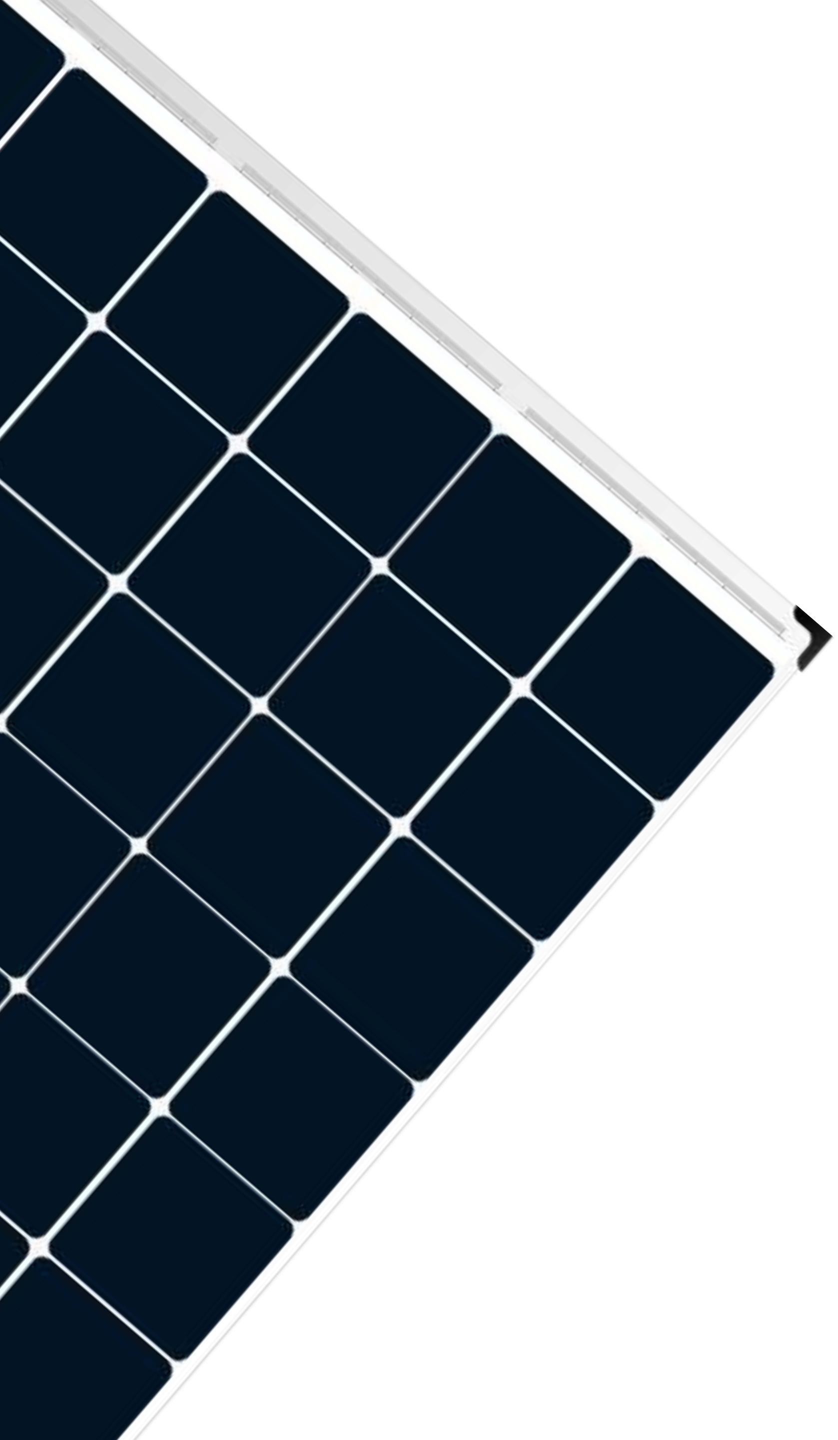

Industrial Application of n-Type Bifacial TOPCon Technology

SiliconPV and nPV conference 2022

Jia Chen

Jolywood Solar Taizhou

2022.03.31

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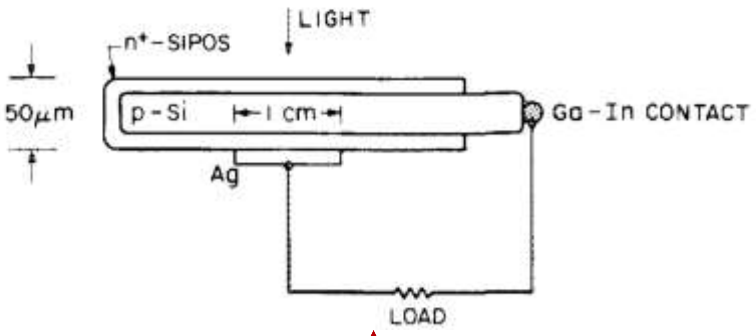
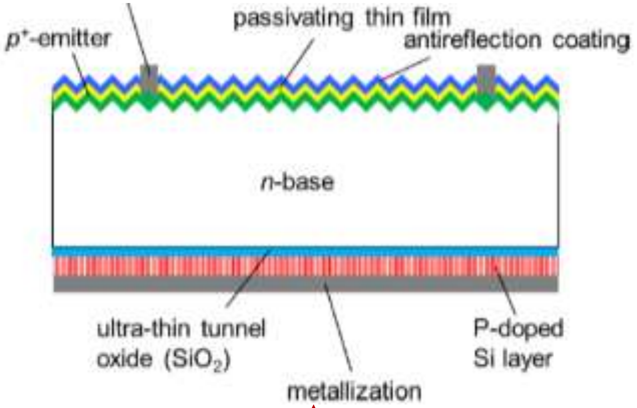
History of TOPCon technology

JOLYWOOD 中来股份

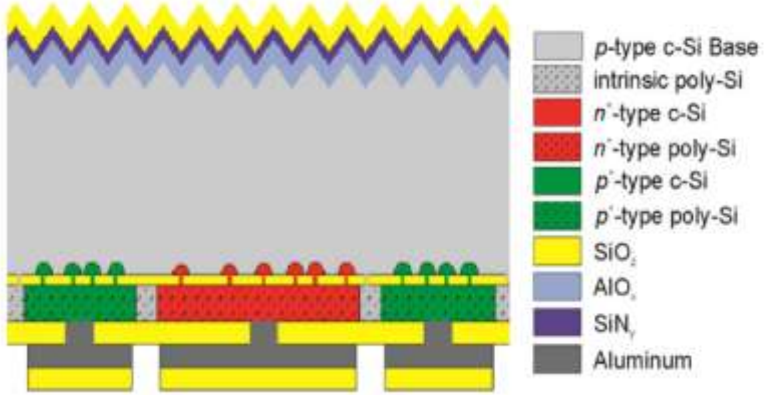
1985, Stanford University
SIPOS, V_{oc} ~ 720 mV



