Precise IV-measurement of busbarless solar cells including process control methods for production

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6th Workshop on Metallization & Interconnection for Crystalline Silicon Solar Cells, Konstanz

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Content

.h.a.l.m.

- Novel solution for contacting busbarless solar cells
- Process control tools
  - Electroluminescence (EL)
  - Grid resistance (GR)
- Reliability of novel busbarless contacting

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h.a.l.m. solution for contacting busbarless solar cells

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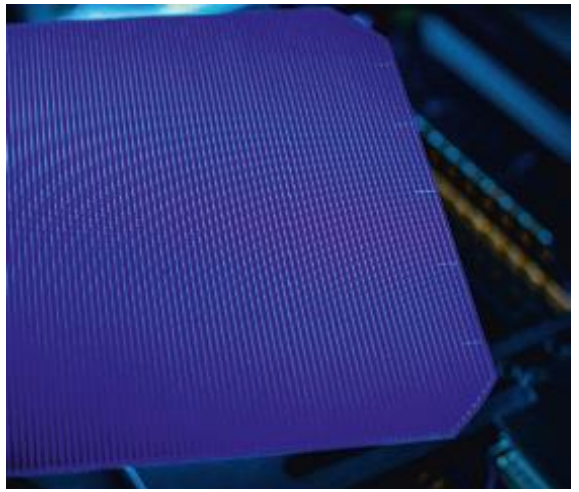
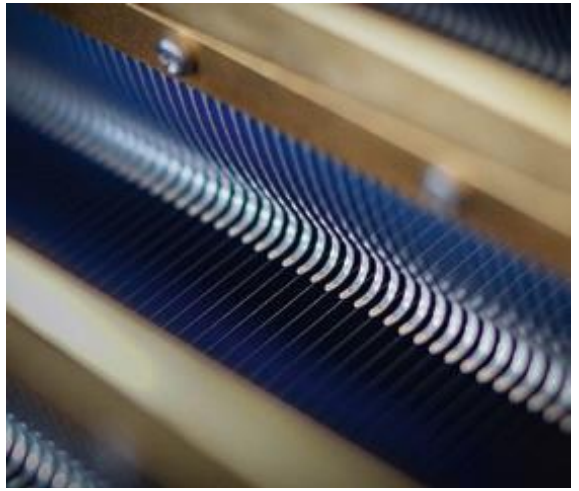
- One elastic contact for each individual finger
- Durable material, no moving parts
- Low point pressure, minimum impact on grid fingers
- Standard contact frame can be used (retrofittable)
- Standard calibration method can be used (transferable)





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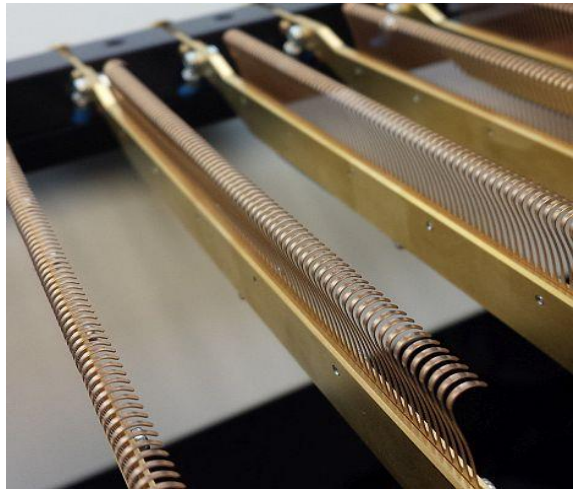
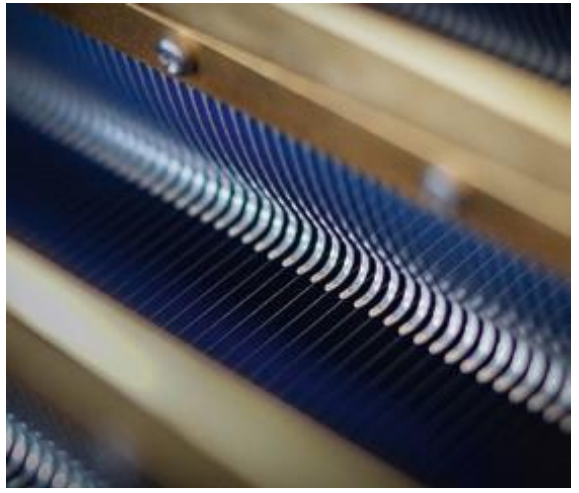
h.a.l.m. solution for contacting busbarless solar cells

- 4-point contact at strips rather than samples
- Enables contacting busbarless cells in mass production
- Low wear part costs and simple wear part exchange
- 4 million contacting events guaranteed





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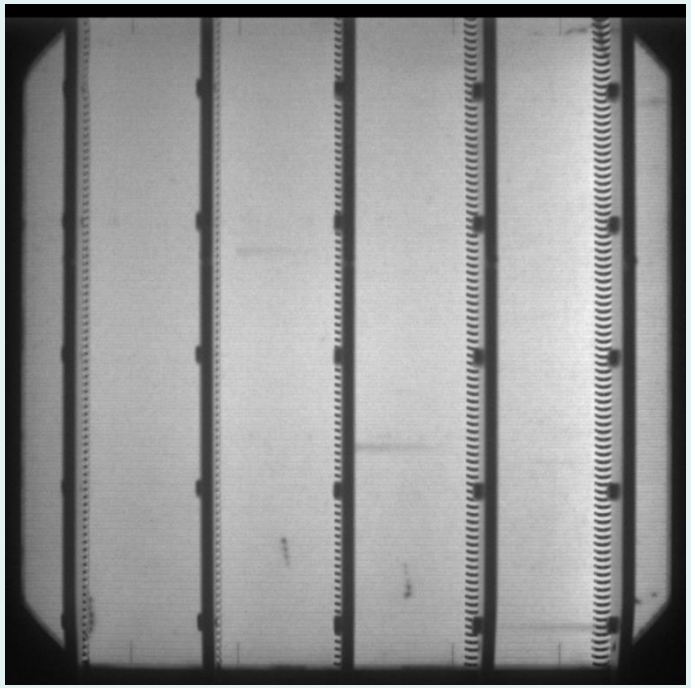
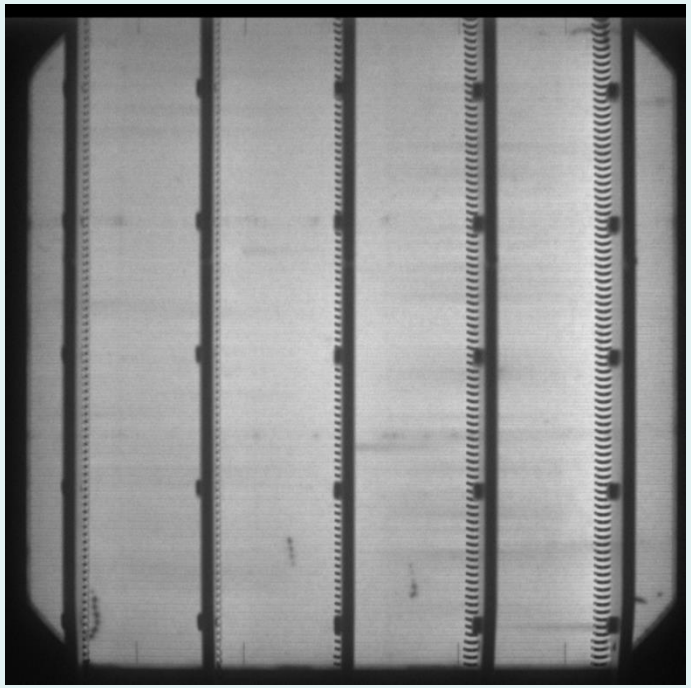
Busbarless contacting results - electroluminescence imaging



