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Industrialization of SHJ concepts

J. Krause, H. Mehlich, J. Zhao, M. König

HERCULES workshop – Konstanz 2015

Motivation - new PV generation

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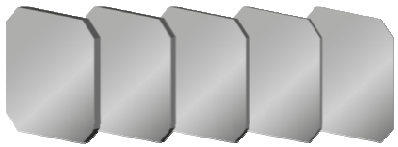
A Diamond Wire

Thinner wafer ➔ Lower costs

180 µm 160 µm 140 µm 120 µm 100 µm



Heterojunction (HJT)

- Texture
- a-Si front/ rear side
- TCO / metal rear contact
- Print front side
- Curing
- Test & Sort

High efficiency
- Lower system cost (BOS)
- Independent of wafer thickness

Only 6 process steps
- Low COO

Temperature coefficient
- Higher energy yield Bifacial ➔ Higher energy yield

C

D Adapted test metrology

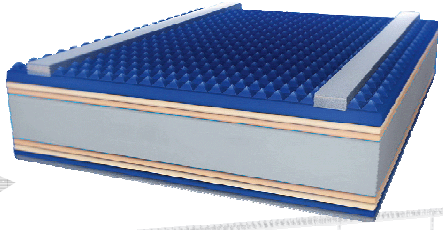
- High cap cells
- Busbarless cells
- DragonBack

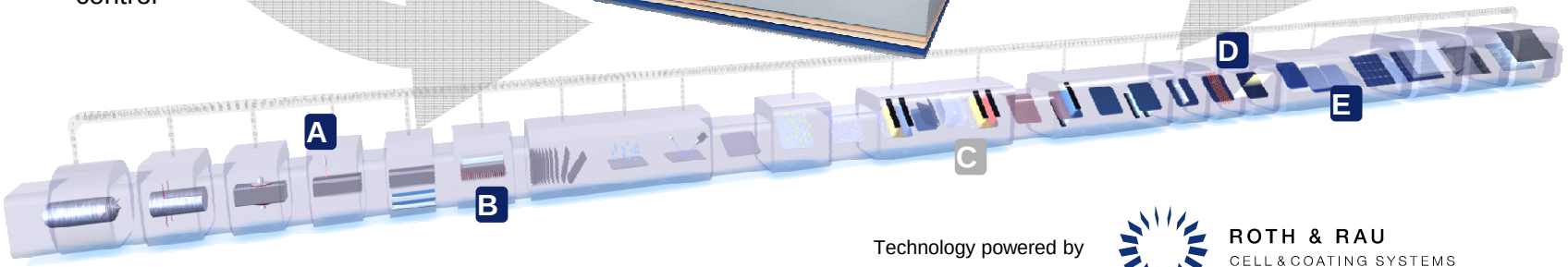
E SmartWire Connection (SWCT)

TCO layer and wafer thickness suitable for SmartWire
- 80% less silver
- Higher energy yield
- Higher efficiency
- Longevity and micro-crack resistant

B Single Wafer Tracking

Quality & performance control





Technology powered by ROTH & RAU CELL & COATING SYSTEMS

Roth & Rau / 22/04/15

Outline

- Heterojunction Cell Concept – Bifacial Rear Emitter
- Module Performance
- Status Demo Line
- First Cell Results in Ramp Up Phase

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Cell concepts/structures
Long term technology roadmap