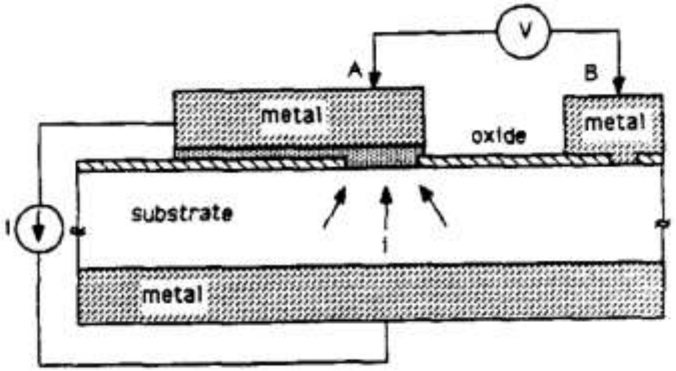
2013, Fraunhofer ISE
TOPCon, η ~ 23.02%



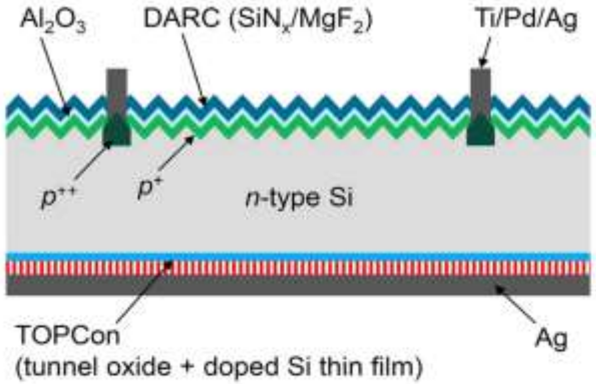
2018, ISFH
POLO-IBC, η ~ 26.10%



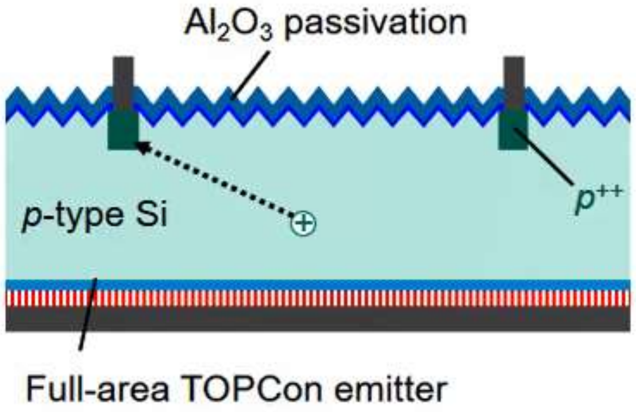
1985 | 1990 | 2013 | 2017 | 2018 | 2020



1990, Stanford University
Poly-Si, low J_0 and ρ_c



2017, Fraunhofer ISE
TOPCon, η ~ 25.7%

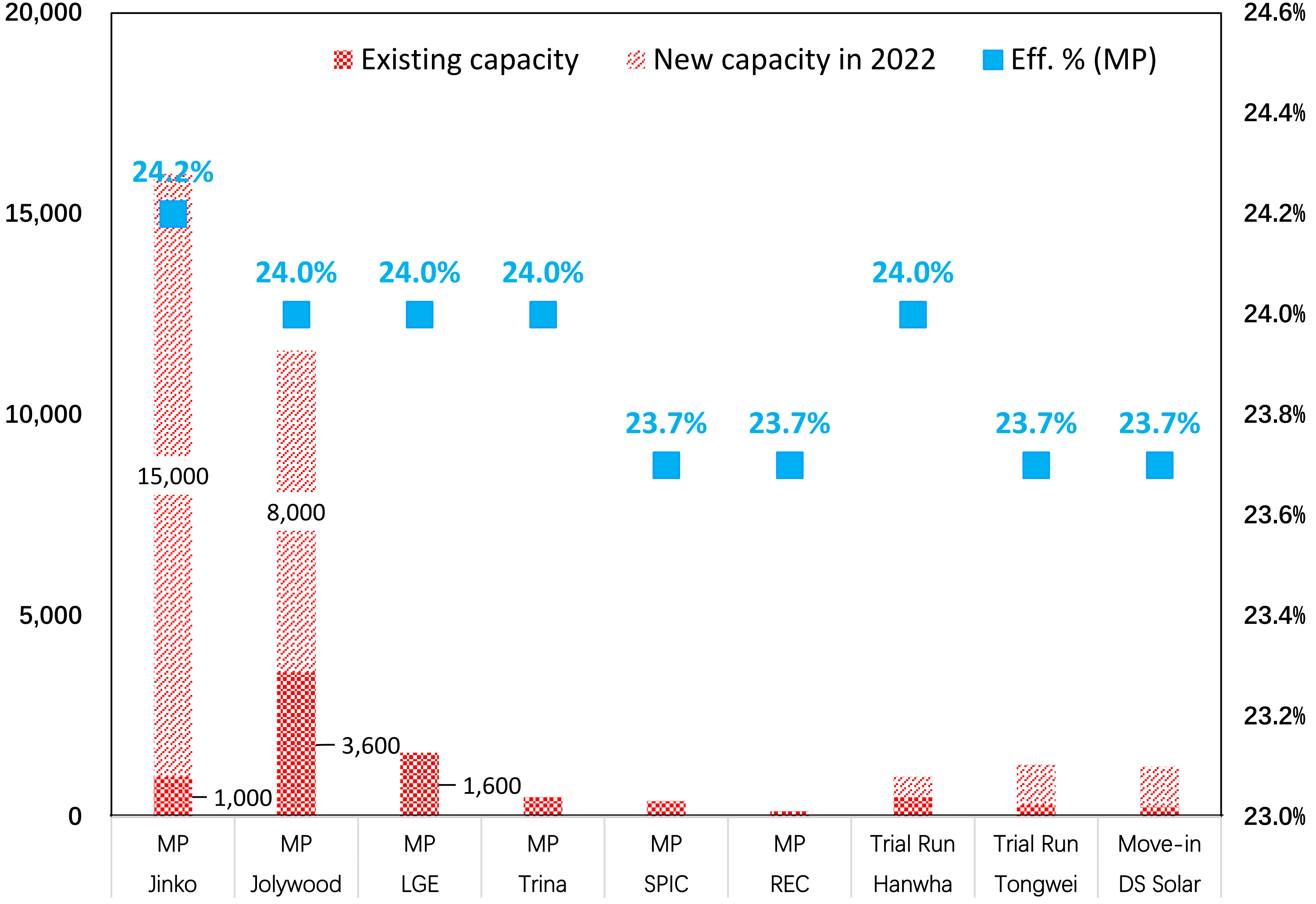


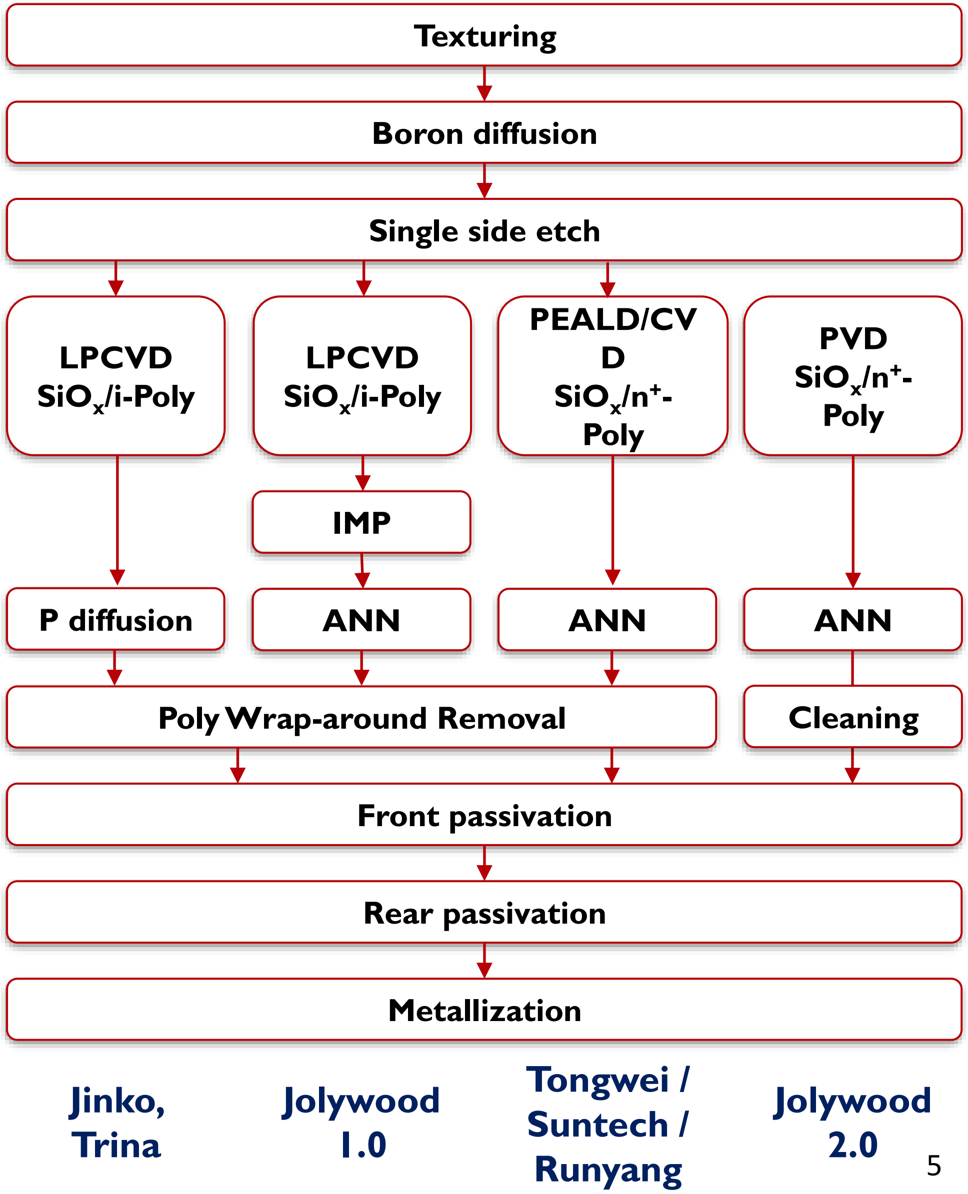
2020, Fraunhofer ISE
TOPCon, η ~ 26.0%

Industry progress of TOPCon technology

中来股份 JOLYWOOD

2022F TOPCon Capacity and Efficiency*, Unit: MW, %





***Data from PV Infolink**

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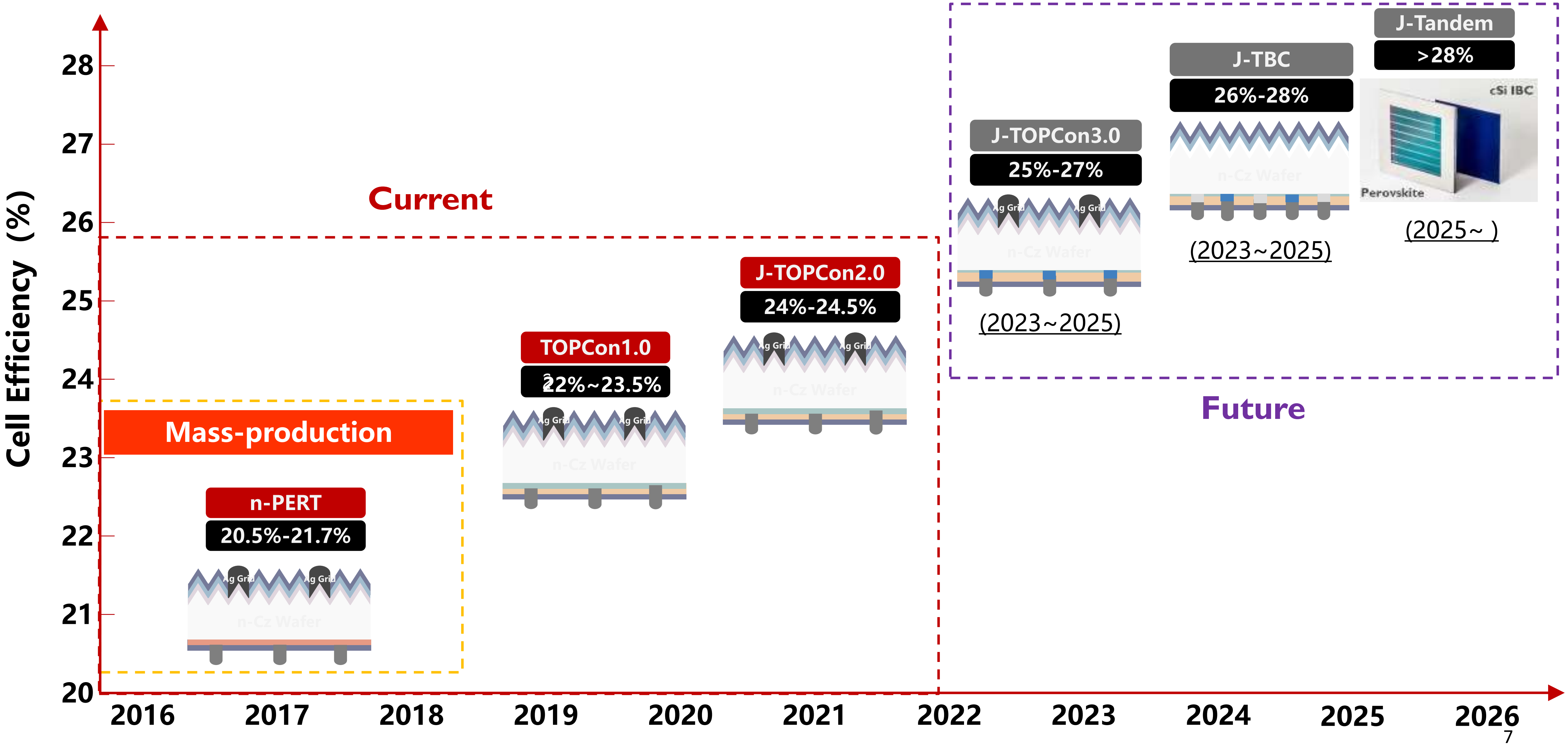
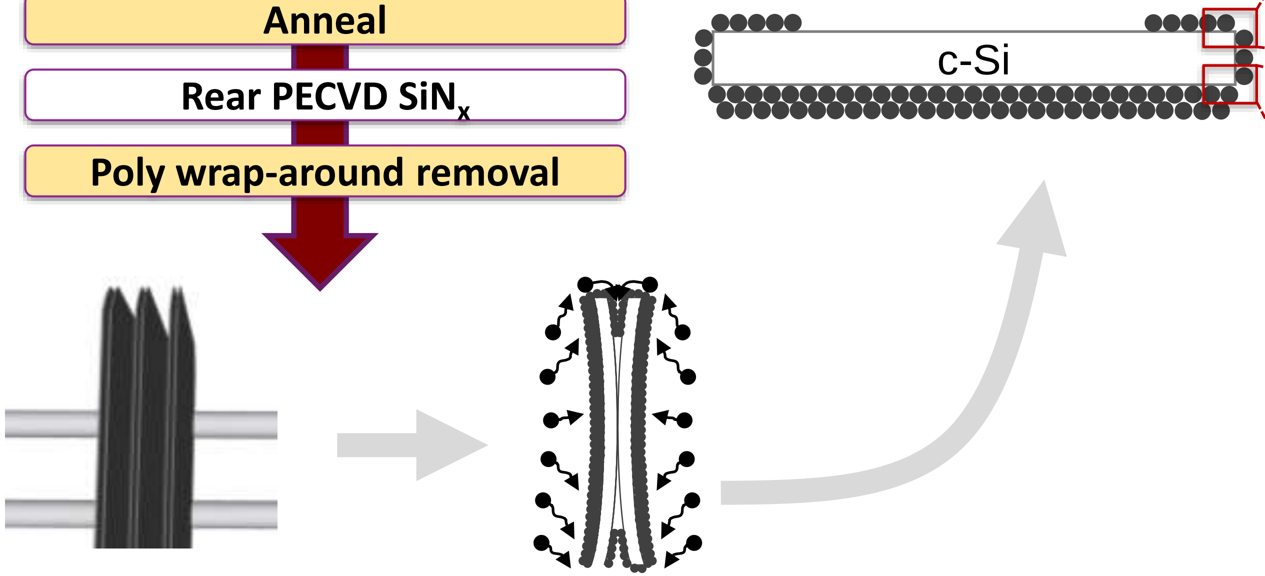
Jolywood technology roadmap