12 A



20A

- Measurement of cells contacted many times before (fingers flattened)
- Contact is very homogeneous, only few of 440 contacts which are not ok

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Busbarless contacting results - electroluminescence imaging

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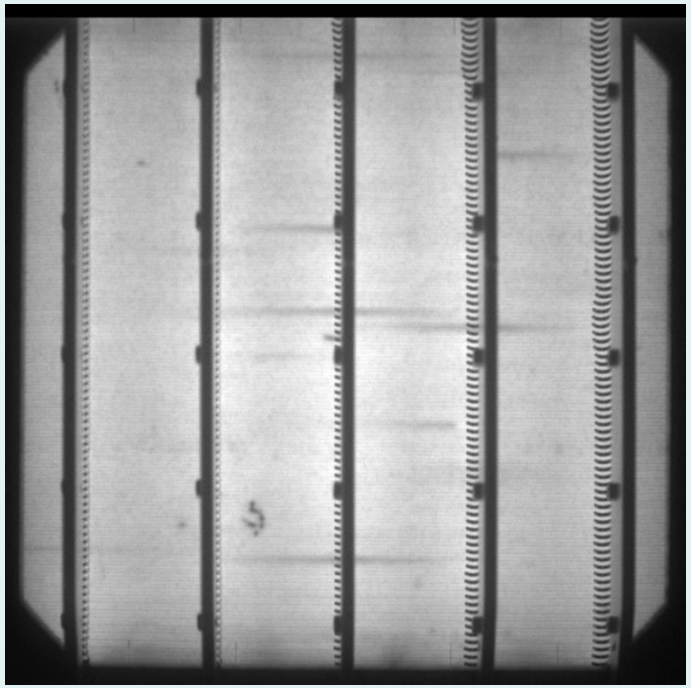
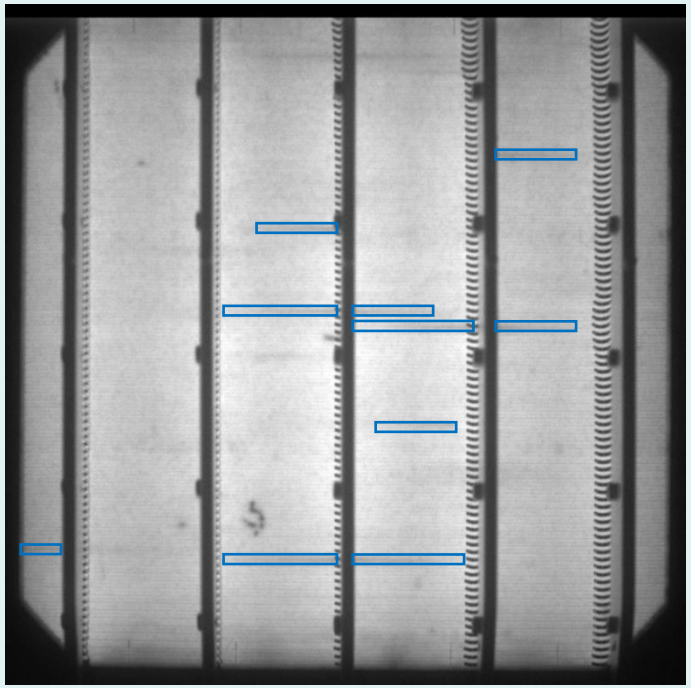


20A (different cell)



automated defect detection

- Measurement of cells contacted many times before (fingers flattened)
- Contact is very homogeneous, only few of 440 contacts which are not ok

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Busbarless contacting results - electric

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- FF around 80 %

	Voc [V]	FF [%]	Rser [Ω]	Sser [Ωcm²]
Cell 1	0.6621	79.96	0.00240	0.573
Cell 2	0.6569	80.13	0.00233	0.556
Cell 3	0.6531	79.44	0.00247	0.590
Cell 4	0.6604	79.93	0.00259	0.620
Cell 5	0.6608	80.26	0.00239	0.572

- FF and series resistance values confirm the good contacting quality

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Calculation of cell-to-module factor

