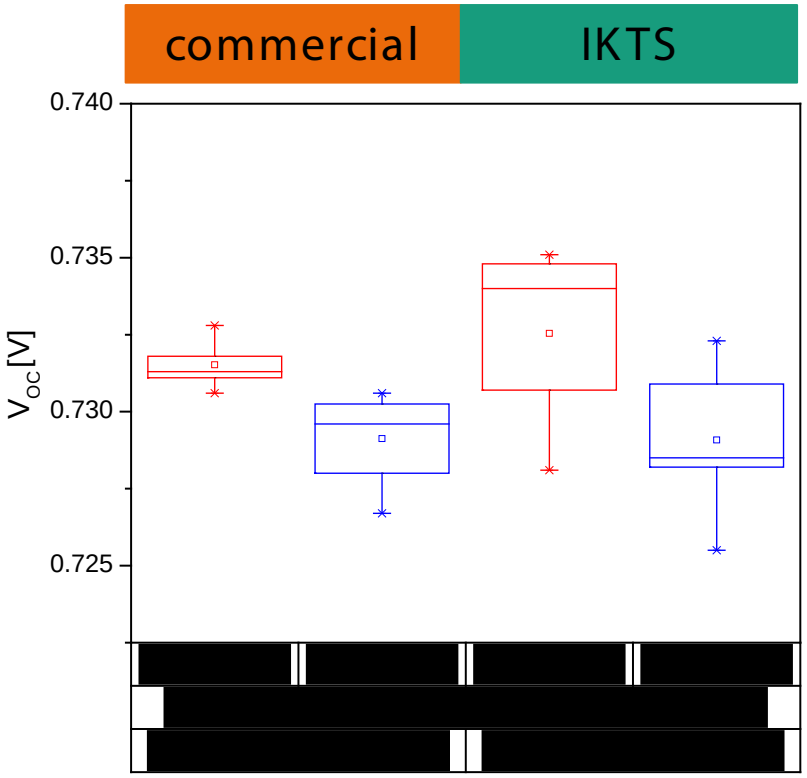
# Electrical performance




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