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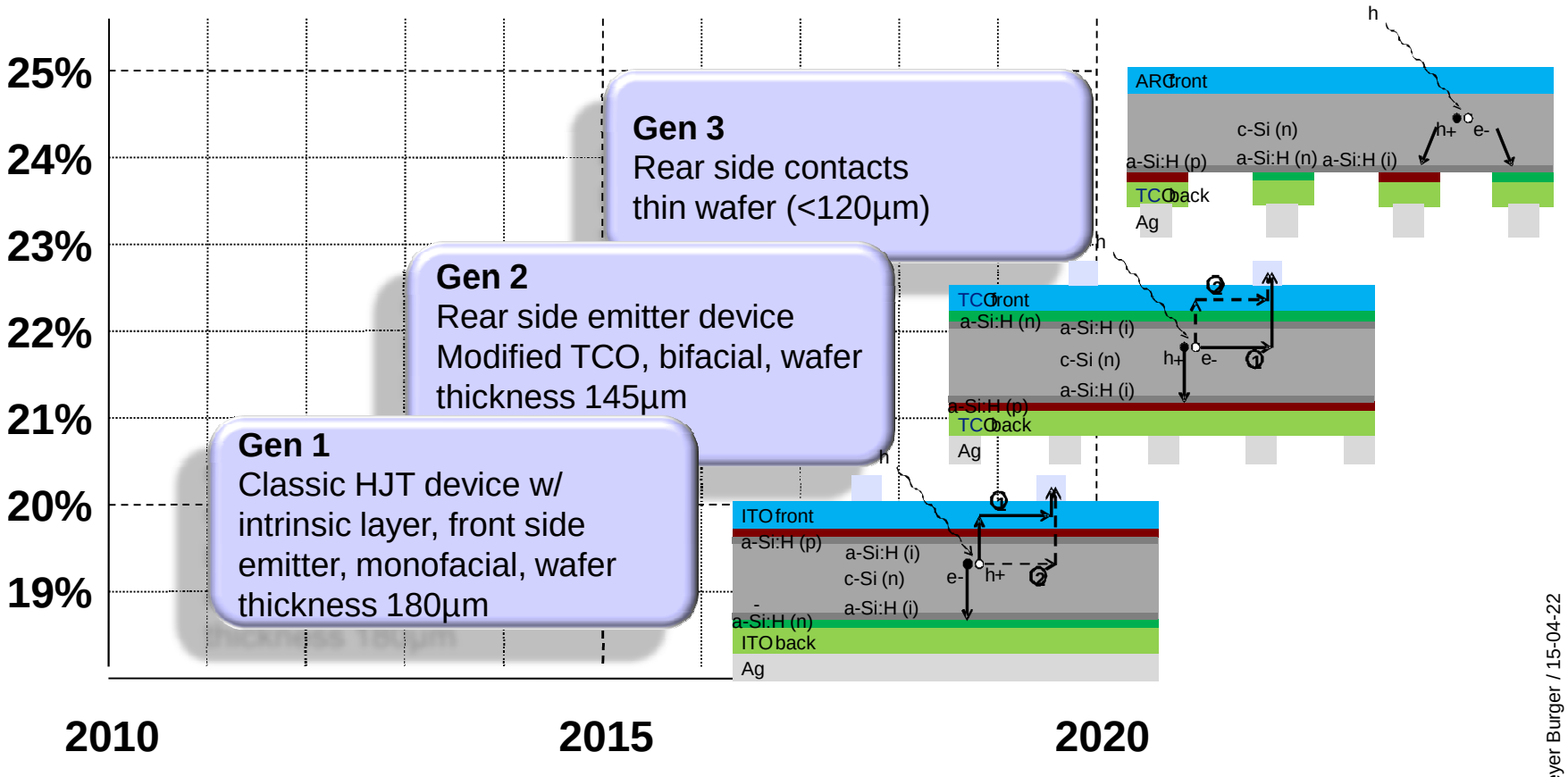