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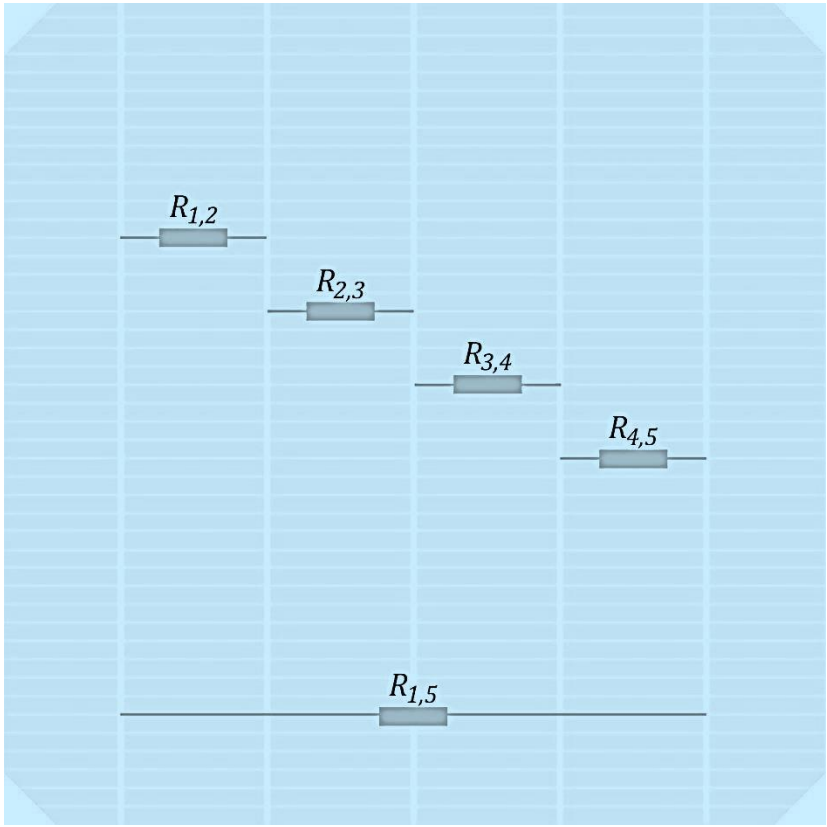
Grid resistance measurements

- Measurement of resistance between any combination of two busbars
- Up to five busbars or contact strips
- Calculation of cell-to-module factor for various numbers of connecting wires



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Description of test

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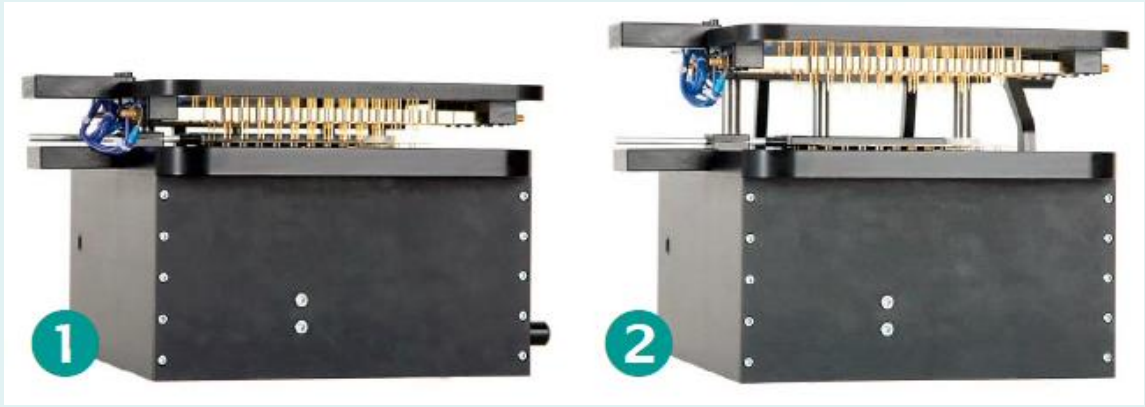
- Busbarless contacting unit is used for about 4 million contacting events in an automated cell test
- To wear down contacting probe, dummy cells are used
- Every 500,000 contacting events, the contact strips are examined using reference groups



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Description of test - samples

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Group with dummy cells	Reference group 1 and 2	Reference group 3 (Golden reference)
Used to wear down contact probes	Used for IV and EL measurements	
No IV measurements	Mono p-Si PERC type cells of very high quality, according to producer LID free	
	Measured approximately after every 500,000 contacting events of contacting probes	Measured only at the beginning and end of test (a few cells measured at the second last IV measurement)
	The same measurement recipe and the same calibration cell is used throughout the test	