# Electrical performance

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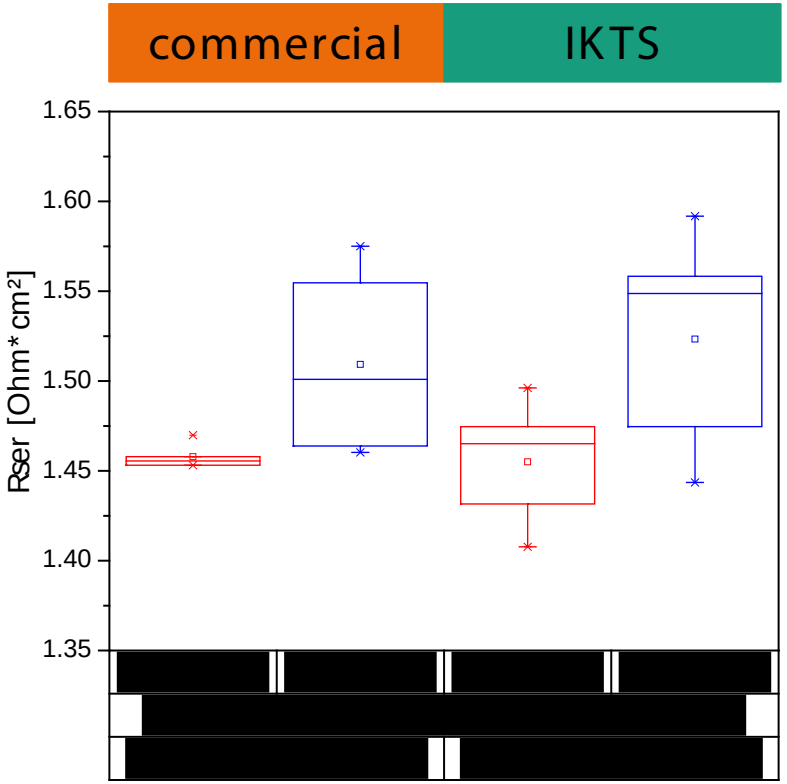
