P-TYPE PASSIVATING CONTACT SOLAR CELLS WITH SCREEN-PRINTED SILVER METALLIZATION

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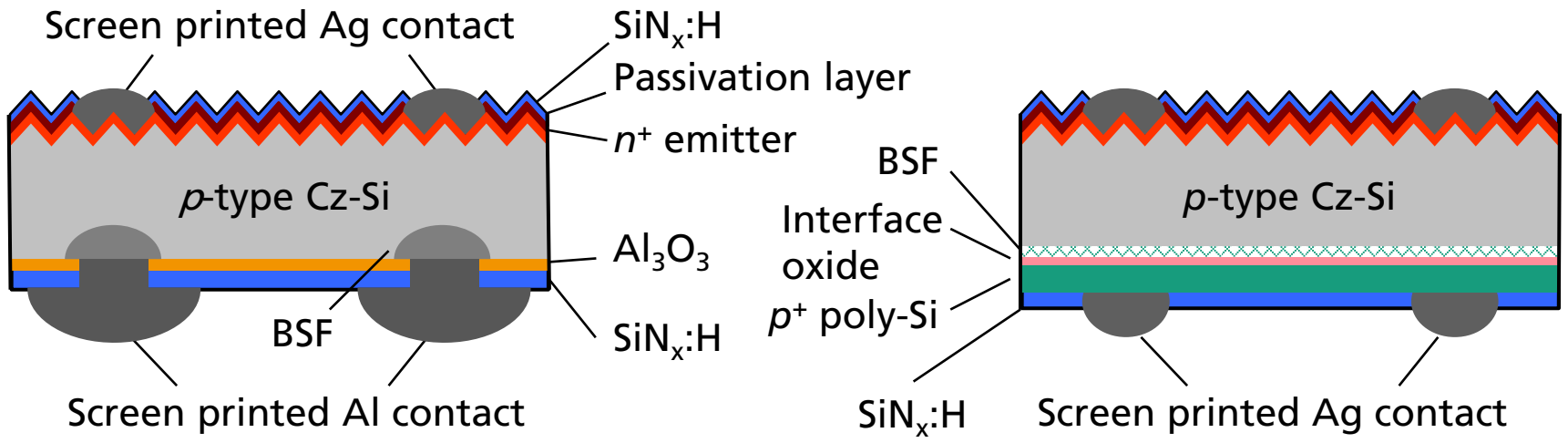
Motivation

- Large interest in solar cells with passivating contact
- Majority of research focuses on n-type passivating contacts
- But: p-type silicon wafers dominate in manufacturing

➔ Replace rear side in bifacial PERC solar cells by passivating contact



PERC: Passivated Emitter and Rear Cell

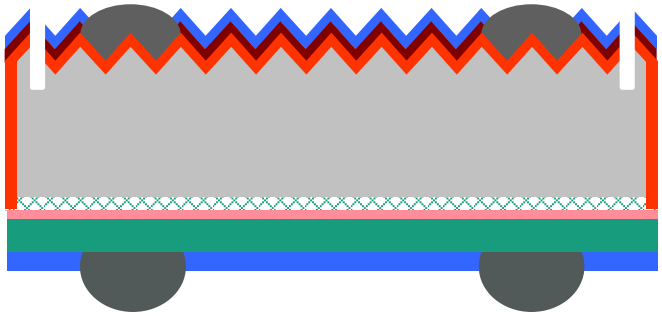
BSF : Back Surface Field

Agenda

- Cell process sequence and related challenges
  - Paste abrasion stability
  - Edge shunt
- Impact of rear grid geometry on contact resistance
  - Experiment and results
- Summary

Process Sequence

- Implementation of LPCVD process in early stage of process sequence
- Established PERC sequence can be almost left unchanged
- Screen printing of commercial Ag paste on both front and rear