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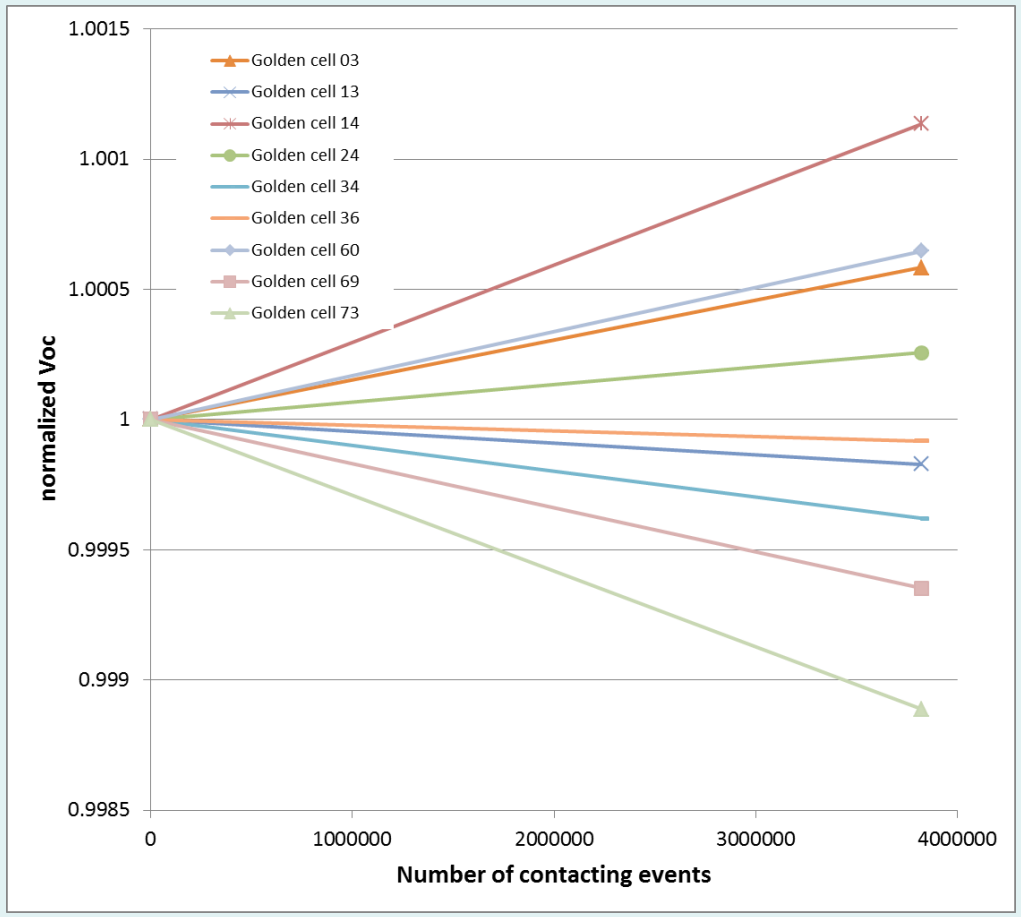
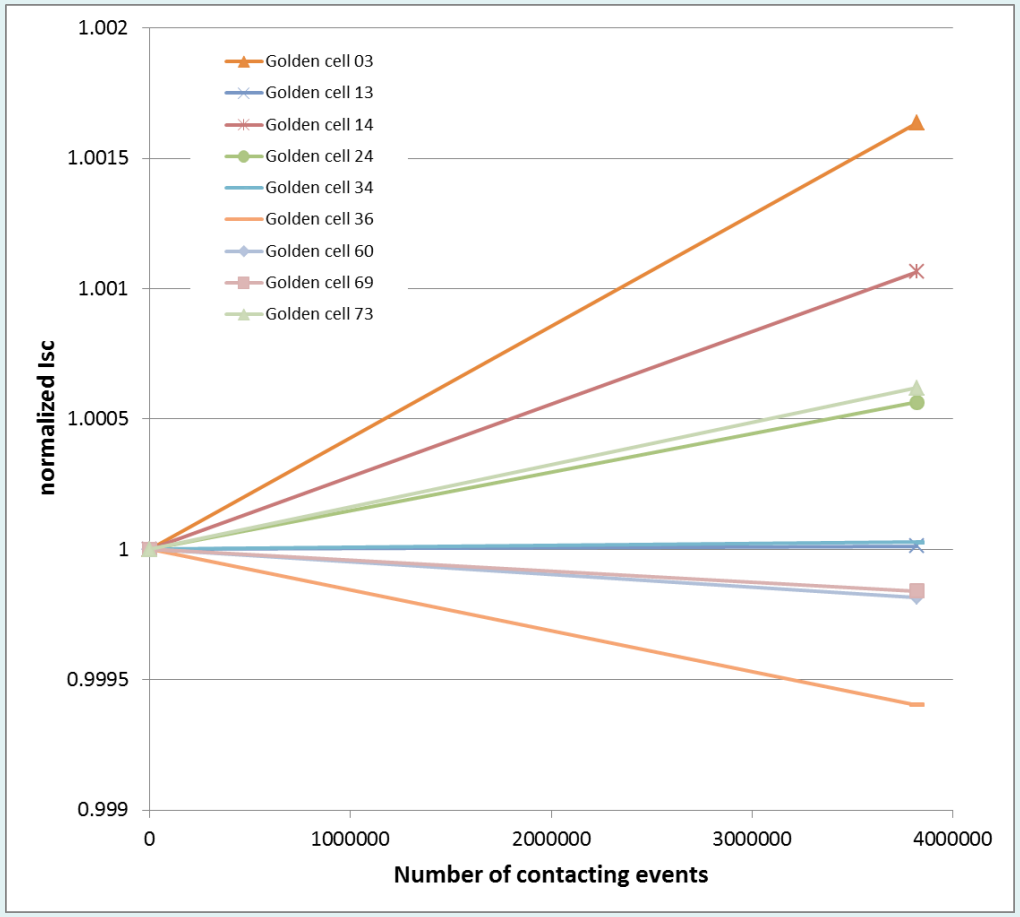
Results of IV-measurements of golden reference





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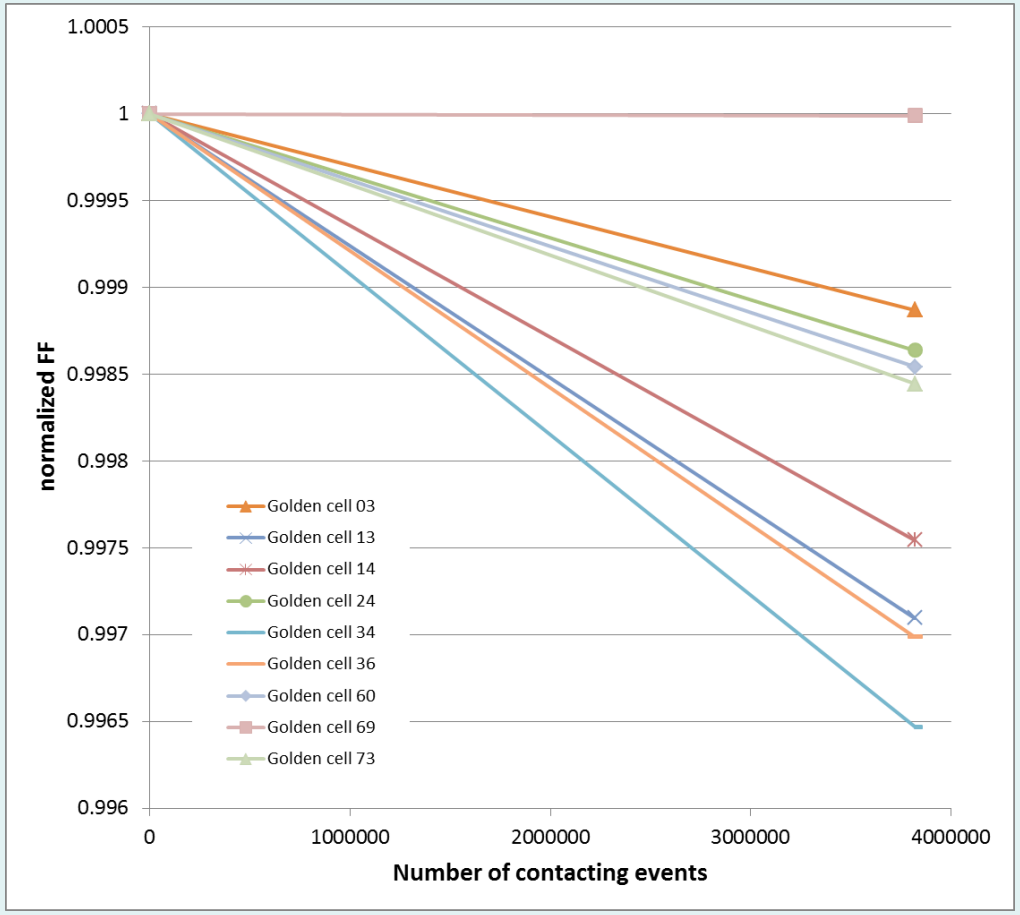
Results of IV-measurements of golden reference

- FF – losses between 0 and 0.35 %rel.
- Average ΔFF is -0.19 % rel. (-0.15 %abs.)