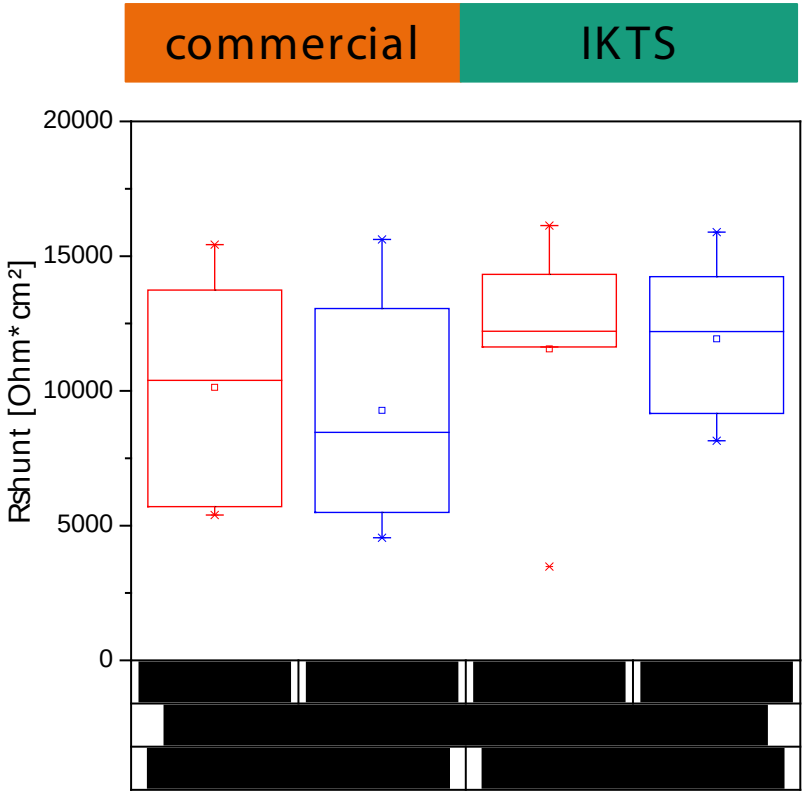
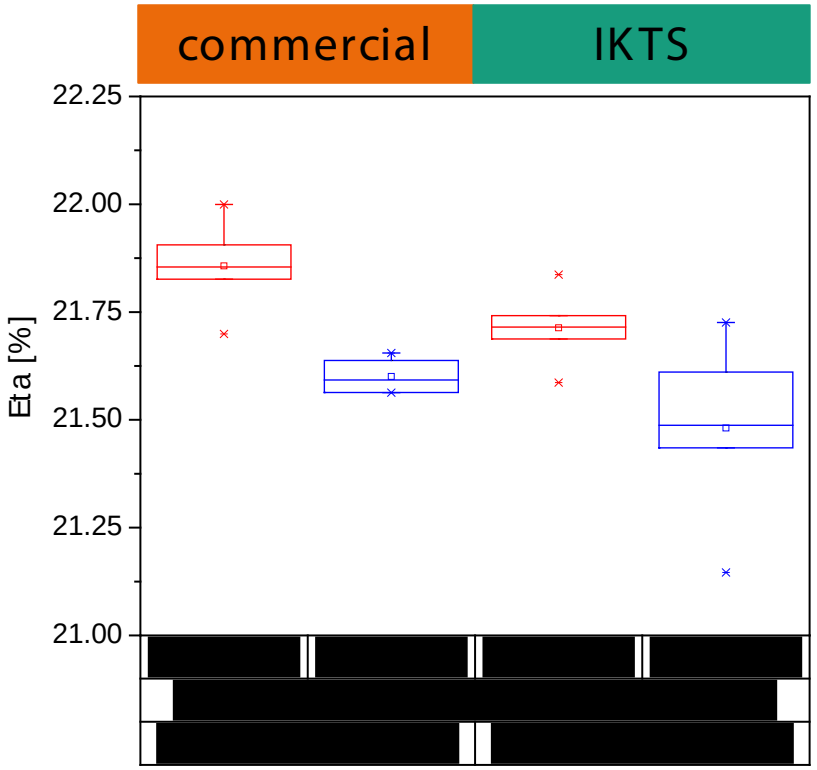
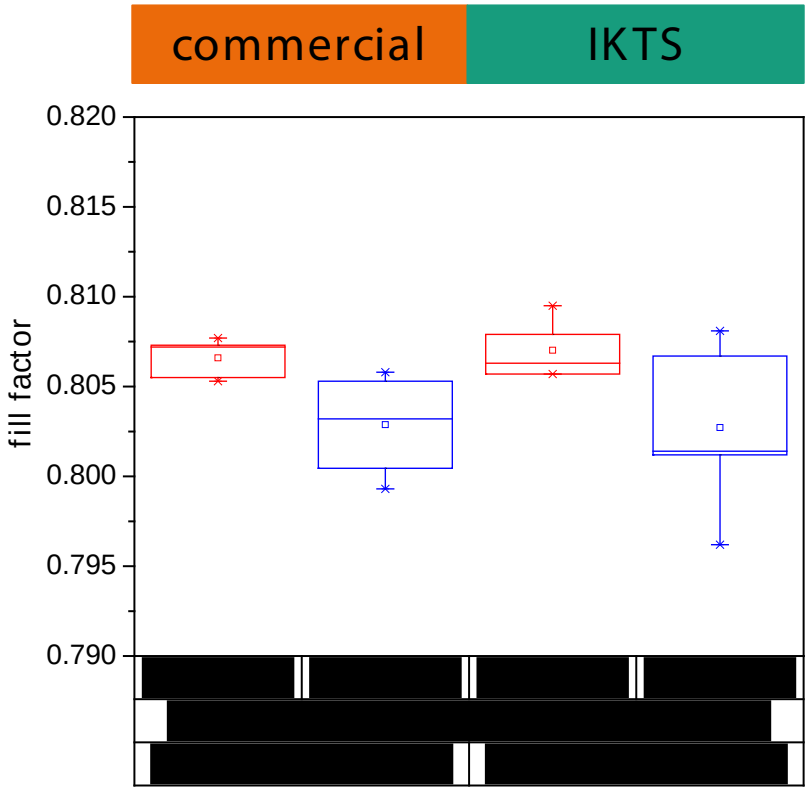