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POR Monitoring SWCT

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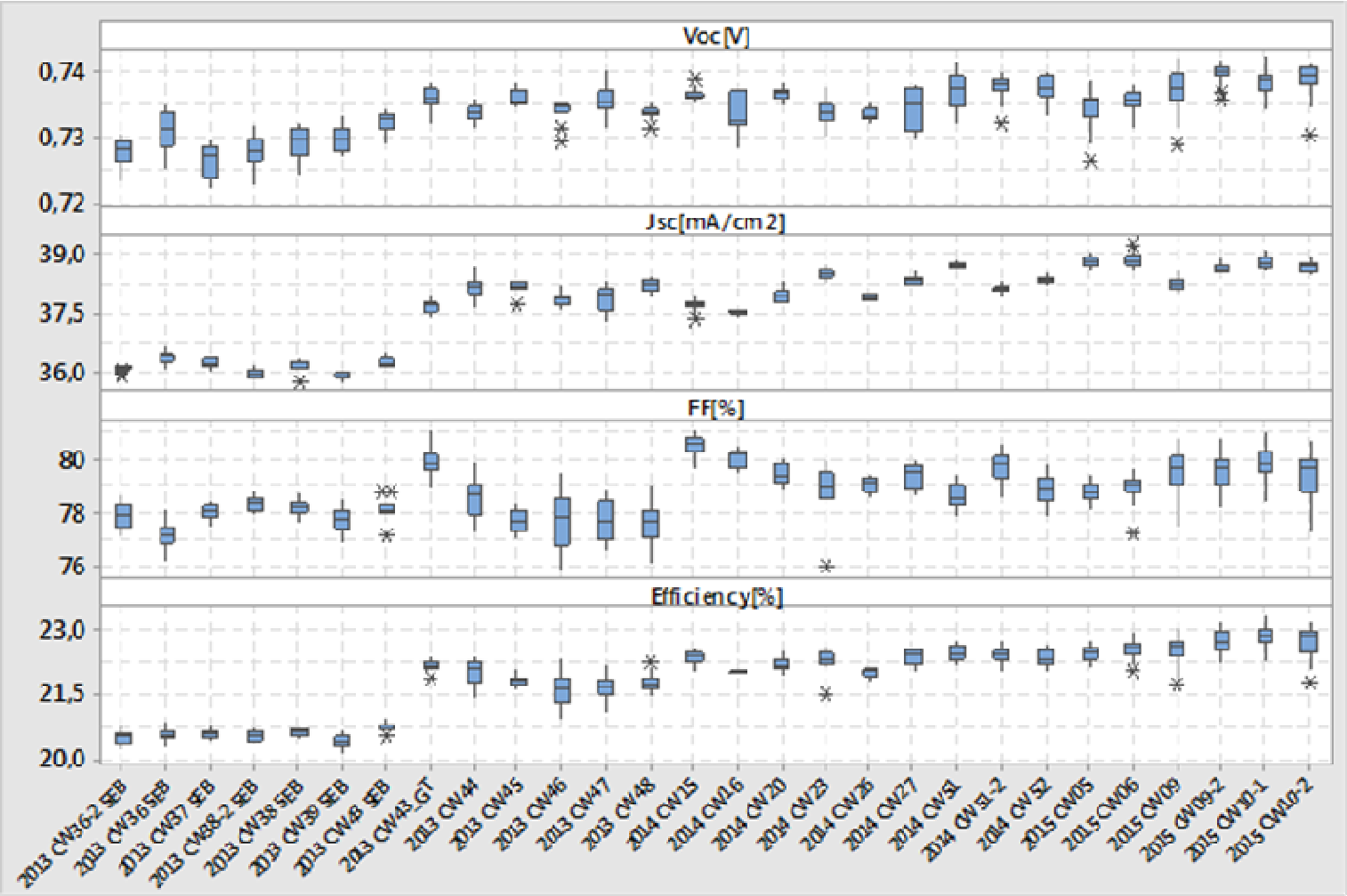
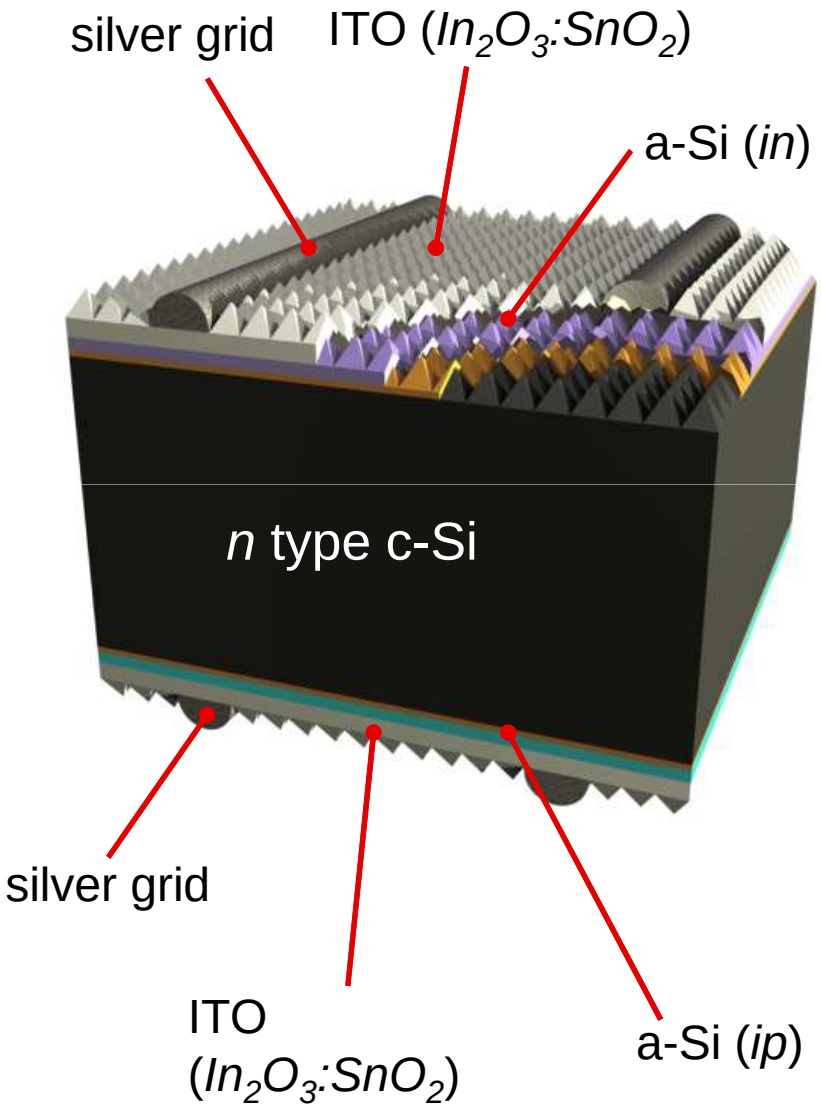


-> increase in I_{sc}, excellent FF

Si-HJT solar cell



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Texture & Clean	Wet chemistry
a-Si Front (~10nm) a-Si Rear (~10nm)	PECVD (< 200℃)
TCO front TCO back	PVD (< 200℃)
Metal + Cure	screen printing (< 200℃)

Outline

- Heterojunction Cell Concept – Bifacial Rear Emitter
- Module Performance
- Status Demo Line
- First Cell Results in Ramp Up Phase

Concept
combine bifacial SHJ cell with SWCT module

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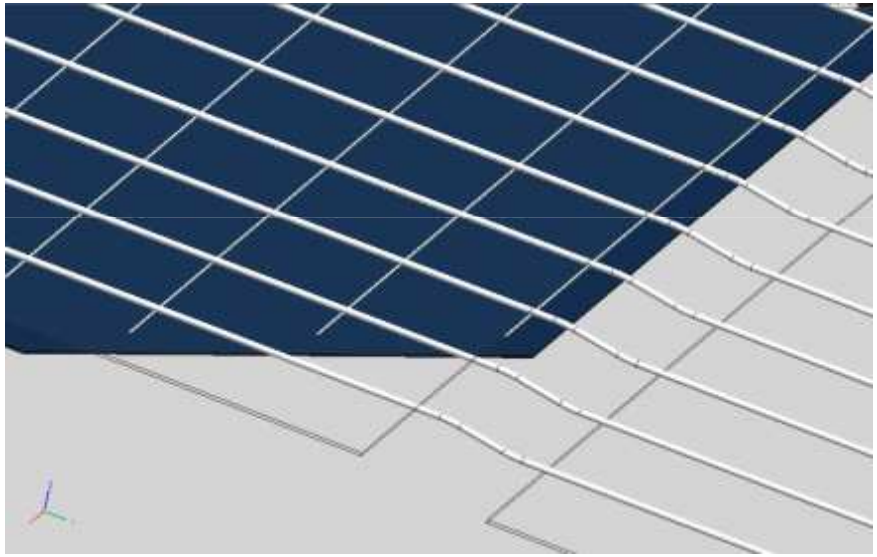