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Results IV measurements

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Group with dummy cells	Reference group 1 and 2	Reference group 3 (Golden reference)
	3.82 million contacting events	
No IV measurements	10 measurements	2 measurements
		Difference (end – beginning) ΔFF = -0.154 %abs.
		ΔR_{Ser} = 4.5 % (2.57 -> 2.69 mΩ)
		ΔEta = -0.04 %abs.

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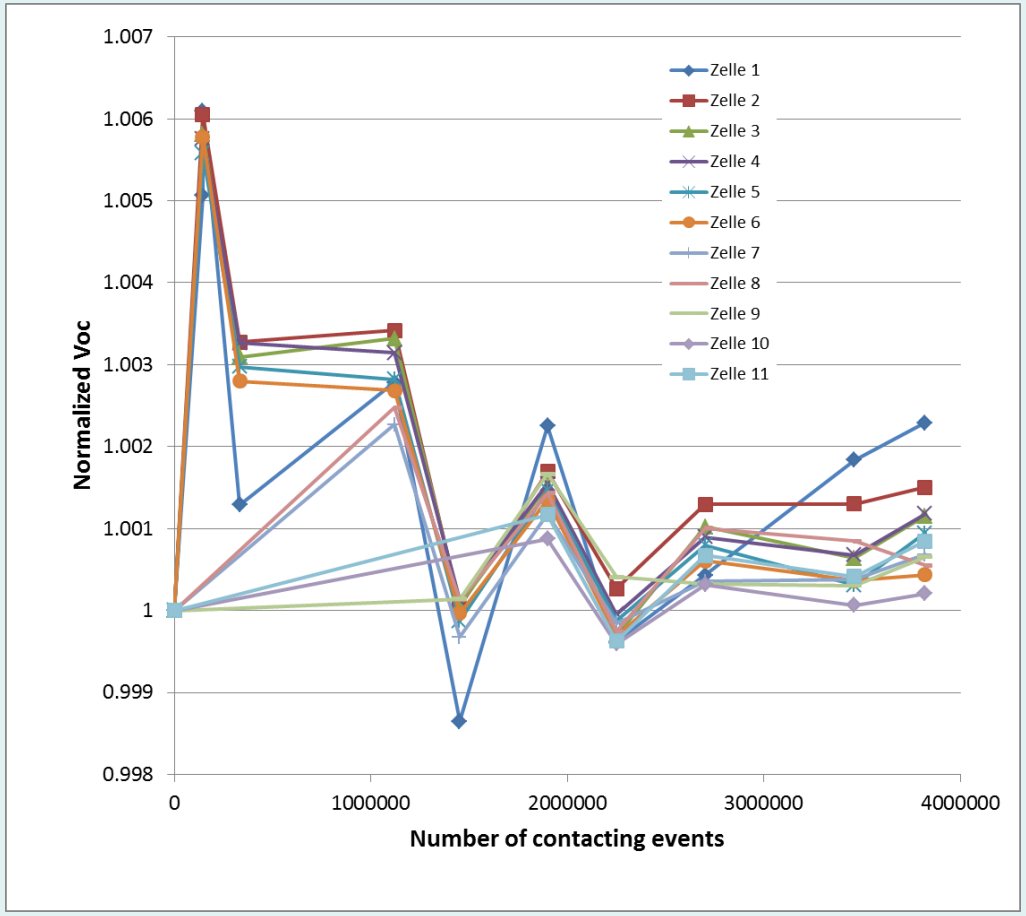
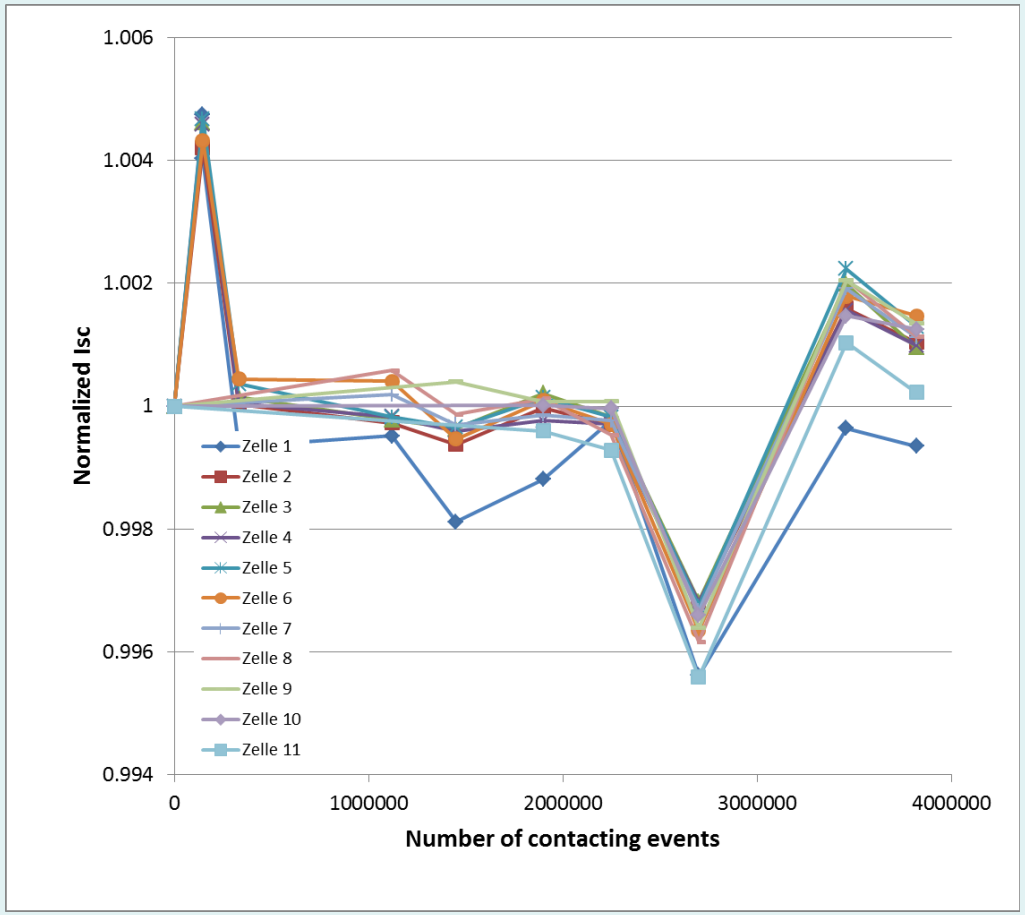
Results of IV-measurements of reference 1 and 2