- Series resistances comparable for both pastes
  - Infrared curing provides lower series resistances as well as a lower standard deviation
    - Optimized heat transfer due to coupling of IR radiation

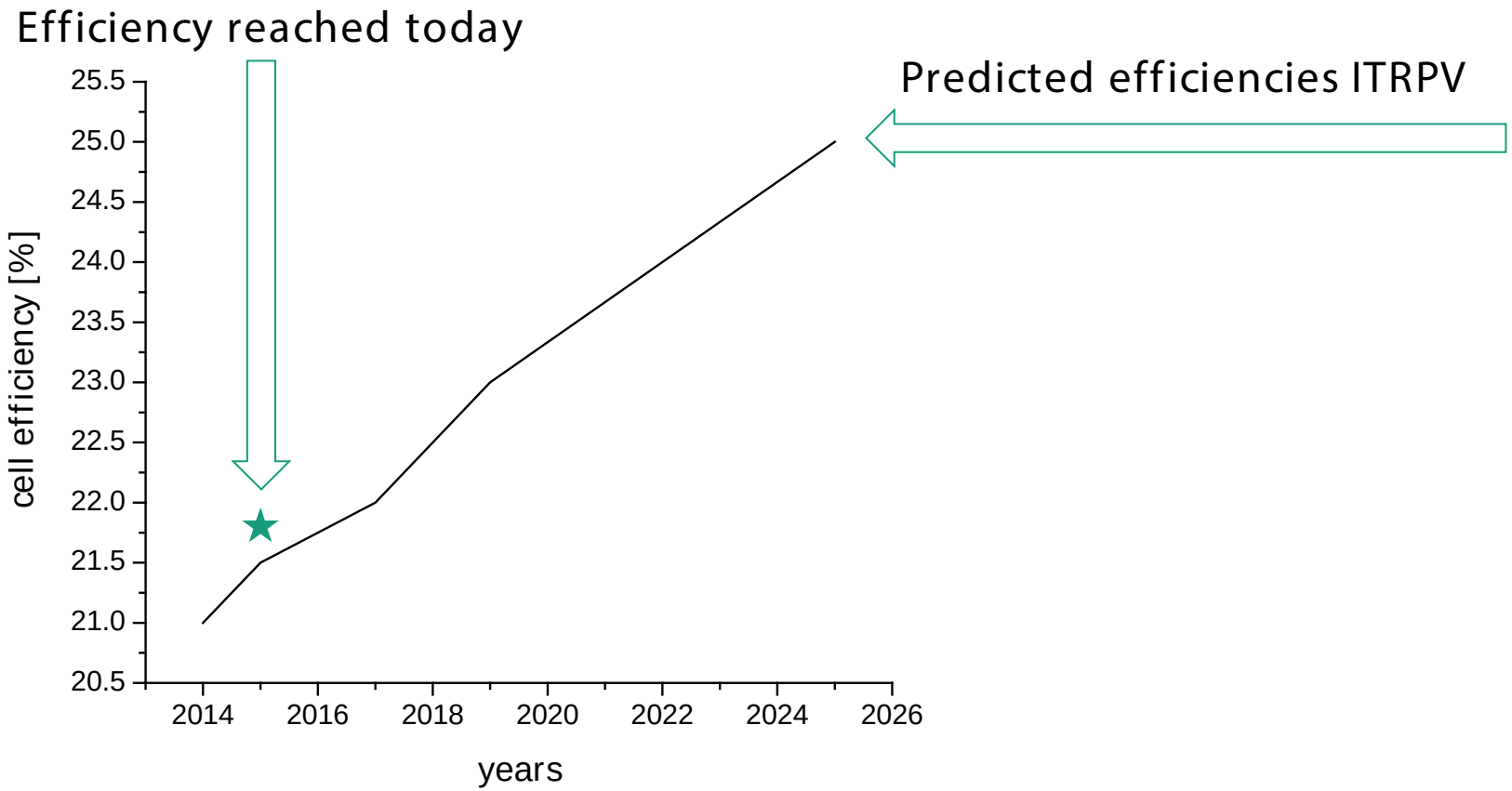
# Electrical performance



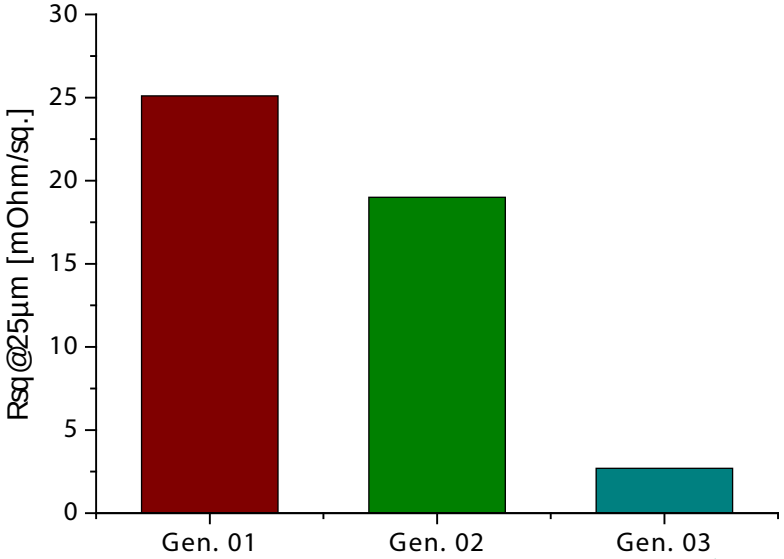



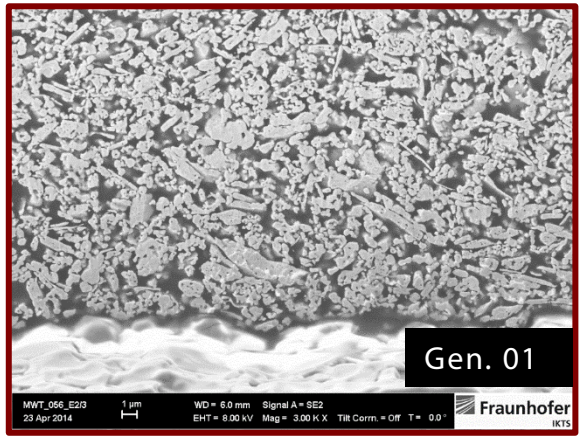

- Efficiency level higher than 21.5 %
  - CC commercial paste 22 % using IR curing → benefit against convection of 0.25 %