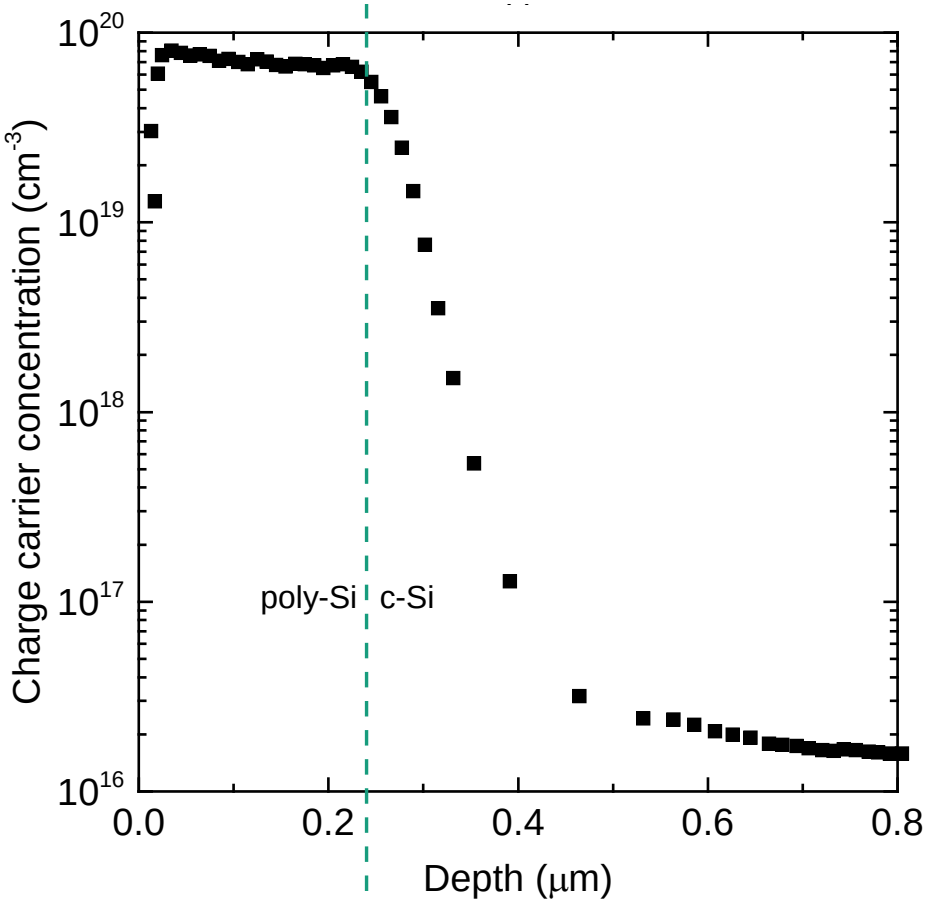


Cz-Si:B wafers
Saw damage etch
Cleaning
Interface oxide + 240nm p^+ poly-Si (LPCVD)
Thermal anneal
SiN_x:H capping layer deposition (rear side)
Alkaline texturing
$POCl_3$ diffusion
PSG removal
Front side passivation
Screen printing (Ag both sides)
Contact firing
Laser edge isolation