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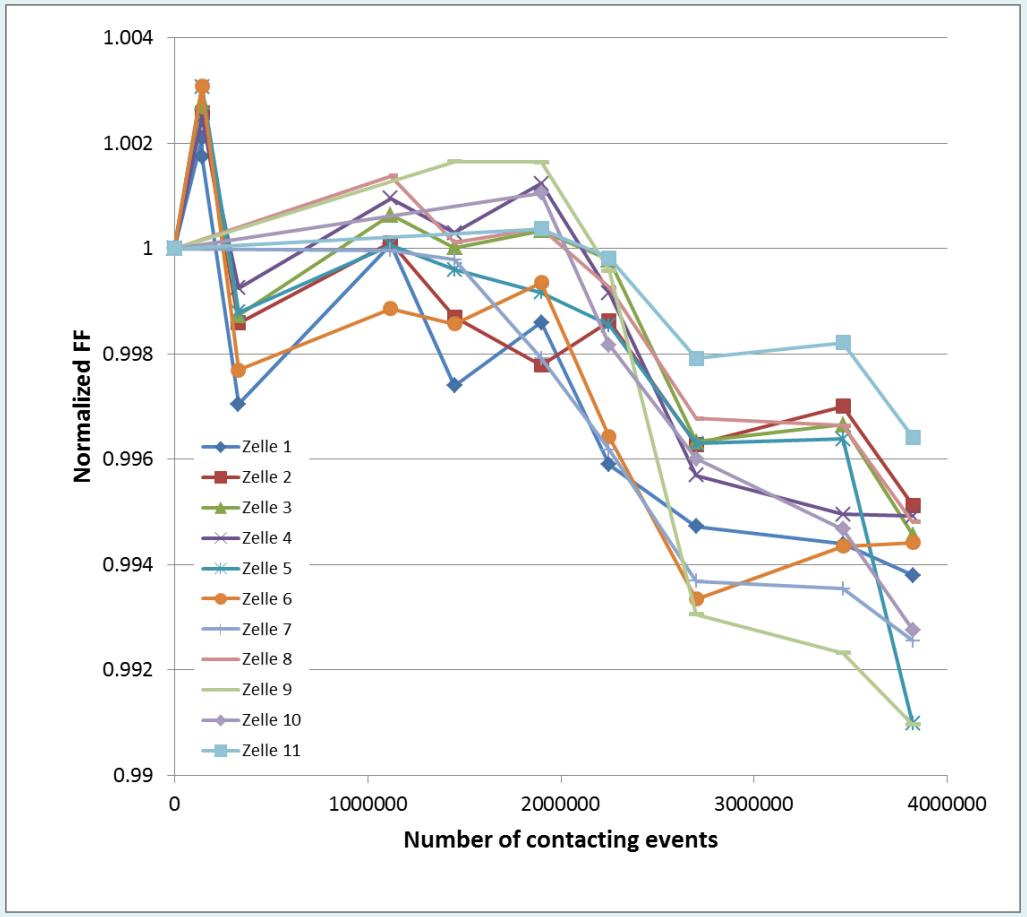
Results of IV-measurements of reference 1 and 2

- FF – losses between 0.4 and 0.9 %rel.



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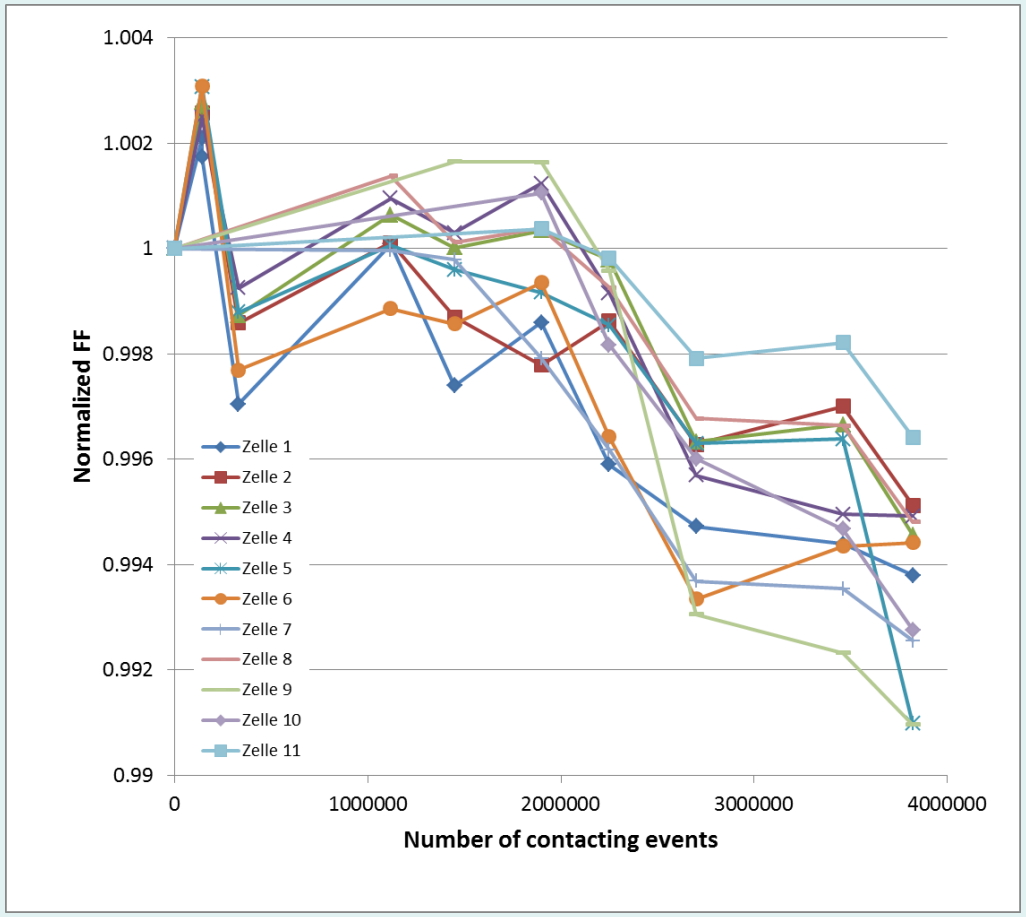
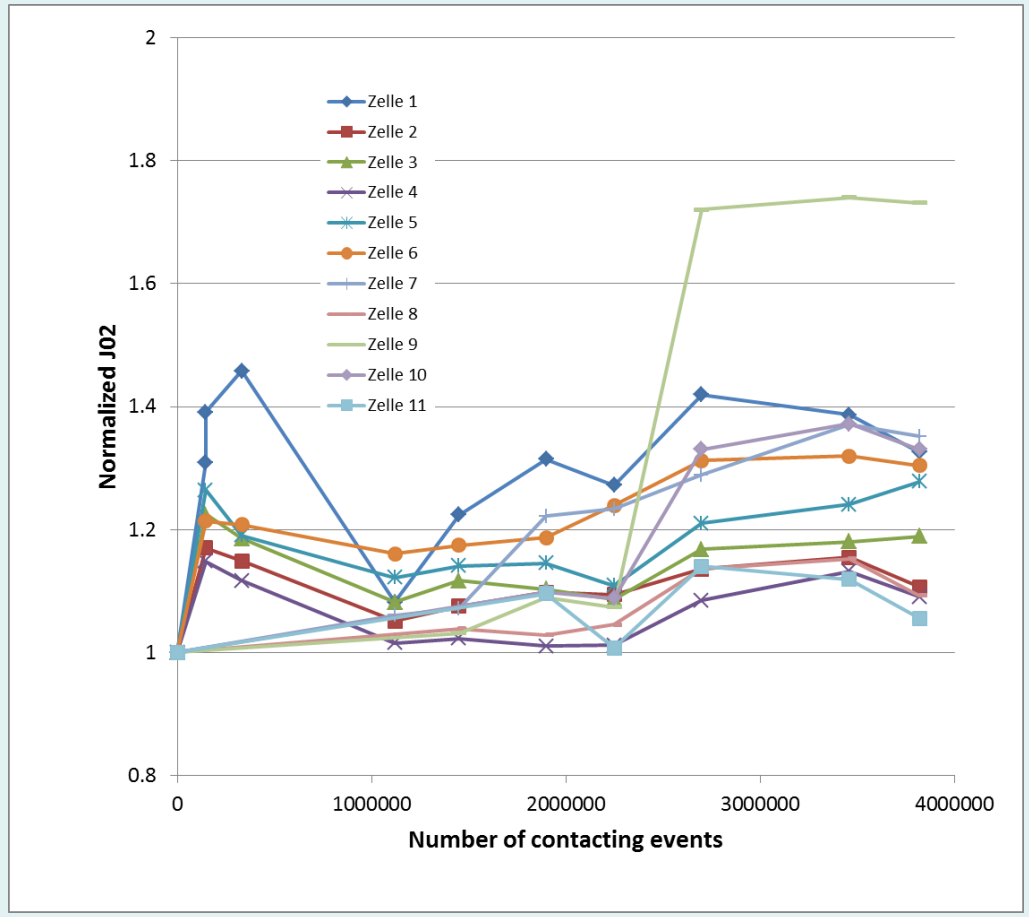
Results of IV-measurements of reference 1 and 2