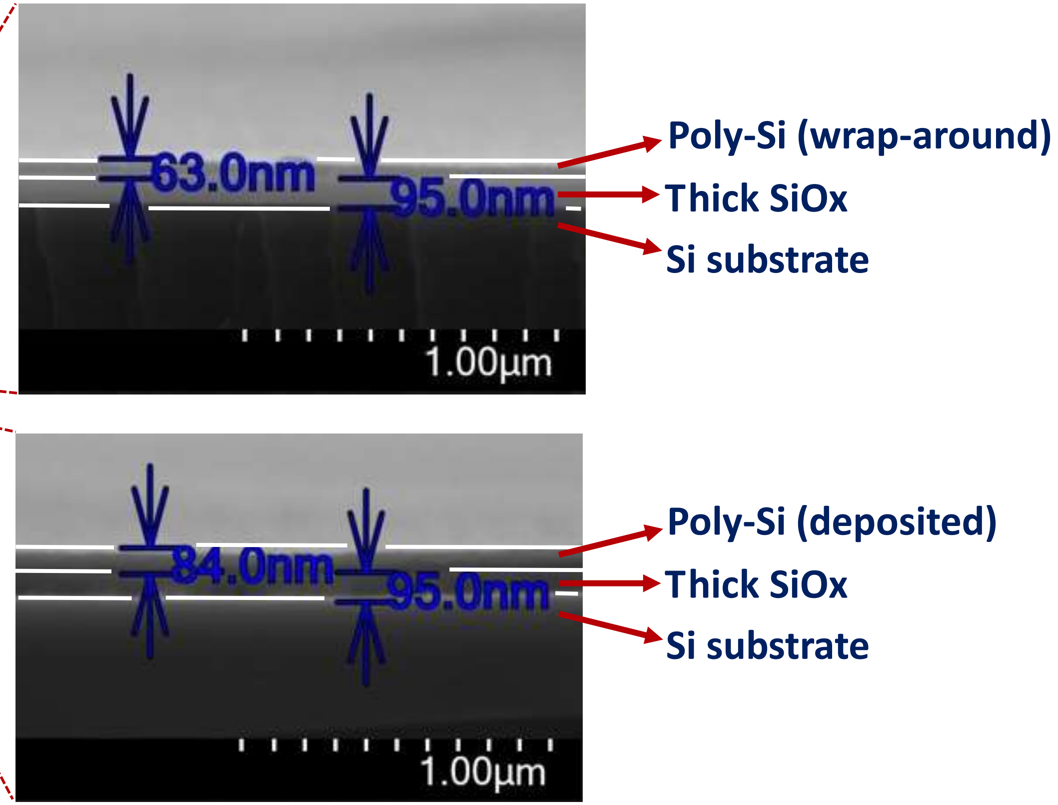


Unavoidable wrap-around poly Si with TOPCon 1.0

J-TOPCon (1.0)

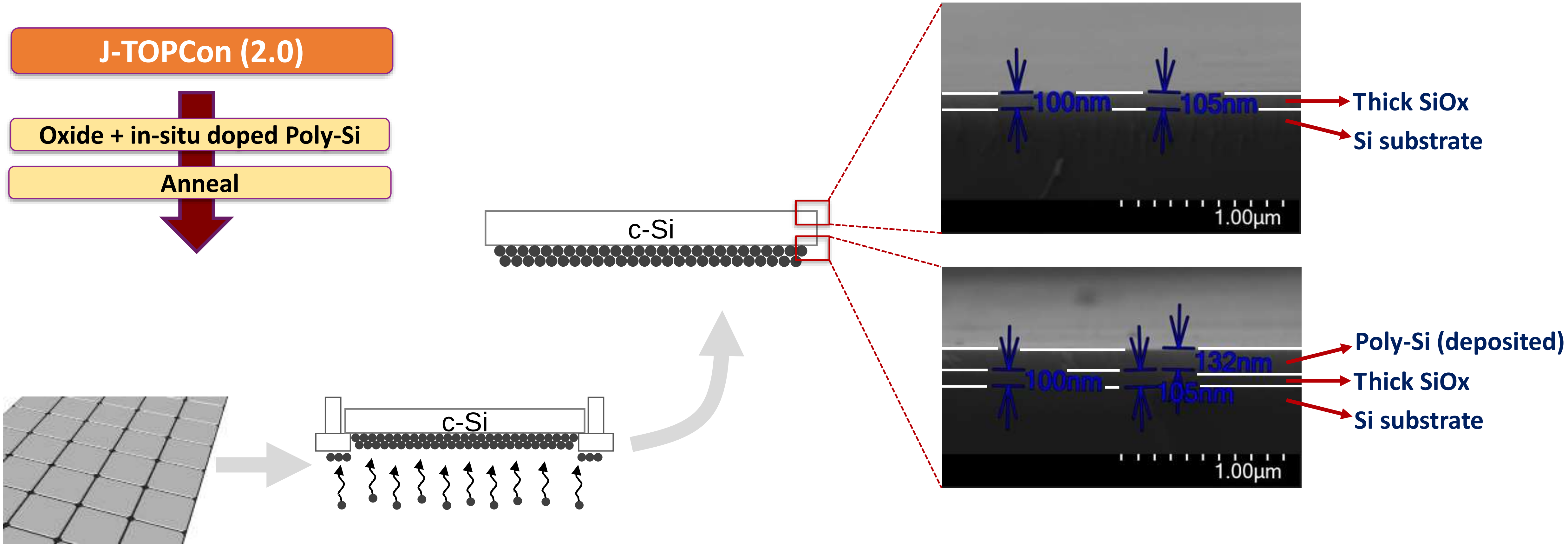
- Oxide + LPCVD Poly-Si
- IMP
- RCA
- Anneal
- Rear PECVD SiN_x
- Poly wrap-around removal





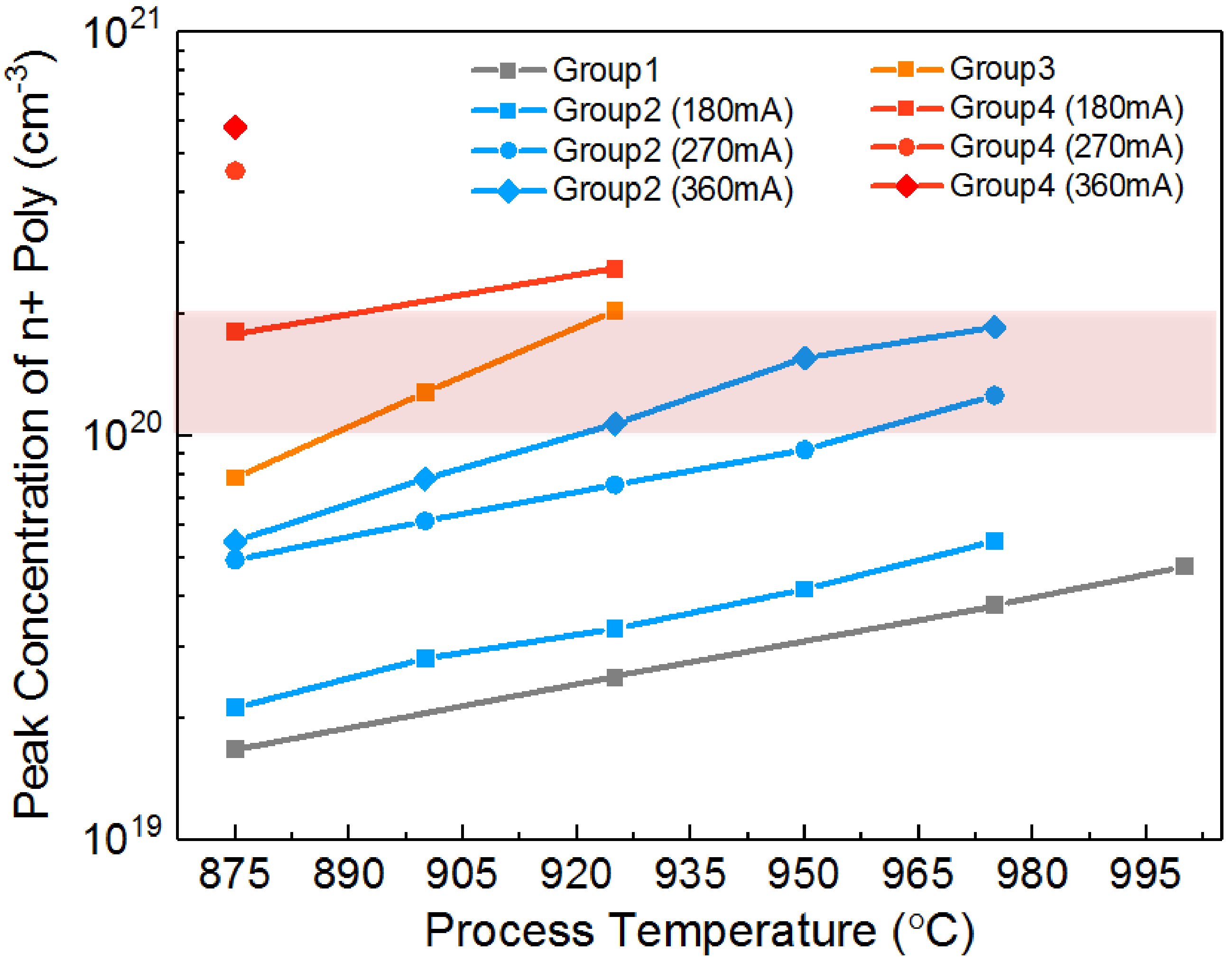
- Unavoidable poly-Si wrap-around during LPCVD poly deposition
- Additional wrap-around removal is necessary and led to low yield and high cost