LPCVD: Low Pressure Chemical Vapor Deposition

Process Sequence
Profile

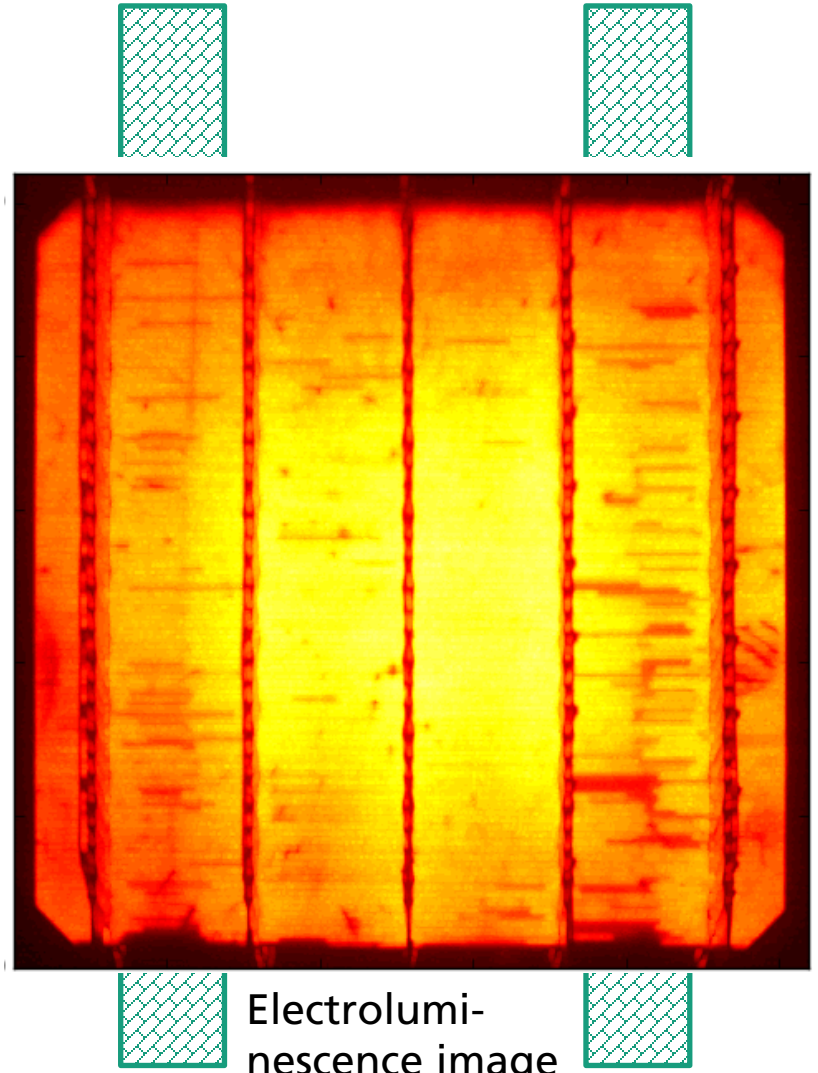
- ECV measurement after thermal anneal
- N_A = 6 to 8*10^{19} cm^{-3} in poly-Si



Process Sequence
Screen printing rear side

- Sequence: SP rear side, drying, SP front side, drying, firing
- Finger interruptions between BBs 1/2 and 4/5 on rear side
- Paste abrasion on rear side by belt transport in automated printing unit during front side Ag printing
- Ag paste not developed for green strength after drying (typically front side printing, no contact to belt)

➔ Workaround by front side printing on semi-automat and manual handling



Electrolumi-nescence image

SP: Screen printing

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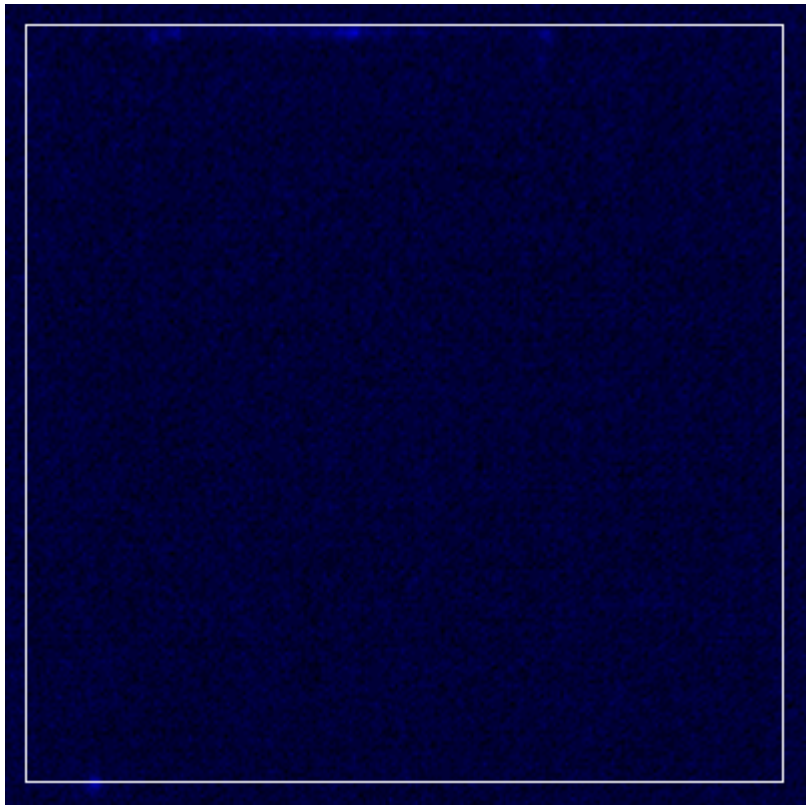
Process Sequence
Edge shunt 5BB cell