- FF – losses between 0.4 and 0.9 %rel.
- J_{02} – gains between 5 and 70 %rel.





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Results IV measurements

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Group with dummy cells	Reference group 1 and 2	Reference group 3 (Golden reference)
	3.82 million contacting events	
No IV measurements	10 measurements	2 measurements
	Difference (end – beginning) ΔFF = -0.495 %abs.	Difference (end – beginning) ΔFF = -0.154 %abs.
	ΔR_{Ser} = 6.3 % (2.61 -> 2.78 mΩ) => Causes ΔFF = -0.18 %abs.	ΔR_{Ser} = 4.5 % (2.57 -> 2.69 mΩ) => Causes entire ΔFF
	ΔJ_{02} = 23 % (10.2 -> 12.5 nA/cm²) => Causes ΔFF = -0.32 %abs.	ΔJ_{02} = 0.5 % (7.06 -> 7.09 nA/cm²)
	ΔEta^* = -0.045 %abs. (R_{Ser}) ΔEta^* = -0.080 %abs. (J_{02})	ΔEta = -0.04 %abs.

ΔEta^* is calculated by dividing ΔFF by 4

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EL – measurement results reference 1 and 2

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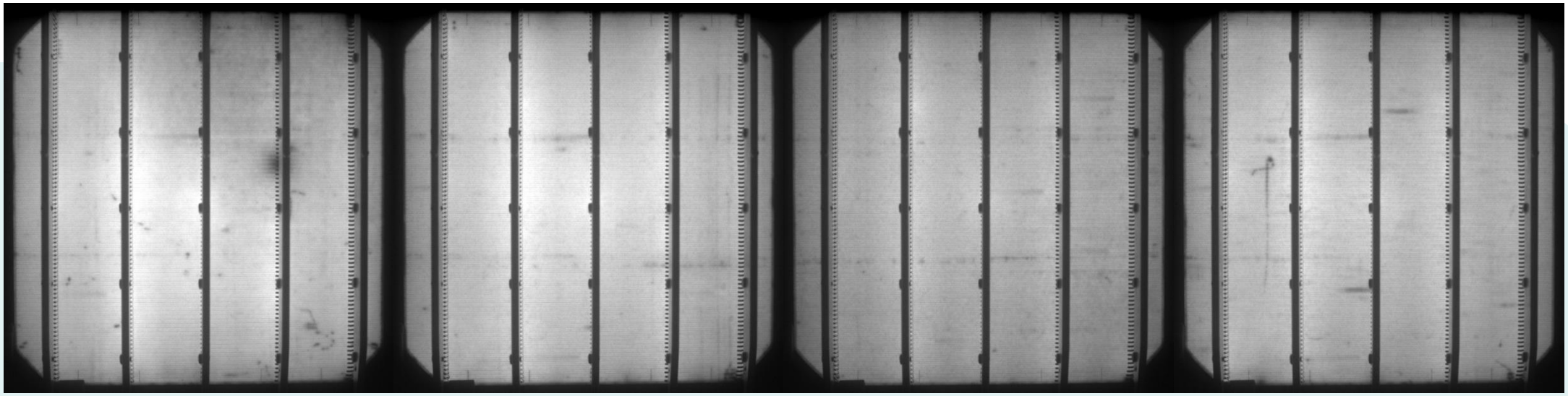
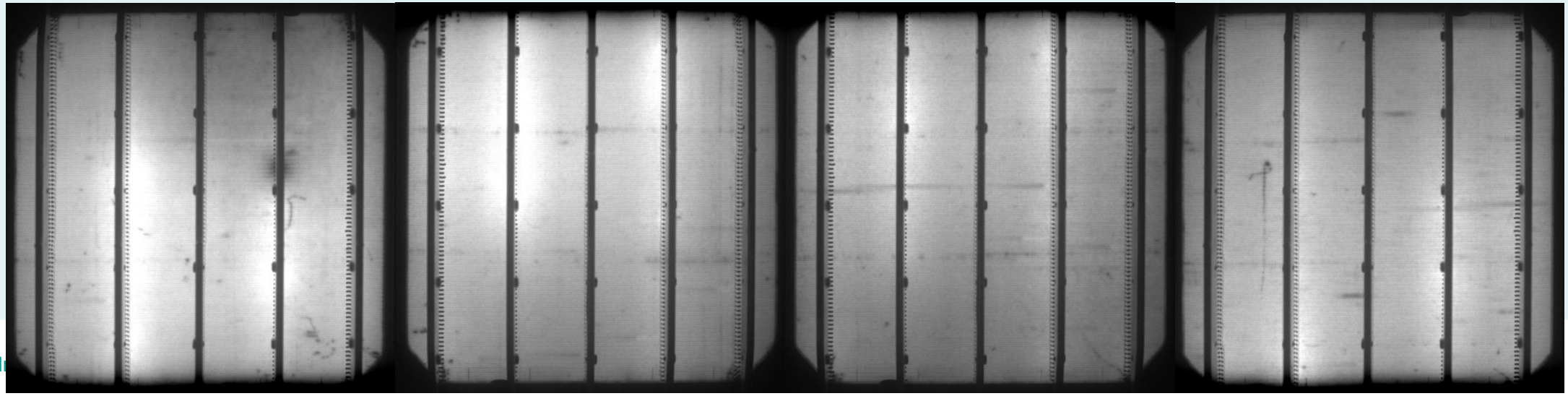
Before test