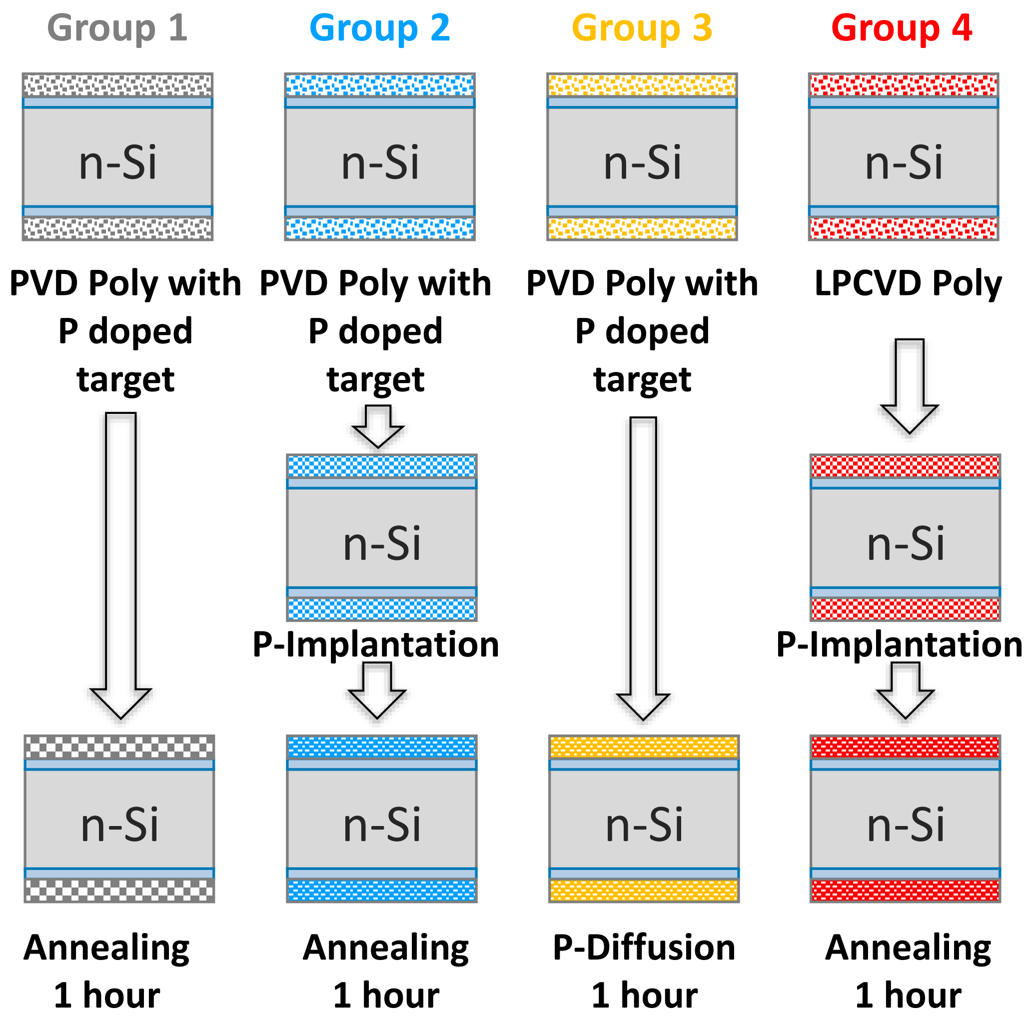
No wrap-around poly Si with TOPCon 2.0



- No wrap-around of poly Si with plate-type PVD process
- No wrap-around removal required, led to shorter process flow and higher yield

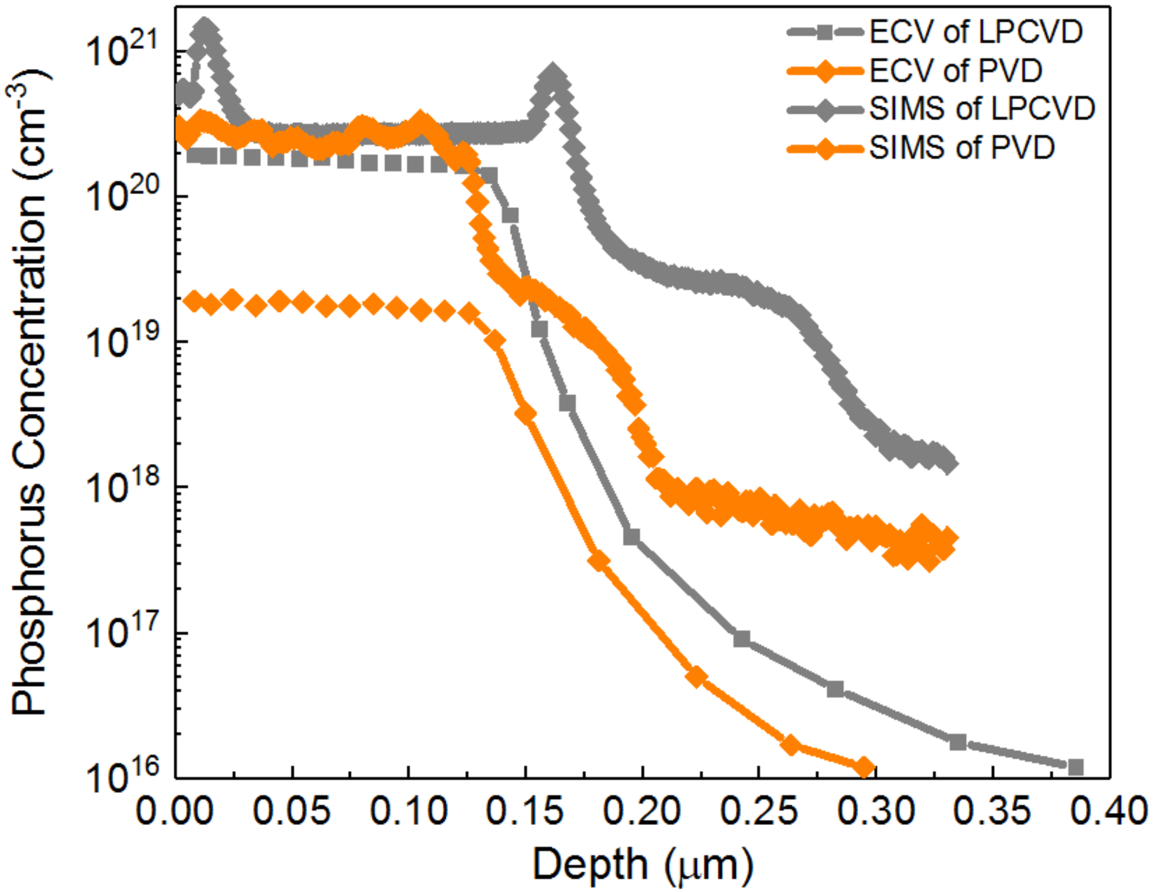
Challenge to reach high doping concentration

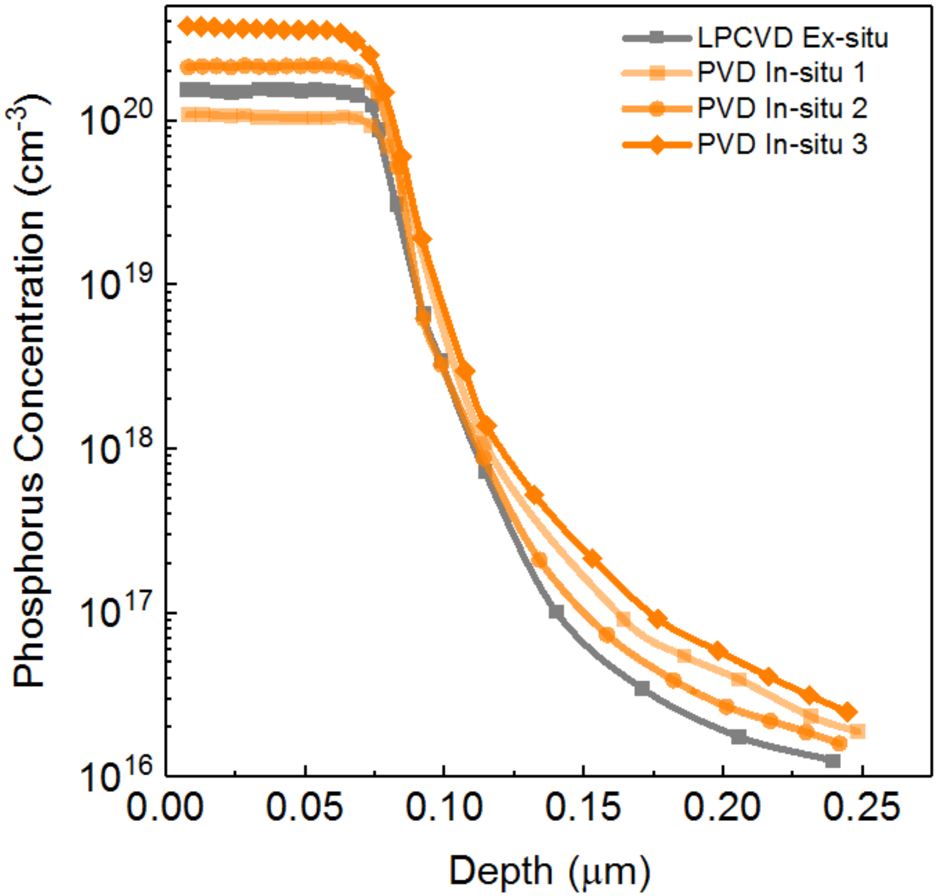


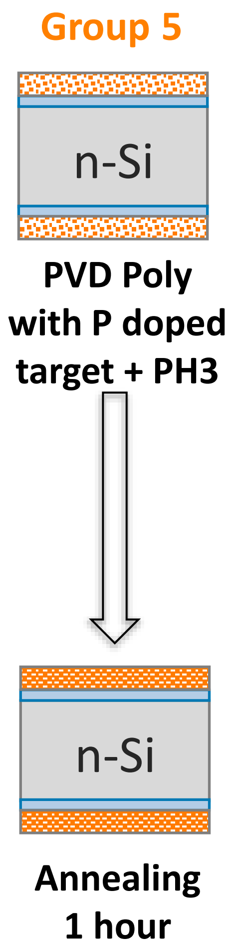


- Difficult to reach high doping level (>1e^{20} cm^{-3}) using ONLY p-doped target during PVD process