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Concept & Performance
Best HJT + SWCT module power

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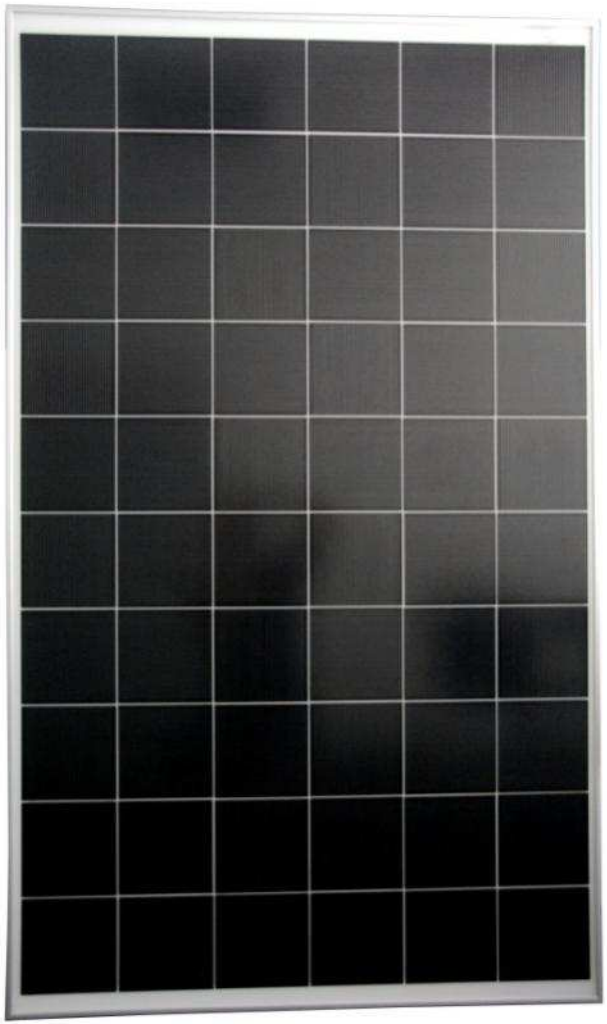

SUPSI

SWISS TESTING
STS 531

P_{MPP}	327W
I_{SC}	9.5 A
V_{OC}	44.01 V
FF	78.2 %

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Concept & Performance
HJT modules are quality tested

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	Initial	*DH3000*	*DH4000*
Eff (%)	21.1	20.8	20.9
J_{SC} (mA/cm2)	37.6	37.0	37.2
V_{OC} (mV/cell)	731	733	733
FF (%)	76.8	76.7	76.7
Pmax (W)	308	304	305
Degradation	0.0	-1.3 %	-1.0 %

	Initial	*TC200*	*TC600*	*TC800*
Pmax(W)	274	273	270	267
I_{SC} (A)	8.21	8.18	8.21	8.27
V_{OC} (V)	43.17	43.2	43.4	43.5
FF (%)	77.4	77.0	75.7	74.8
Degradation	0.0	-0.4%	-1.6%	-2.5%

Excellent Reliability
4 x IEC passed

[Faes, PVSEC 2014]

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Concept & Performance
HJT SWCT module reliability proven

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SGS TÜV SAAR

ZERTIFIKAT NR. PV/71/220/12/0023 SEITE 1/1

GENEHMIGUNGSINHABER
ROTH & RAU AG
AN DER BAUMSCHULE 6 – 8
09337 HOHENSTEINERNSTTHAL
GERMANY

FERTIGUNGSSTÄTTE
PV-0023

Projekt-Nr./ID: CTS12_2277897

GENEHMIGTES PRÜFZEICHEN: SGS TÜV SAAR IEC 61215 IEC 61730

Prüfberichts-Nr.: IEC61215 02277897 A, IEC 61730-1_02277897 B, IEC 61730-2_02277897 C

Geprüft nach: IEC 61215:2005 / EN 61215:2005; IEC 61730-1:2004 (ed.1) / EN 61730-1:2007; IEC 61730-2:2004 (ed.1) / EN 61730-2:2007

Zertifizierte(s) Produkt(e): Crystalline Silicon PV Modules

Modell(e): M255, M260, M265, M270, M275, M280, M285, M290

Technische Daten: Details of certified solar modules are documented in the test report.

Bemerkung(en): The certificate is for type approval and based on voluntarily product tests. Any changes to the design, materials, components or processing may require repetition of some of the qualification tests in order to retain type approval.