  - CC IKTS paste 21.8 % using IR curing → benefit against convection of 0.1 %
- Fill factor constant higher than 80 %

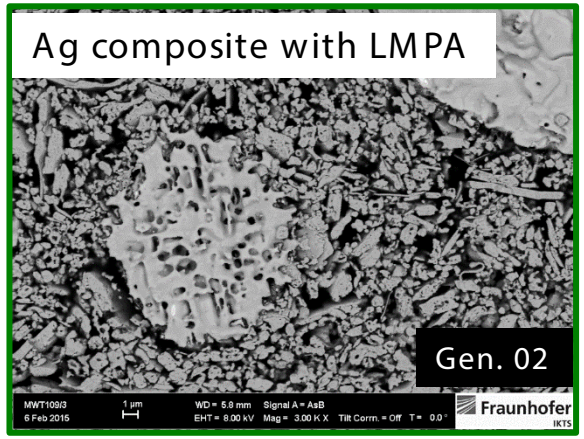
# Presence and future of crystalline silicon solar cell

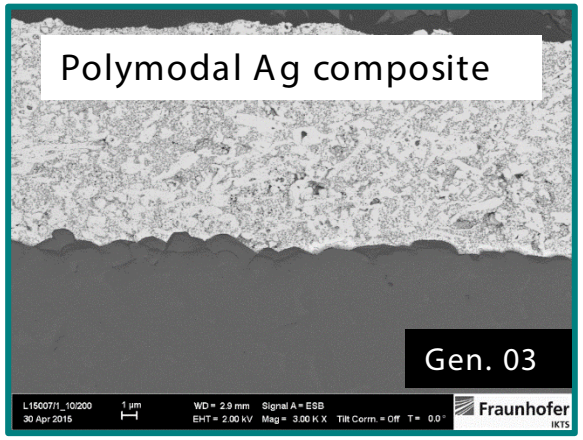


# Performance forecast



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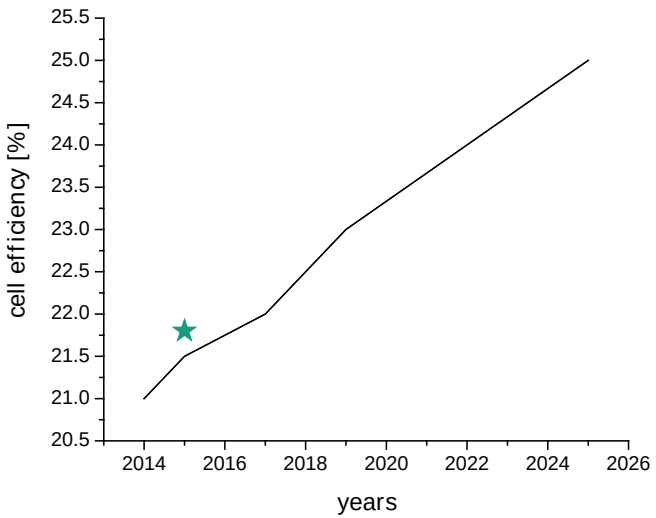
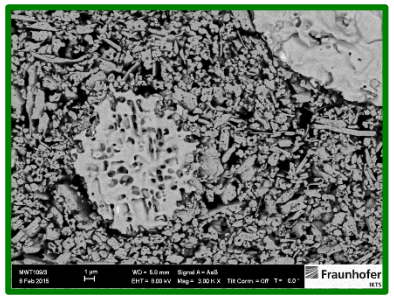
# Summary

- 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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