Tunable doping concentration achieved

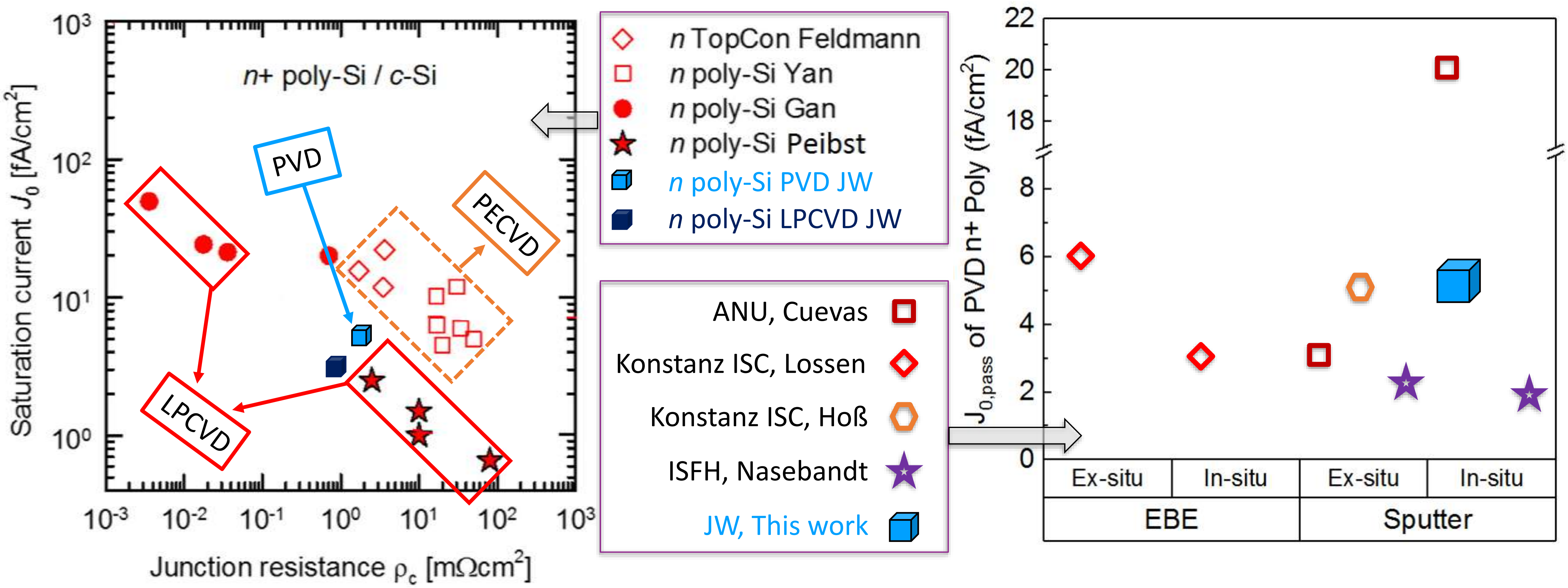






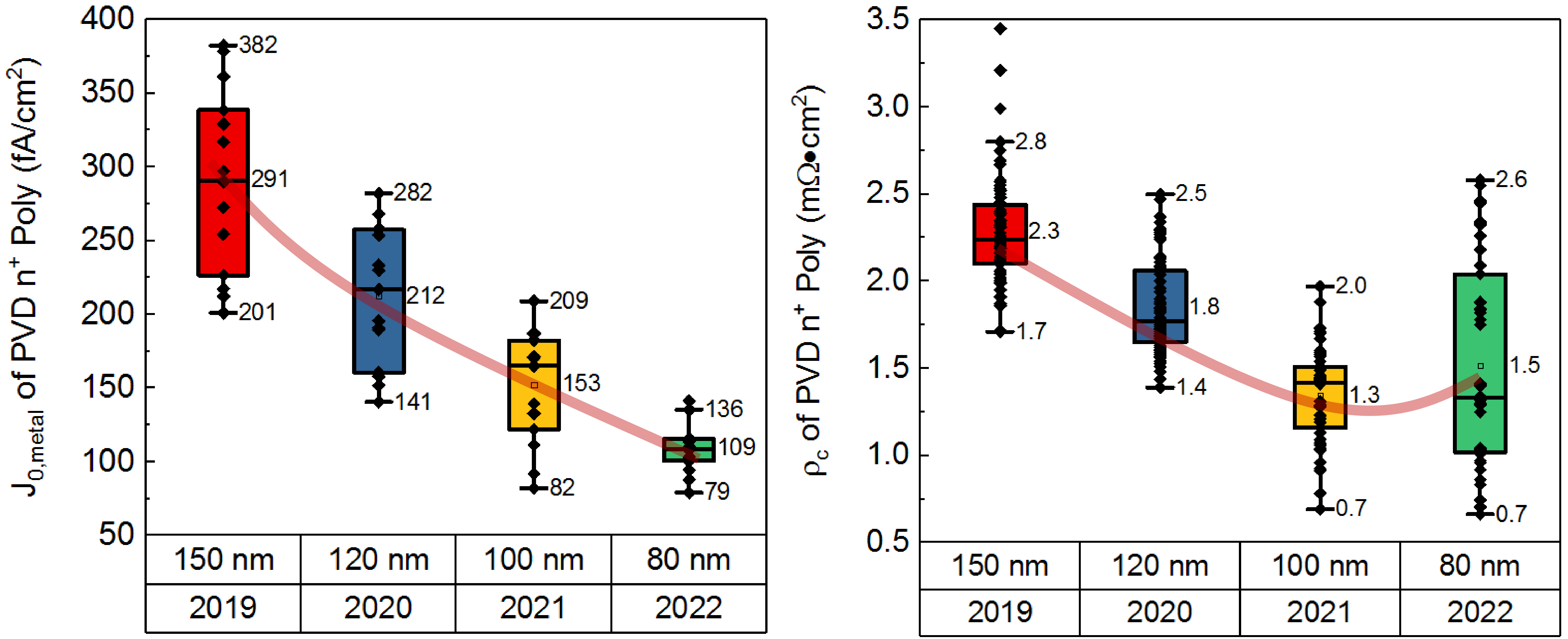
- Challenge to activate the phosphorous atoms from the doped target
- Tunable doping concentration achieved with additional PH3 during deposition process

Low J_{0pass} and ρ_c achieved in production line



- Similar J_{0pass} and ρ_c achieved using PVD deposited n^+ poly compared with LPCVD n^+ poly

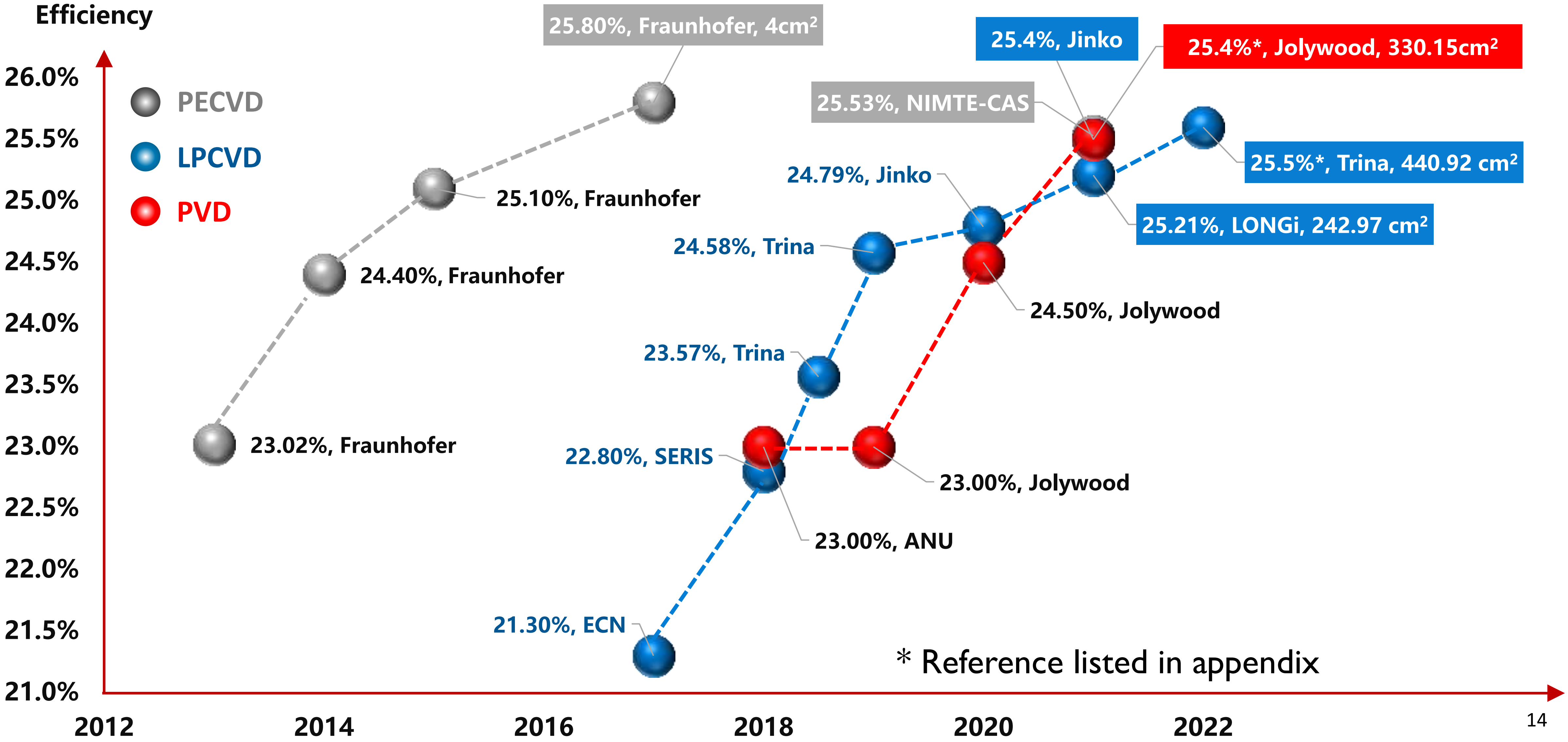
Low J_{0metal} and ρ_c with different poly thickness



- Good contact formed on PVD deposited n^+ poly with 100nm thickness in production line and 80nm in pilot-line