Längste Gültigkeitsdauer: 17.09.2017

Zertifizierungsstelle für Produkte SGS-TÜV Saar GmbH

SGS-TÜV SAAR GMBH CERTIFICATION BODY

Taunusstein, 18.09.2012

Markus Spies

CERTIFICATE

Certified by TÜV Saar according IEC 61215/61730, fire & PID testing included

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Concept & Performance
Superior temperature coefficient – high energy yield

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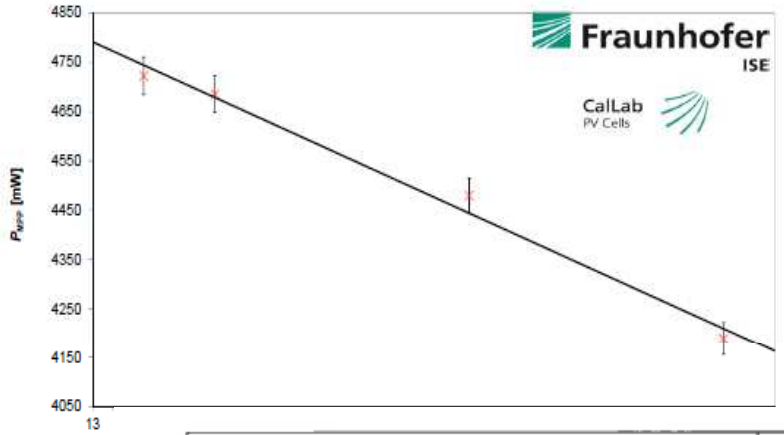
Power:
$TK(P_{MPP}) = (-9.43 \pm 0.79)$ mW / K
$TK(P_{MPP}) = (-0.201 \pm 0.017)$ % / K



-0,20 %/K on Cell level!

-0,22 %/K on Module level!

Test date [DD.MM.YYYY]		13.12.2012
Irradiance [W/m²]		1000 ± 50
Module temperature [°C] high / low		56 / 22
Sample #	Coefficient	Calculated value
20120007554	α [% / K]	0.031
	β [% / K]	-0.200
	γ [% / K]	-0.219

TÜVRheinland®
Precisely Right.

Excellent Temperature Coefficient certified by ISE CalLab and TÜV Rheinland!

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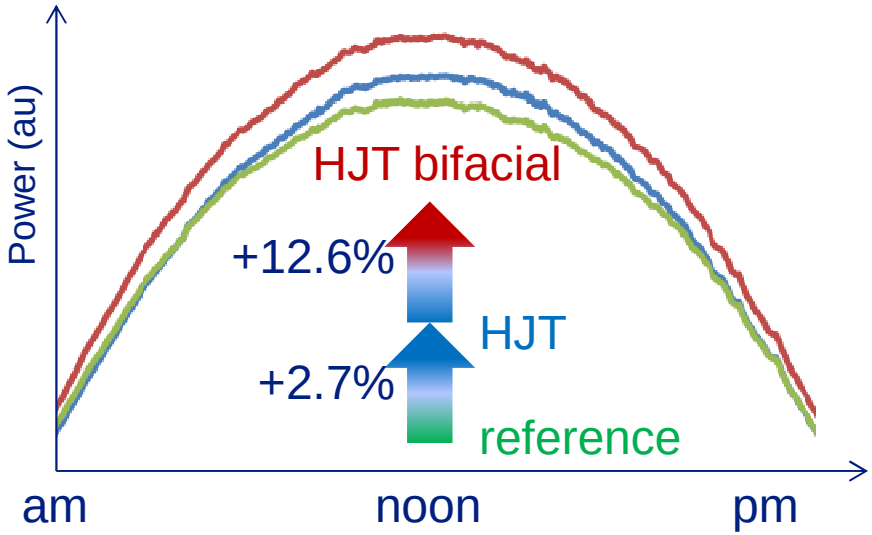
Energy yield – reliability in the field



<u>+12.6% energy yield</u> with HJT bifacial module compared to monofacial HJT.

SWISS INNO HJT

csem

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- Heterojunction Cell Concept – Bifacial Rear Emitter
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- Status Demo Line
- First Cell Results in Ramp Up Phase