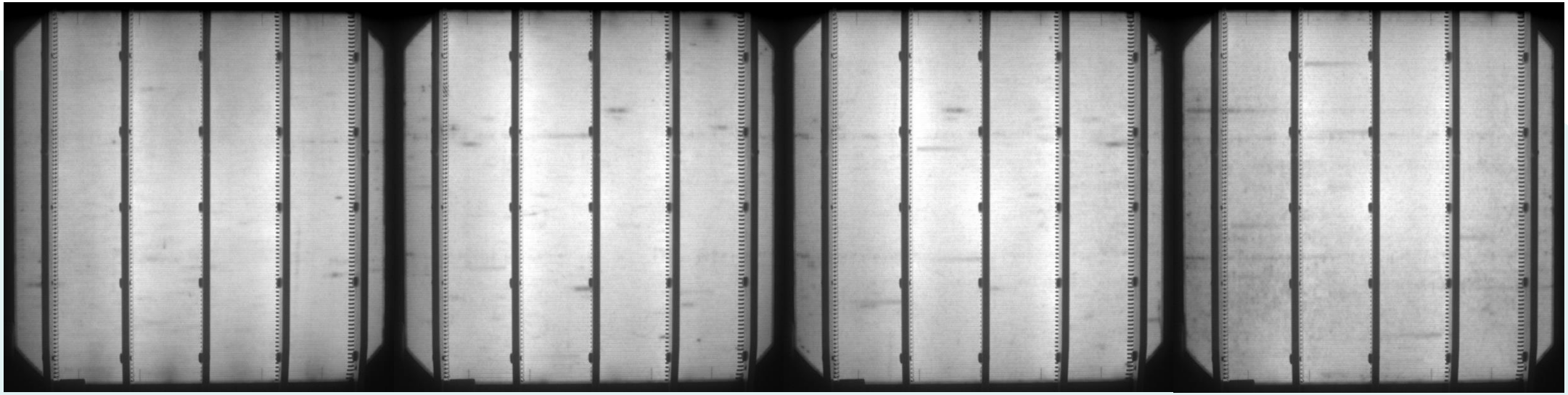


After test

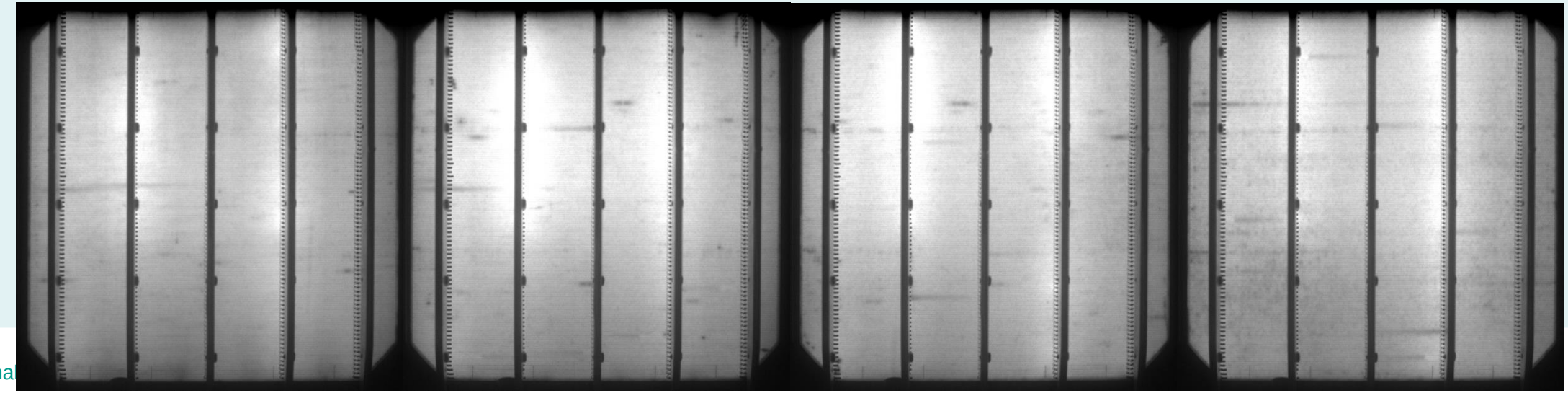


EL – measurement results of the golden reference .h.a.l.m.

Before test



After test



Summary

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h.a.l.m. solution for contacting busbarless solar cells

- Enables contacting busbarless cells in mass production
- Low wear part costs and simple wear part exchange
- Easy calibration procedure
- Reliable, $|\Delta F| < 0.2\%$abs., $|\Delta Eta| < 0.05$ %abs.
- No observable degradation of individual contact probes in EL

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Thank you for your attention

Job offers (for details see www.halm.de)

Project engineer

Research engineer

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