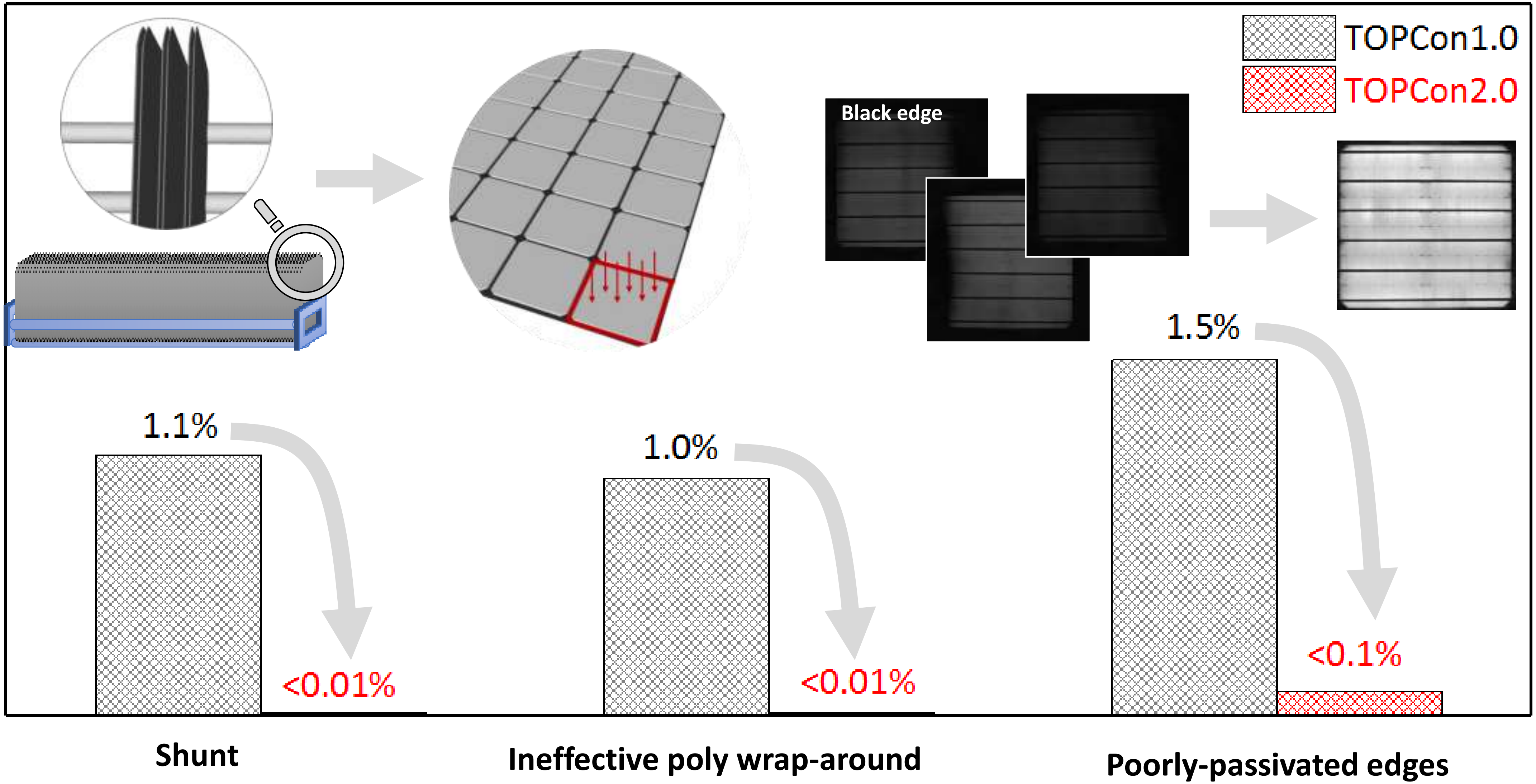
Lab-efficiency achieved with various poly depositions

The reported lab-efficiency of TOPCon solar cells with various poly deposition methods



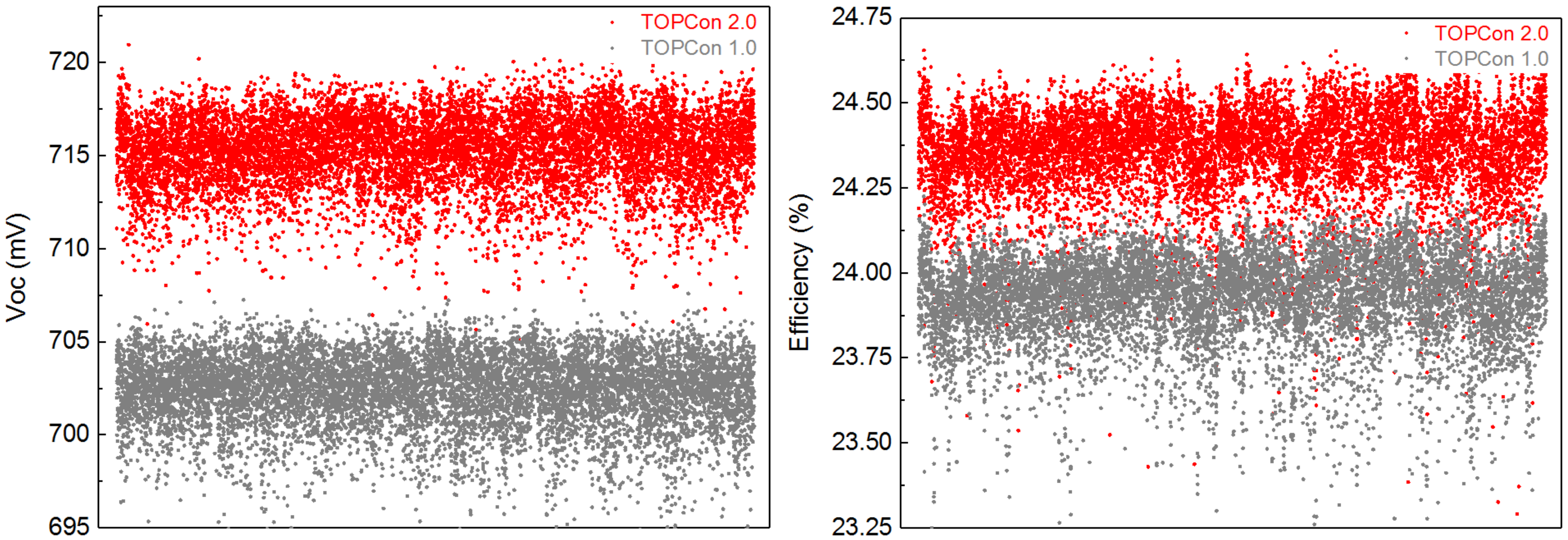
* Reference listed in appendix

Yield improvement with TOPCon 2.0



- Yield significantly improved from TOPcon 1.0 to TOPCon 2.0

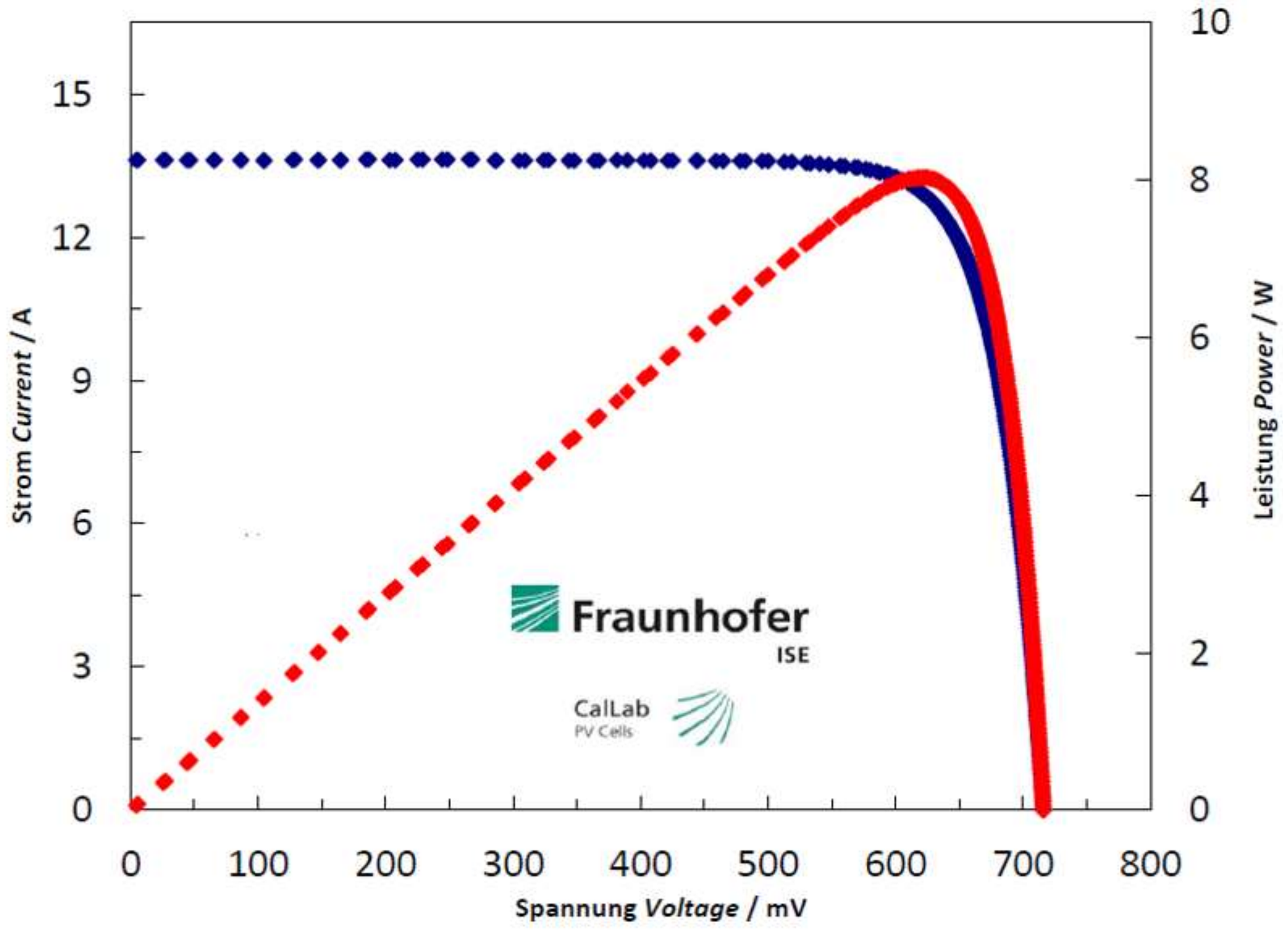
Voc and Eff improved from TOPCon 1.0 to 2.0



- Efficiency and open-circuit voltage significantly improved from TOPCon 1.0 to TOPCon 2.0