Demo cell line

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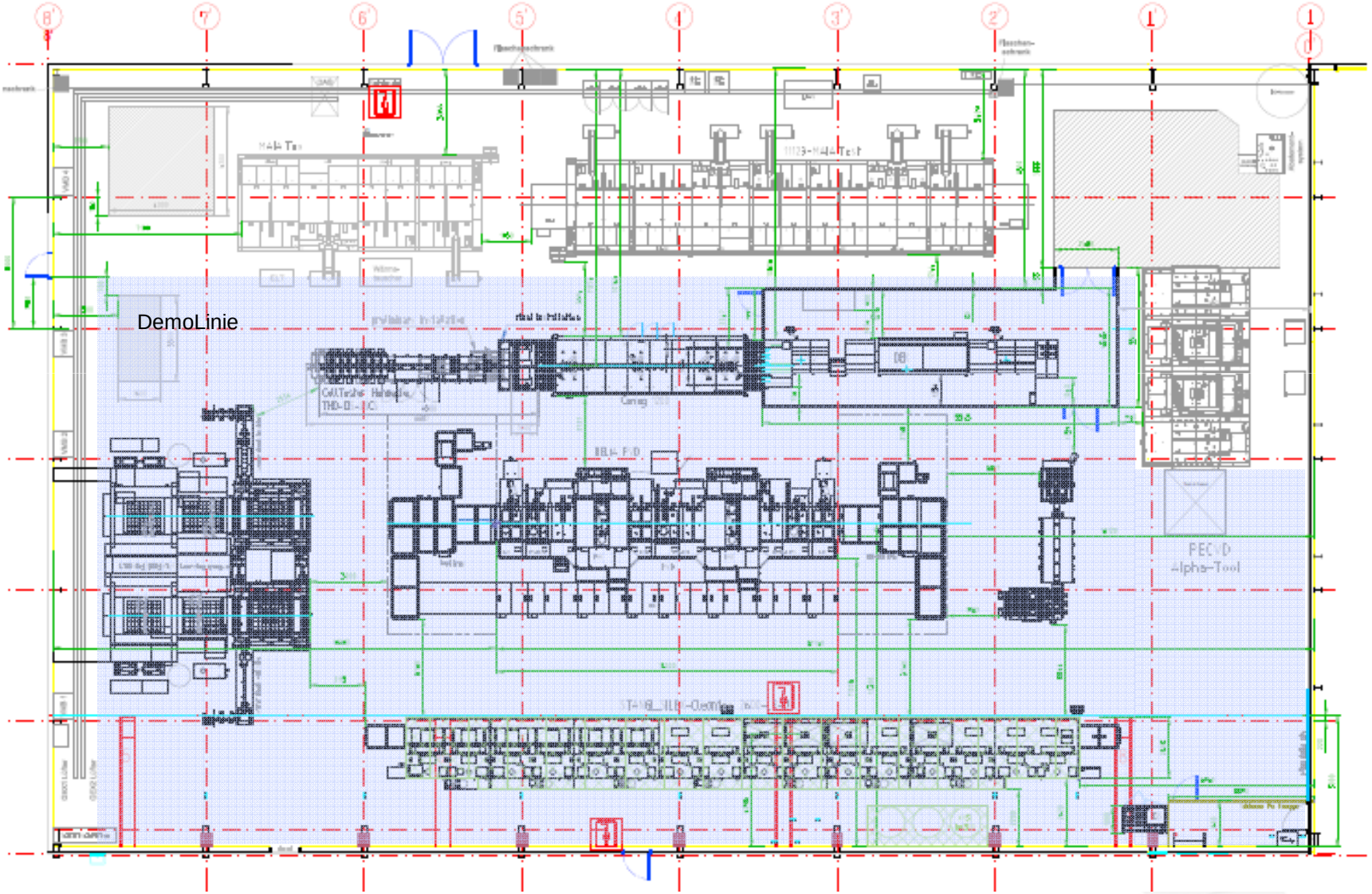
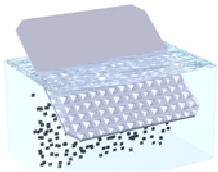
Demo cell line
Layout





Processes
Texturing and clean

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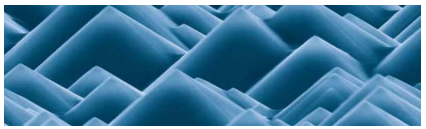

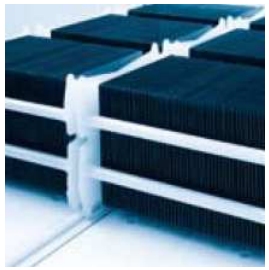

Wet Bench – Texturing & Clean
Advanced texturing & cleaning process for HJT solar cells
Alkaline Texturing and Cleaning
IPA free alkaline texturing
Automatic Carrier Handling System
Process steps: – Saw damage removal – Texturing – Clean and surface preparation

Texturing & clean | PECVD a-Si:H | PVD TCO + metal | Contact Printing | Curing | Test/Sort

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Processes
PECVD a-Si:H

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HELiA$_{PECVD}$ – Intrinsic and doped Si layer
PECVD system for the deposition of semiconductor and dielectric layers
Batch system with modular design and integrated automation
Excellent intrinsic and doped a-Si layer properties
Stable and uniform process without cross contamination
Low temperature processing: lowest production costs, compatible with thin wafers
Maintenance free chamber, dry clean

Texturing & clean | PECVD a-Si:H | PVD TCO + metal | Contact Printing | Curing | Test/Sort

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Processes
PVD TCO + metal

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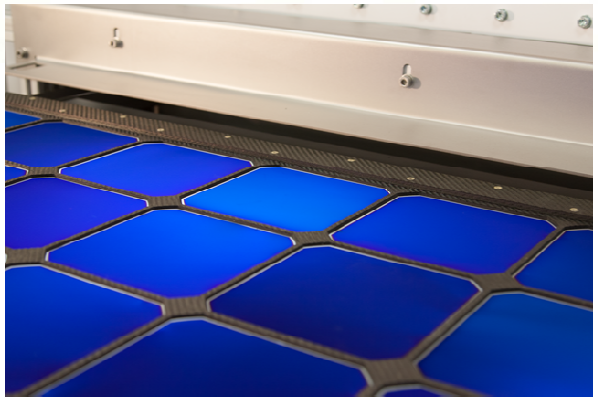