- Process sequence does not remove emitter at wafer edge
- Without treatment of wafer edges ➔ shunt ➔ locally increased temperature
- Laser edge isolation ensures no spots of increased temperature



Thermography image

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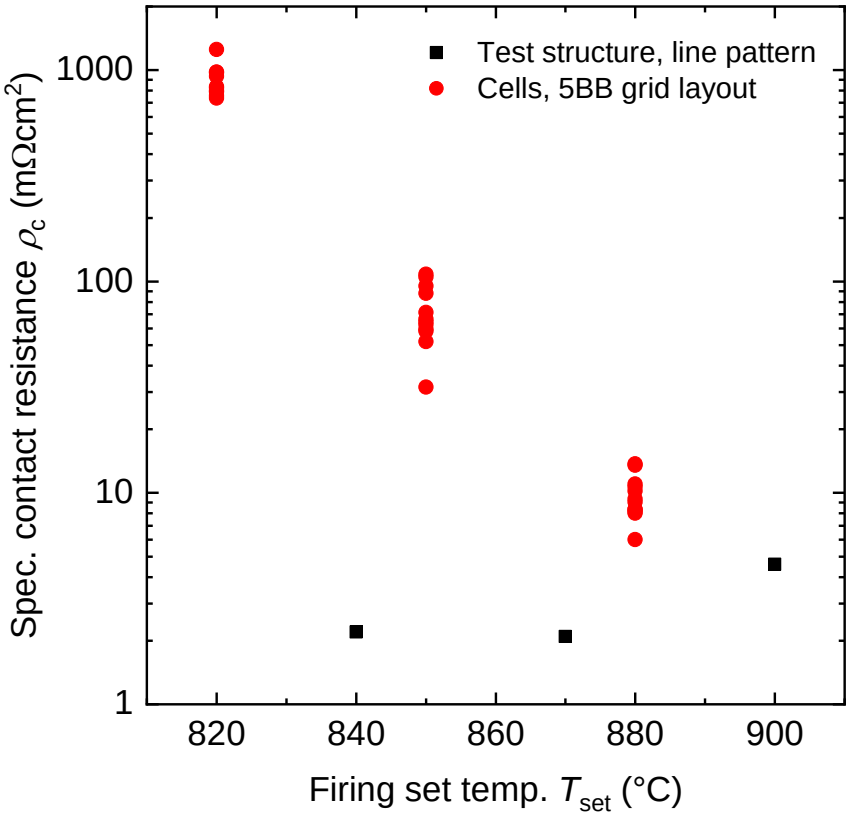
Specific Contact Resistance ρ_c on Rear Side
Literature data

- Test structure with line pattern [1], ρ_c = 2 mΩcm²
- Solar cell with 5 busbar (BB) grid pattern, minimum ρ_c = 9 mΩcm²
- Reason for increased contact resistance?
- Busbar affects contact formation of screen printed Ag paste to diffused profile [2, 3]
- Short-circuit effect during firing changes electron concentration in Si and thus crystallite formation [2, 3]