Voc and Eff improved from TOPCon 1.0 to 2.0

中来股份 JOLYWOOD

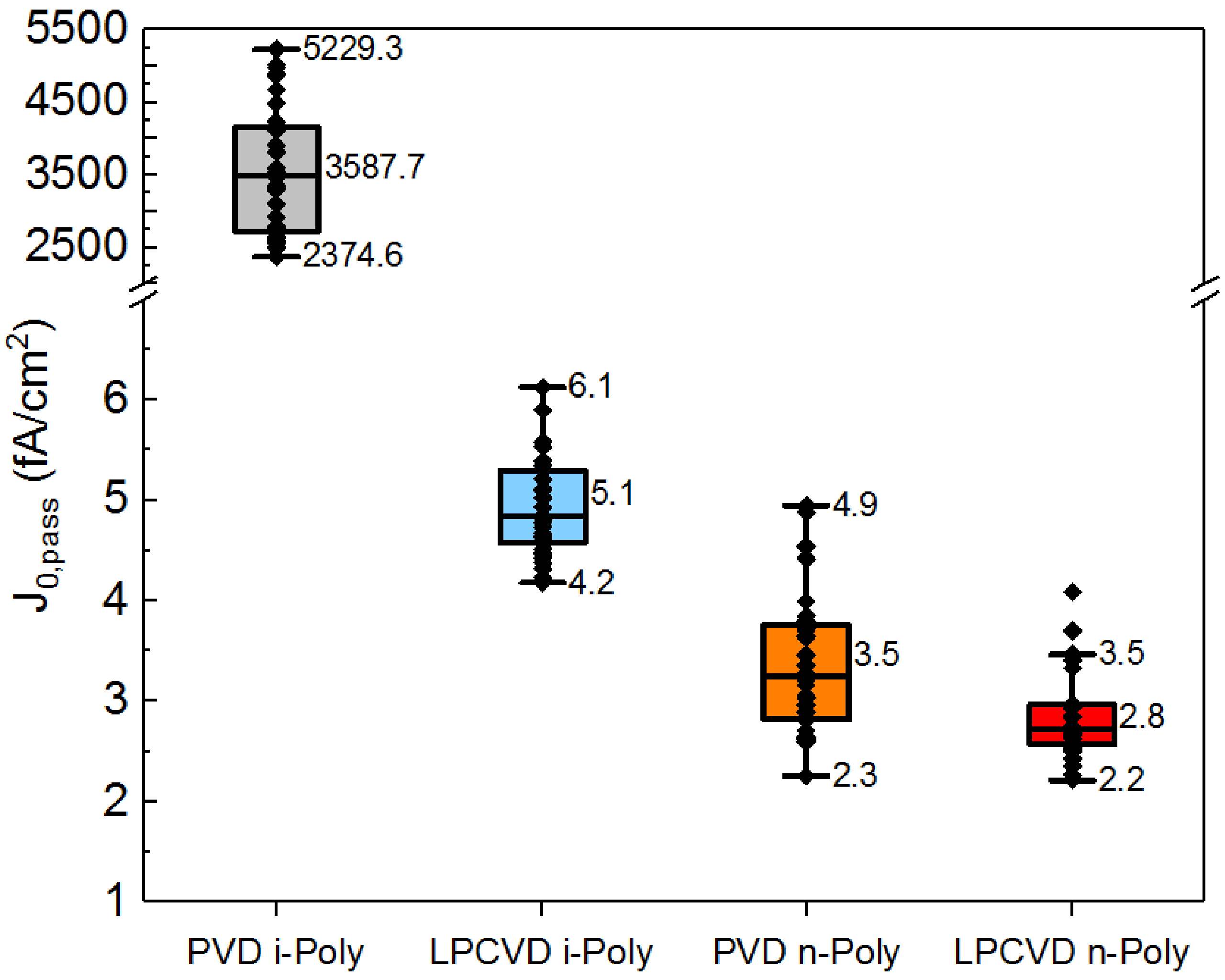


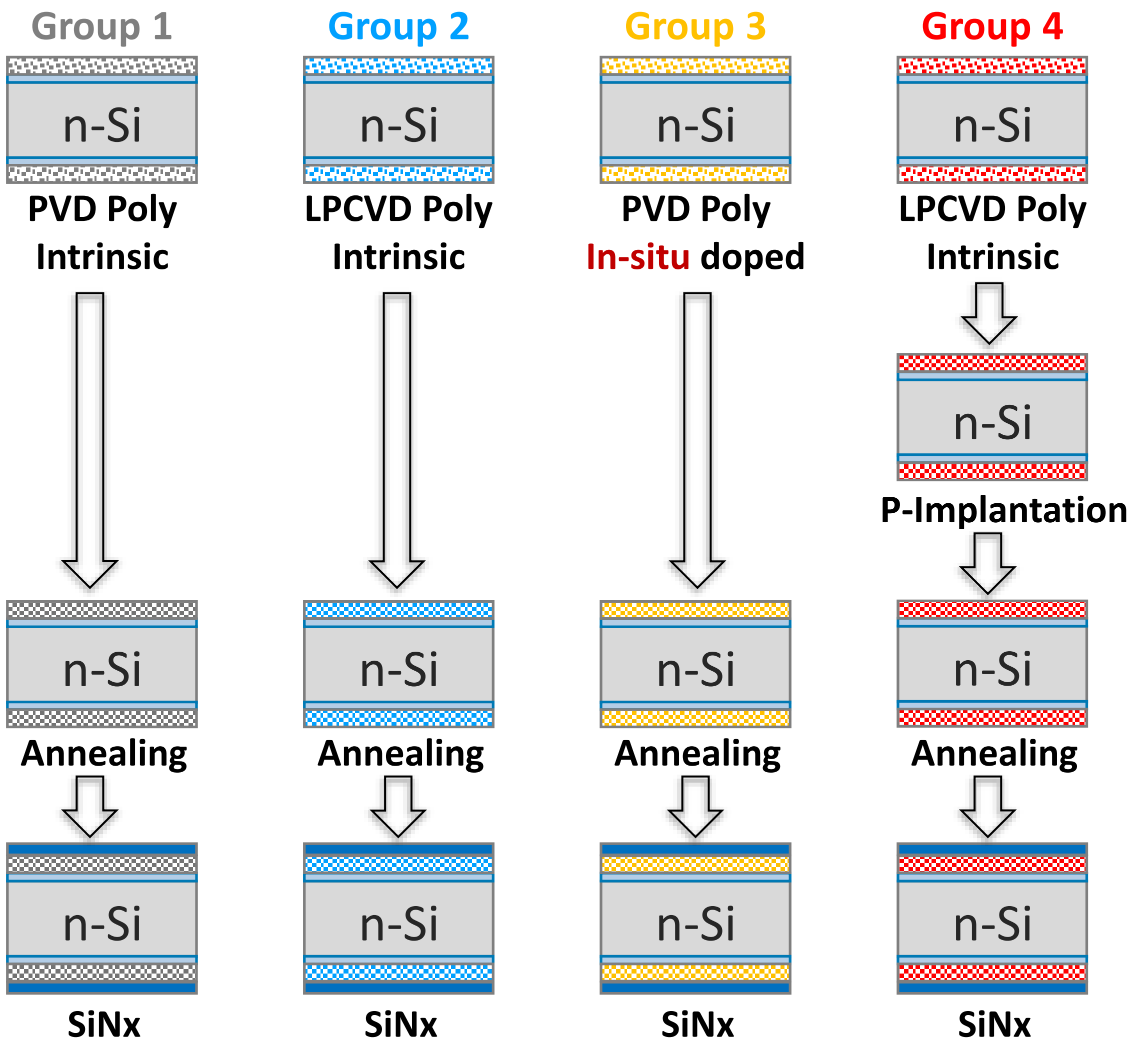
Fläche / Area (t)[1]:	=	(	330.21	±	0.33	) cm²
V_{OC}	=	(	715.9	±	2.3	) mV
I_{SC} (Ed.4 - 2019) /2/	=	(	13.62	±	0.19	) A
J_{SC}	=	(	41.25	±	0.58	) mA/cm²
I_{MPP}	=		12.94			A
V_{MPP}	=		620.6			mV
P_{MPP}	=	(	8.03	±	0.16	) W
FF	=	(	82.3	±	1.2	) %
η	=	(	24.32	±	0.49	) %

M10 Size	Jsc	Uoc	FF	Eta	Area
Unit	[mA/cm^2]	[mV]	[%]	[%]	[cm^2]
Jolywood	41.32	716.6	82.75	24.50	330.15
Fraunhofer ISE	41.25	715.9	82.3	**24.32**	330.21

- Similar Eff and Voc measured in the production line and certified by Fraunhofer CalLab

Further improvement





- Possible sputtered damage causes higher J0,pass with PVD i-poly compared with LPCVD i-poly

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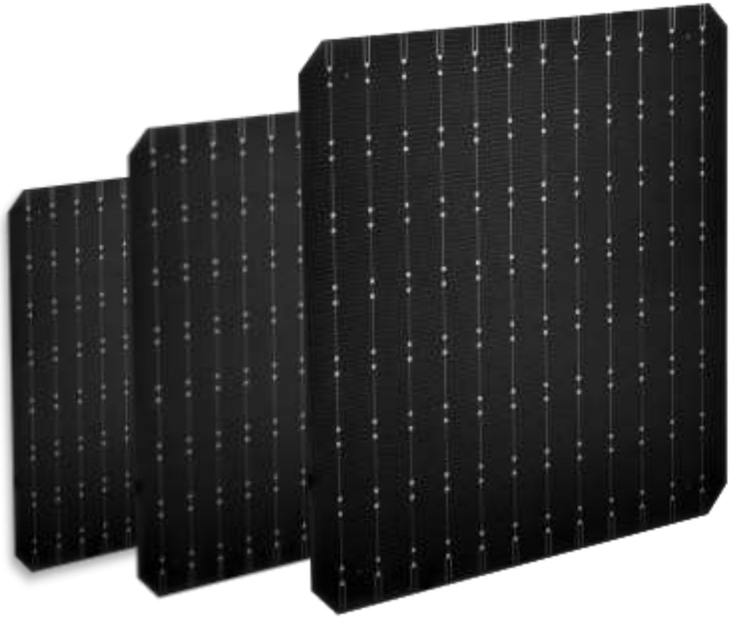
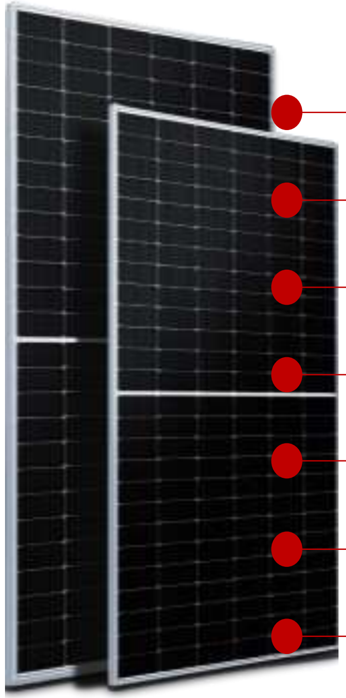
Jolywood TOPCon 2.0 module

TOPCon 2.0 + large-size wafer



TOPCon 2.0 module



- High Power ~560-570W
- High Bifaciality ~80%
- Low Temperature Coefficient ~0.31%/K
- Low Degradation
- High Reliability
- New POPAID technology
- Large Size Wafer

- About 3% BOS cost reduction and 4-5% energy yield achieved with J-TOPCon 2.0 modules compared with p-PERC bifacial modules*