HELiA$_{PVD}$ – TCO and metal layer
PVD system for the deposition of TCO and metal layers
Double-side deposition in one pass through without wafer flipping
Integrated edge isolation
TCO and metal layers with excellent optical, electrical and mechanical performance
Inline system with integrated automation
Modular system: flexible coating-layer design, different custom stack-structures possible
Rotary magnetrons for high target utilization, long MTBM and short MTTM for low production cost

Texturing & clean | PECVD a-Si:H | **PVD TCO + metal** | Contact Printing | Curing | Test/Sort

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Processes
Fine line printing

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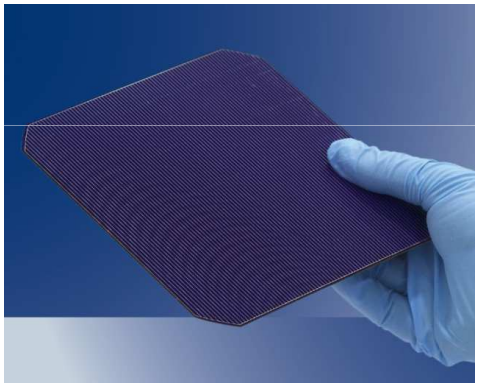

Metallization – Printing front contacts
High throughput metallization front side contacts
High speed screen printer with multiple and flexible printing modules
High accuracy and print repeatability
Integrated front side inspection and paste-saving automatic dispensing
Sensitive process adjustment
Low footprint

Texturing & clean | PECVD a-Si:H | PVD TCO + metal | **Contact Printing** | Curing | Test/Sort

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Processes
Curing

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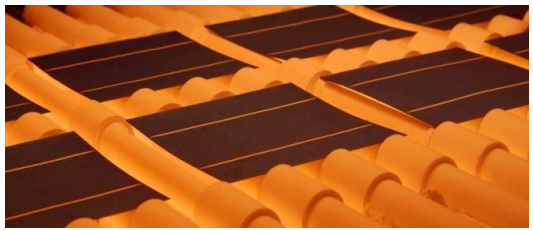
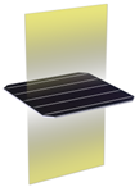


CALiPSO – Flexible curing furnace

Using the flexible inline furnace platform CALiPSO in A-C-D configuration
Ceramic roller transport system for metal free and smooth cell transport
Precise temperature control and excellent temperature uniformity
Stable process conditions – excellent temperature uniformity (± 2℃ across lanes)
Lower consumption due to thermal equilibrium and low heat loss



Processes
Test & Sort

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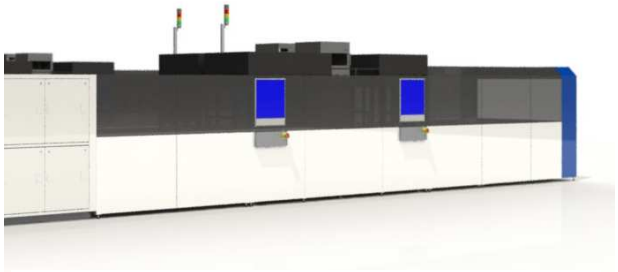

Tester & Sorter – SPOT^{LIGHT} technology
Cell testing & sorting system
Special flasher design for characterization of high capacitive HJT solar cells
Two parallel flasher for high throughput
EL integration optionally

Texturing & clean | PECVD a-Si:H | PVD TCO + metal | Contact Printing | Curing | Test/Sort

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Outline

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Concept & Performance
Champion cell on full production tool (BB-less)

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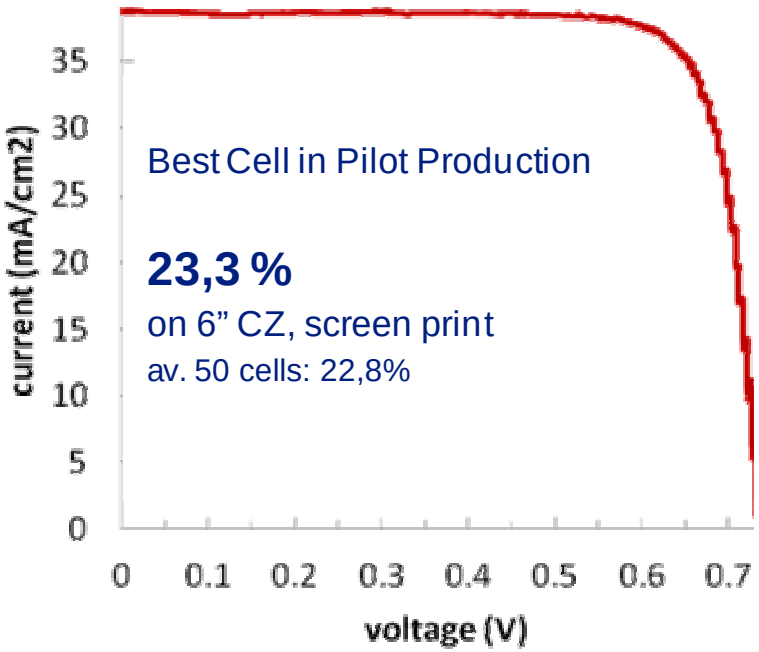