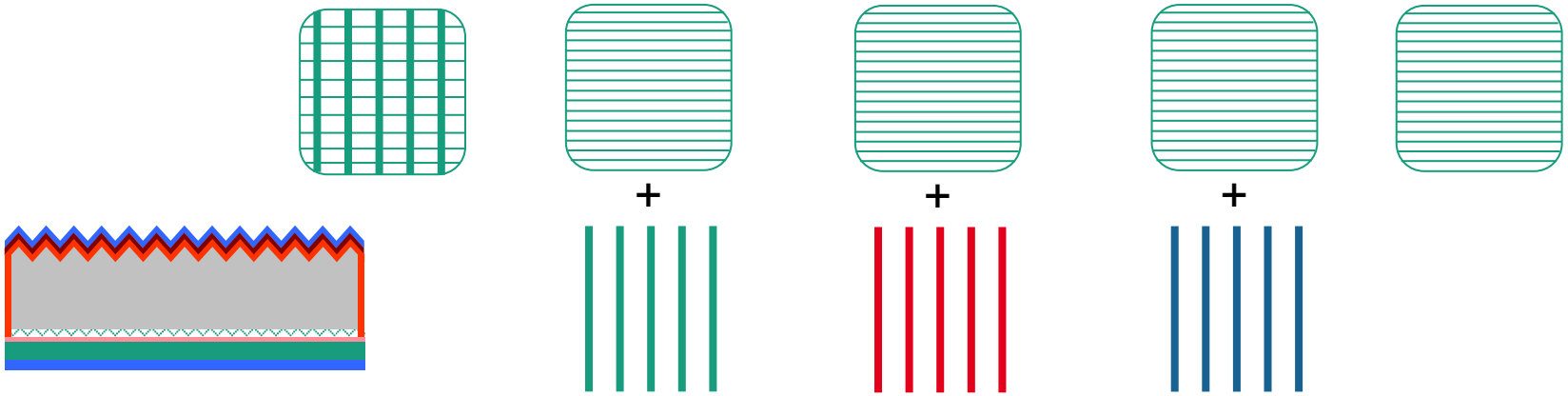
[1]S. Mack *et al.*, RRL 2017, 1700334



[2]H.-S. Kim, Prog. Photovolt: 2016; 24.

[3]H. Chu, IEEE J-PV, 2018, 8, p 923.

Experiment



Gr. 1 | Gr. 2 | Gr. 3 | Gr. 4 | Gr. 5

Cz-Si:B wafers, processed until antireflection coating

Rear side printing

5BB, 101F

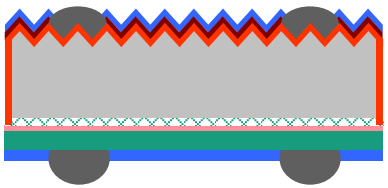
0BB, 150F

5BB, contacting

5BB, non-contacting

Front side screen printing, Ag paste (5BB, 101F)

Contact firing (880, 900, 920°C), fingers perpendicular to transport direction



5BB, LT paste

Curing

F: Finger

LT: Low Temperature

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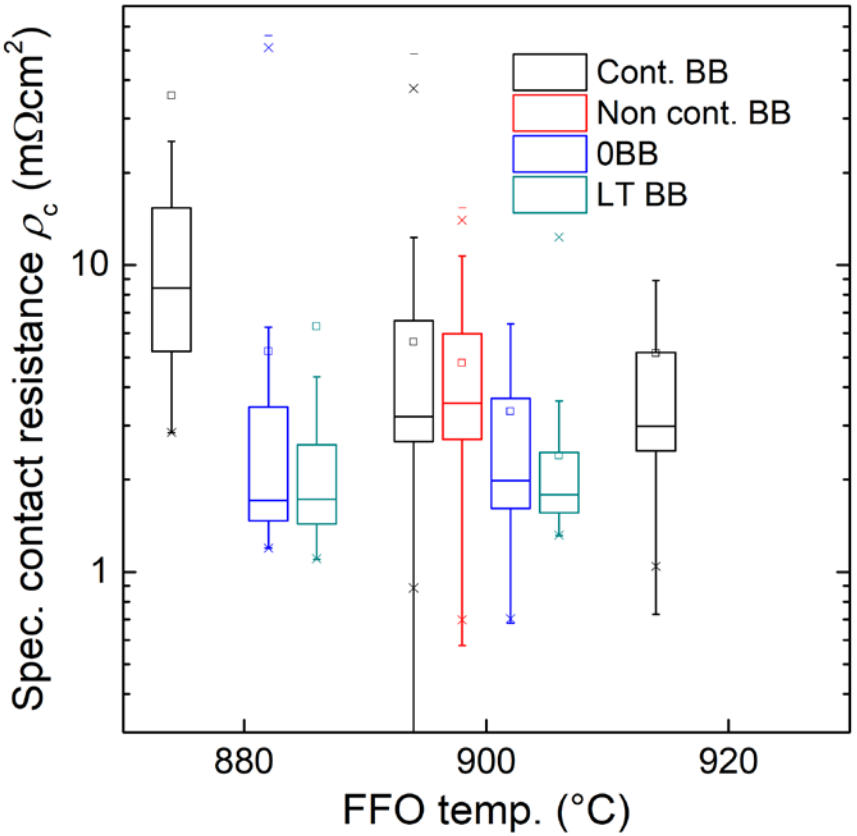
Specific Contact Resistance
Solar cells rear side