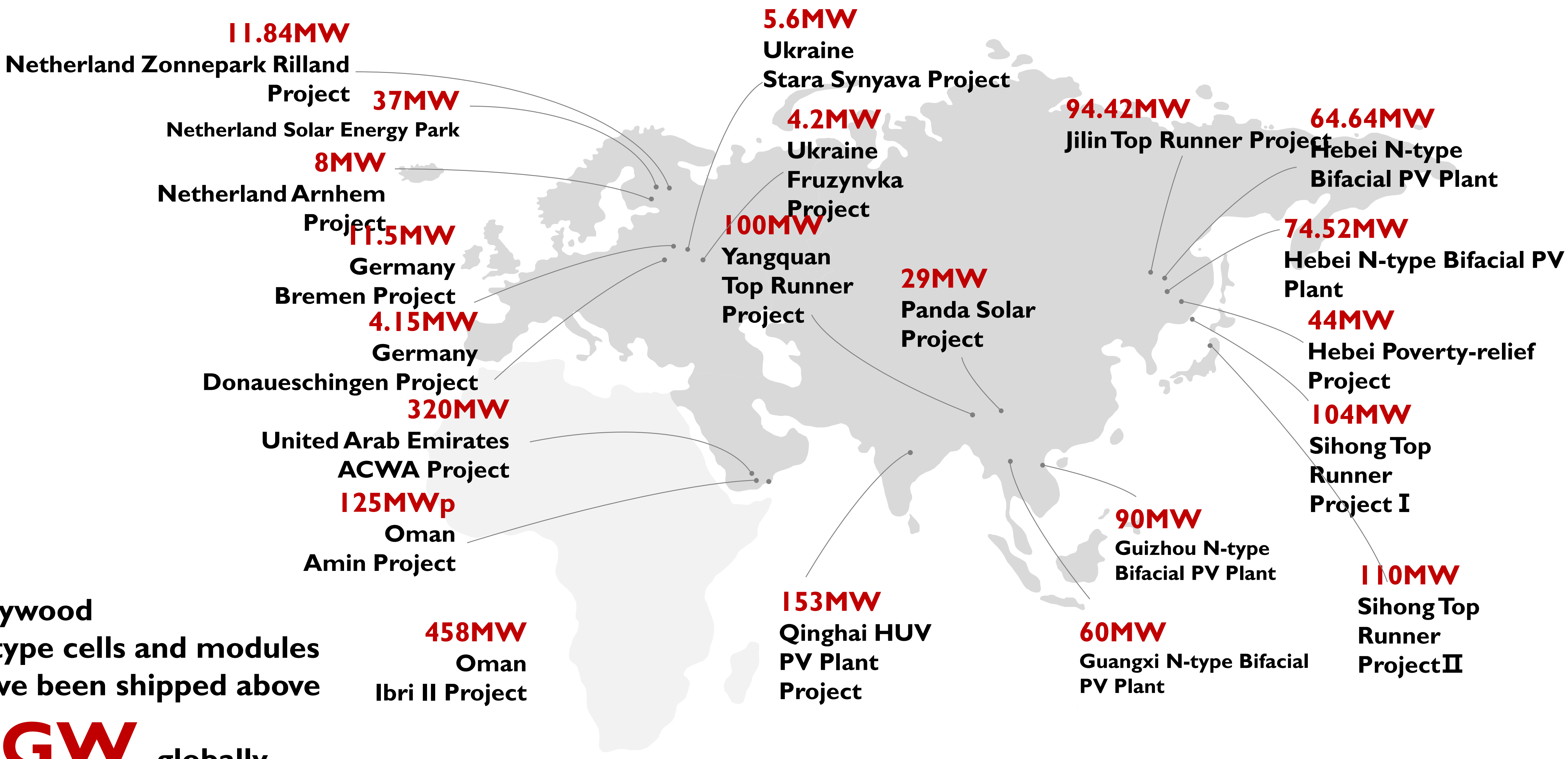
**Calculation varies from case to case depending on the actual application*

LCOE Calculation

	PERC - M10	TOPCon - M10	unit
Module Power	540	560	Wp
Module Size	2278*1134	2278*1134	mm
Efficiency	20.91	21.68	%
Bifaciality	70	80	%
P_{mpp} Temper. Coeff	-0.35%	-0.31%	/°C
1^{st} year Degradation	2	1	%
Annual Degradation	0.45%	0.40%	/yr
Specific production	1150	1200	kWh/kW$_p$/yr
Module cost	29.06	32.36	
BOS cost	26.30	25.66	¢/Wp
CAPEX cost	55.36	58.02	
LCOE	3.17	3.17	US ¢/kWh

- Up to ~11% price premium possible with Jolywood TOPCon 2.0 modules due to its higher module power and higher electricity generation per wattpeak

Outstanding n-type Shipment



Jolywood
n-type cells and modules
have been shipped above

5GW **globally**

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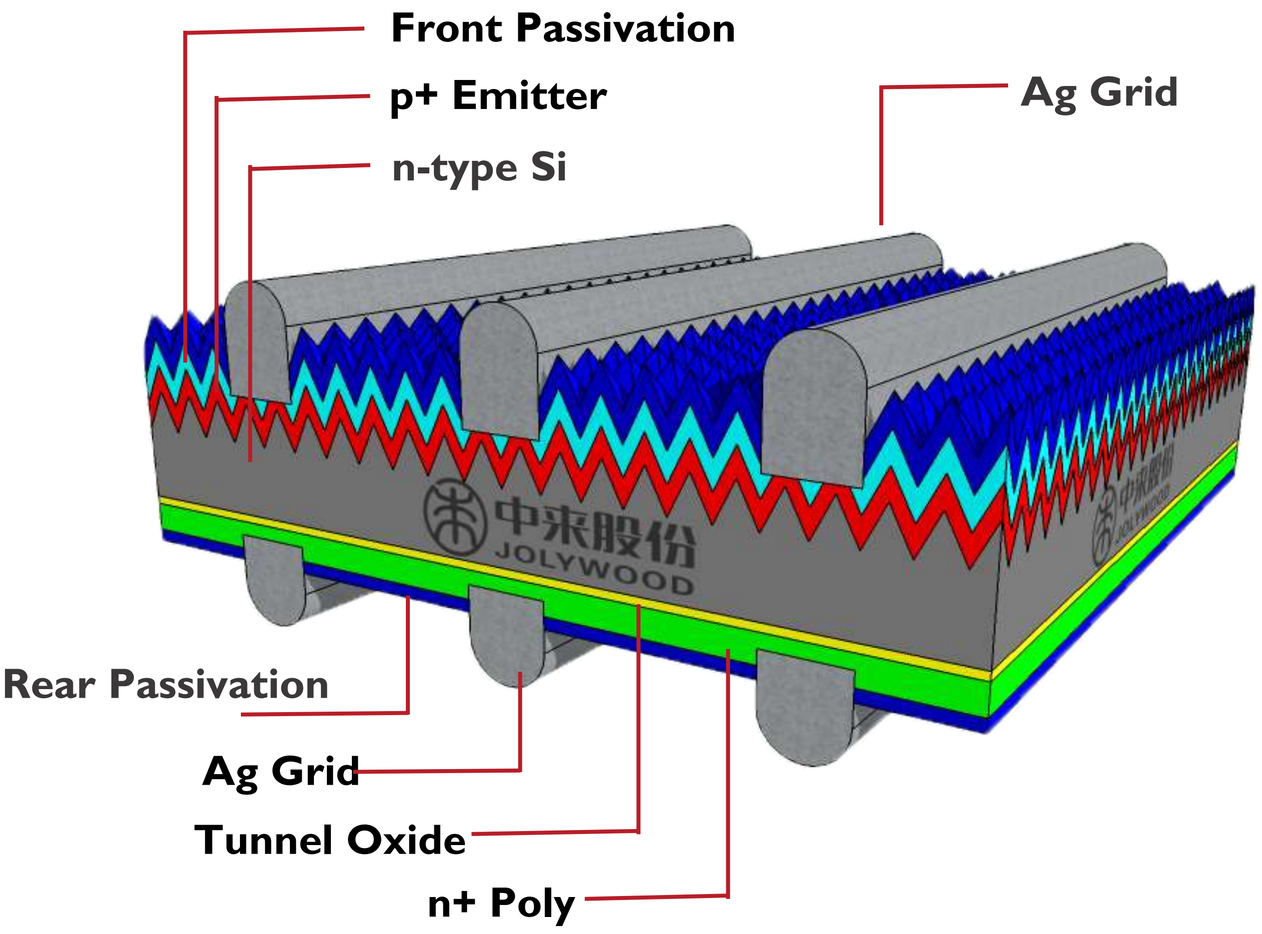
What’s next?



Efficiency Improvement:

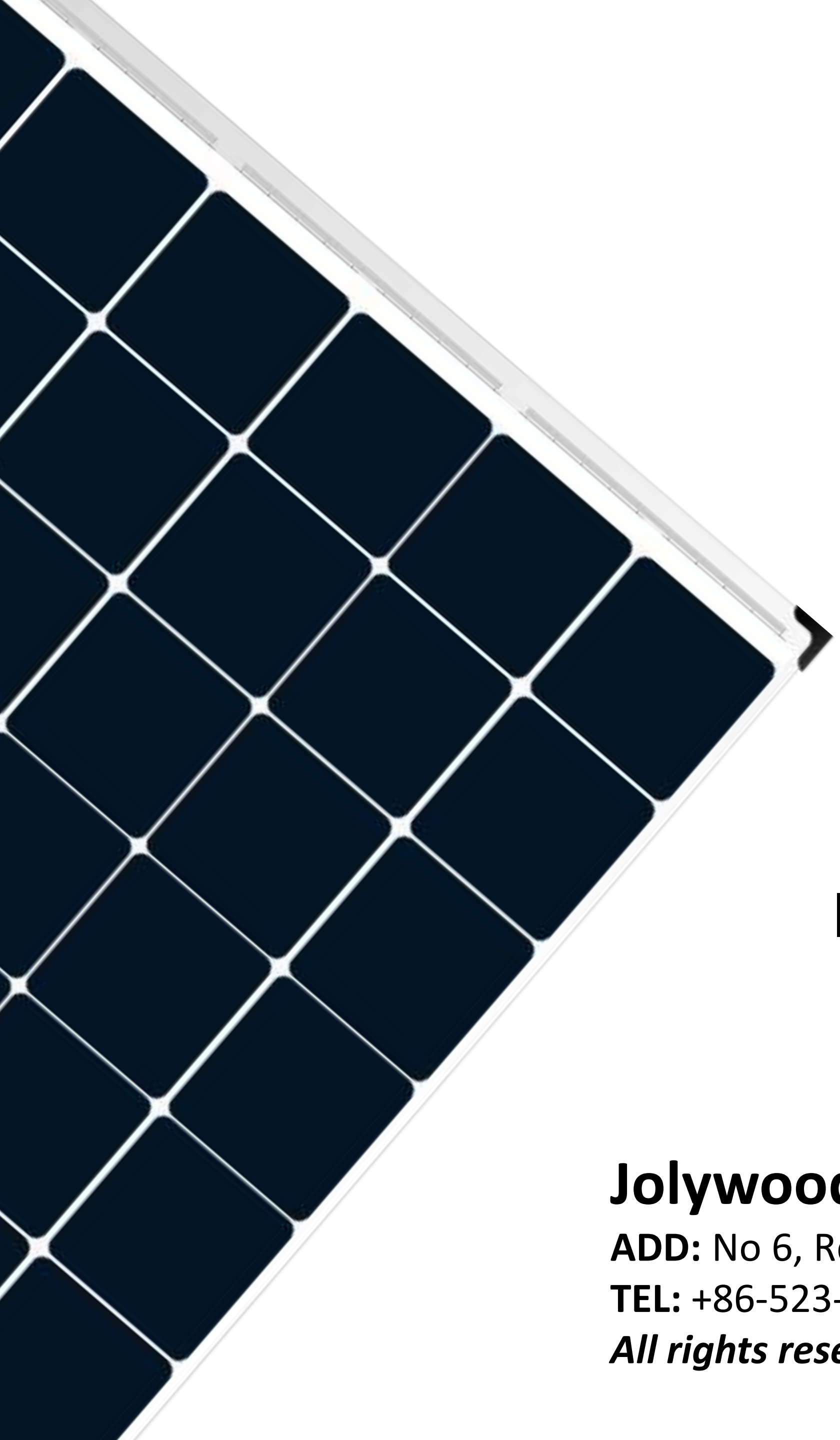
- Highest efficiency loss at emitter contact
- Improved emitter contact required with limited high-temperature steps and time
- Selective emitter necessary?

Cost reduction:

- Highest cost difference compared with PERC attributed to higher Ag consumption
- Revolutionary approaches required to reduce Ag consumption

JW TOPCon 2.0 → JW TOPCon 3.0:

The same efficiency and BB no, conventional screen-printing, but at least 1/3 less Ag



中来股份
JOLYWOOD

THANK YOU

It's always darkest before dawn. Keep the faith!

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