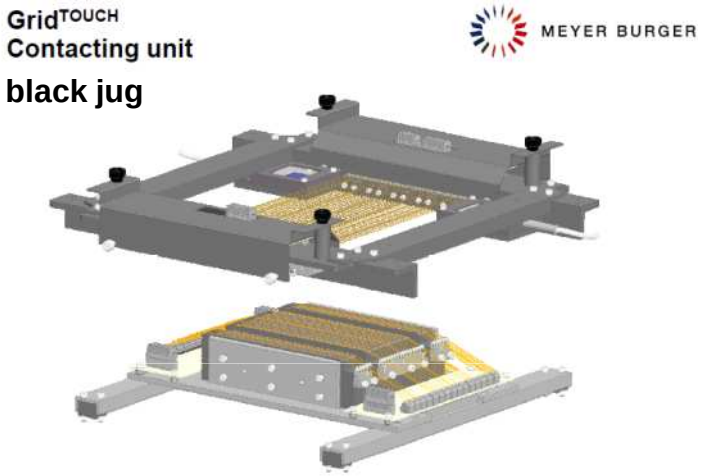

Status	Cell	Area (cm^2)	Eff. (%)	V_{oc} (mV)	FF (%)	J_{sc} (mA/cm^2)
March 2015	CZ	238.5	**23.32**	739	80,7	39,06
Dec 2013	FZ	238.5	23.5%	738.8	83.1	38.3

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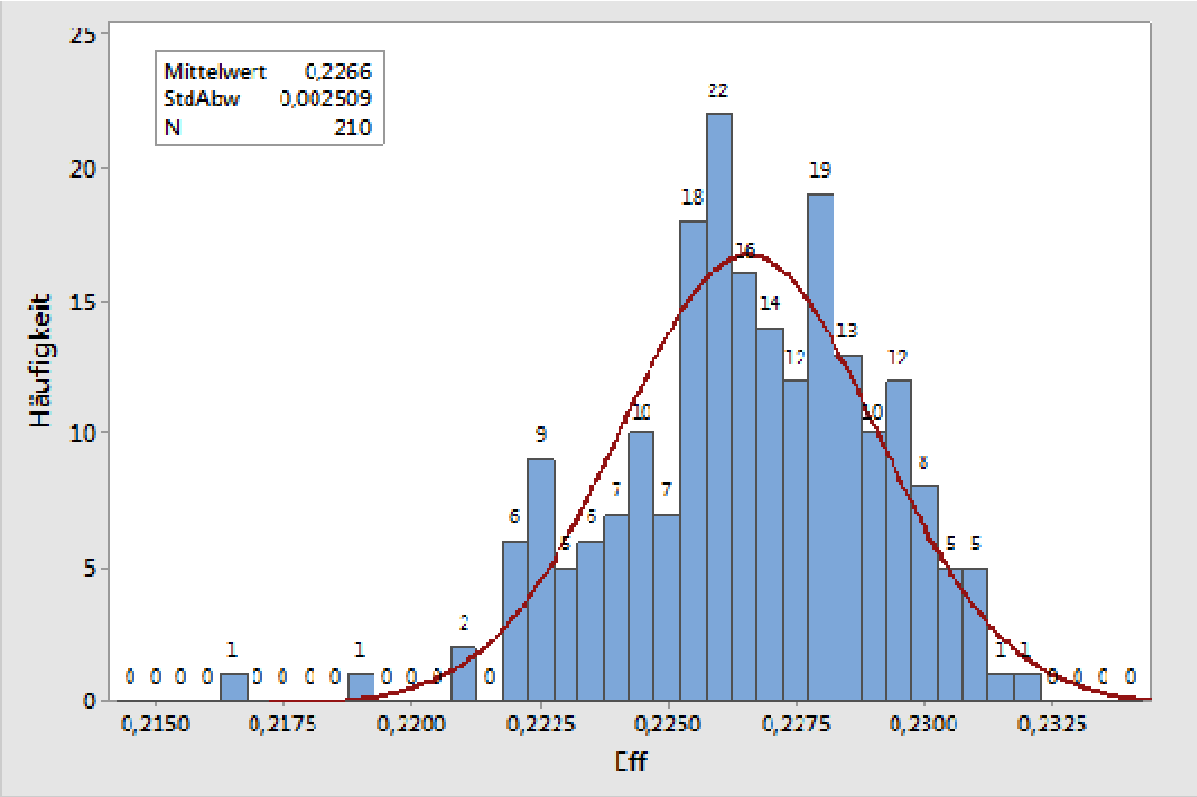
Rump UpTest
Cell efficiency distribution



Production run

March 2015

- Median 210 cells: 22,66% %
- Yield 98,1%

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Next Steps

- further process window investigation
- Volume/Marathon testing, starting in May
- Manufacturing logistic optimization

Conclusion

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- High Reliability for SHJ & SWCT certified
- Best Cell of Rear Emitter SHJ from production line >23% Eta
- av. 22,6% of 200 wafers in Ramp Up Phase

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Thank you for your attention!

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