- Cont. BB: ρ_c keeps decreasing for higher firing set temperatures
- Non-cont. (but conducting) BB same ρ_c as for contacting BB
- 0BB cells (with redundant line) reduced ρ_c, even at lower T_{set}
- LT BB does not change ρ_c compared to 0BB

➔ 0BB lower ρ_c, wider process window, at lower T_{set} (reduces impact of overfired front side)

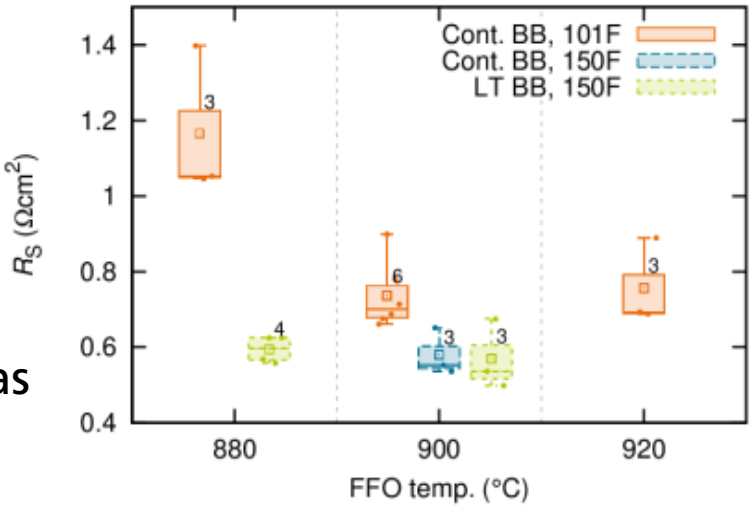


[1]H.-S. Kim, Prog. Photovolt: 2016, 24.

[2]H. Chu, IEEE J-PV, 2018, 8, p. 923.

IV Data
Variation of rear grid

- R_s heavily affected by finger count and busbar type
  - Firing temp. of 900°C needed to achieve acceptable R_s
  - Lower R_s for more fingers
  - Alternatively, LT BB allows same R_s as 5BB cell at lower firing temperature



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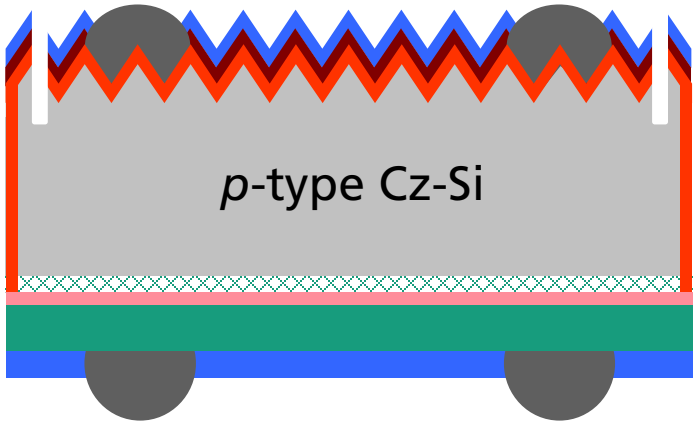
Cell Results

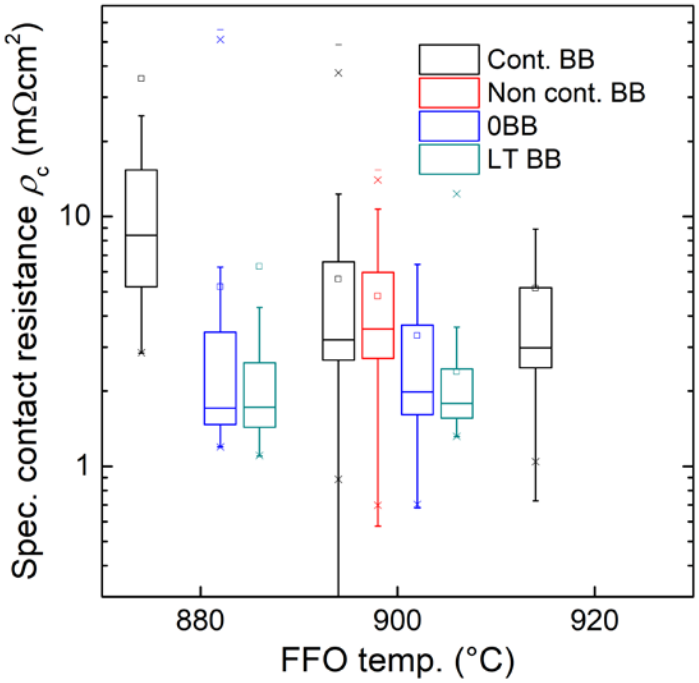
- Cz-Si:B, ρ = 1.65 Ωcm
- 0BB, 120 fingers on both front and rear
- Same screen, same Ag paste
- iV_{oc} = 684 mV without metallization
- η_{calc} = 20.9% expected in next experiment



Best cell	η (%)	V_{oc} (mV)	J_{sc} (mA/cm²)	FF (%)	pFF (%)	R_s (Ωcm²)	$\rho_{c,rear}$ (mΩcm²)
0BB	20.4	659.7	39.3	78.6	82.1	0.7	2.7

Summary

- Absence of busbars strongly reduces contact resistance of screen printed Ag paste to p-type passivating contacts
- Same ρ_c for non contacting (floating) and contacting busbar
- Improvement strategy: Use low temperature busbar or no busbar at all!
- 0BB cell with 20.4% in early stage of process development



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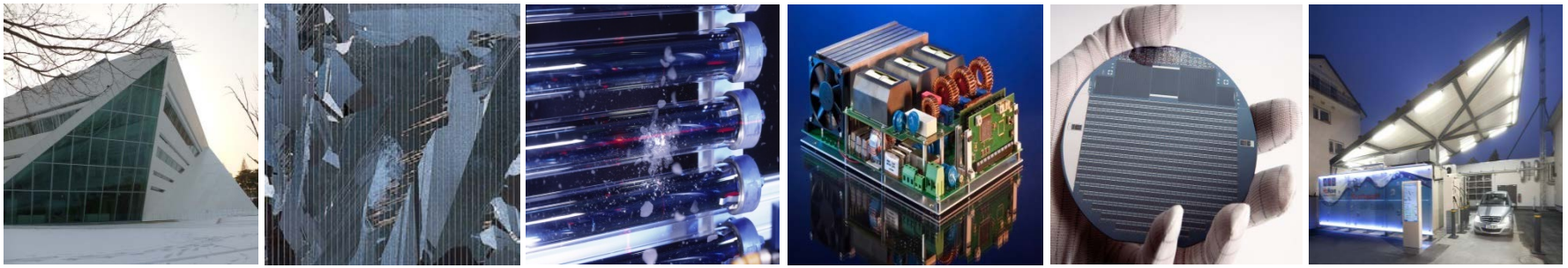
Thank you for your Attention!



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