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Current Trends in Silicon-Based Solar Cell Technology

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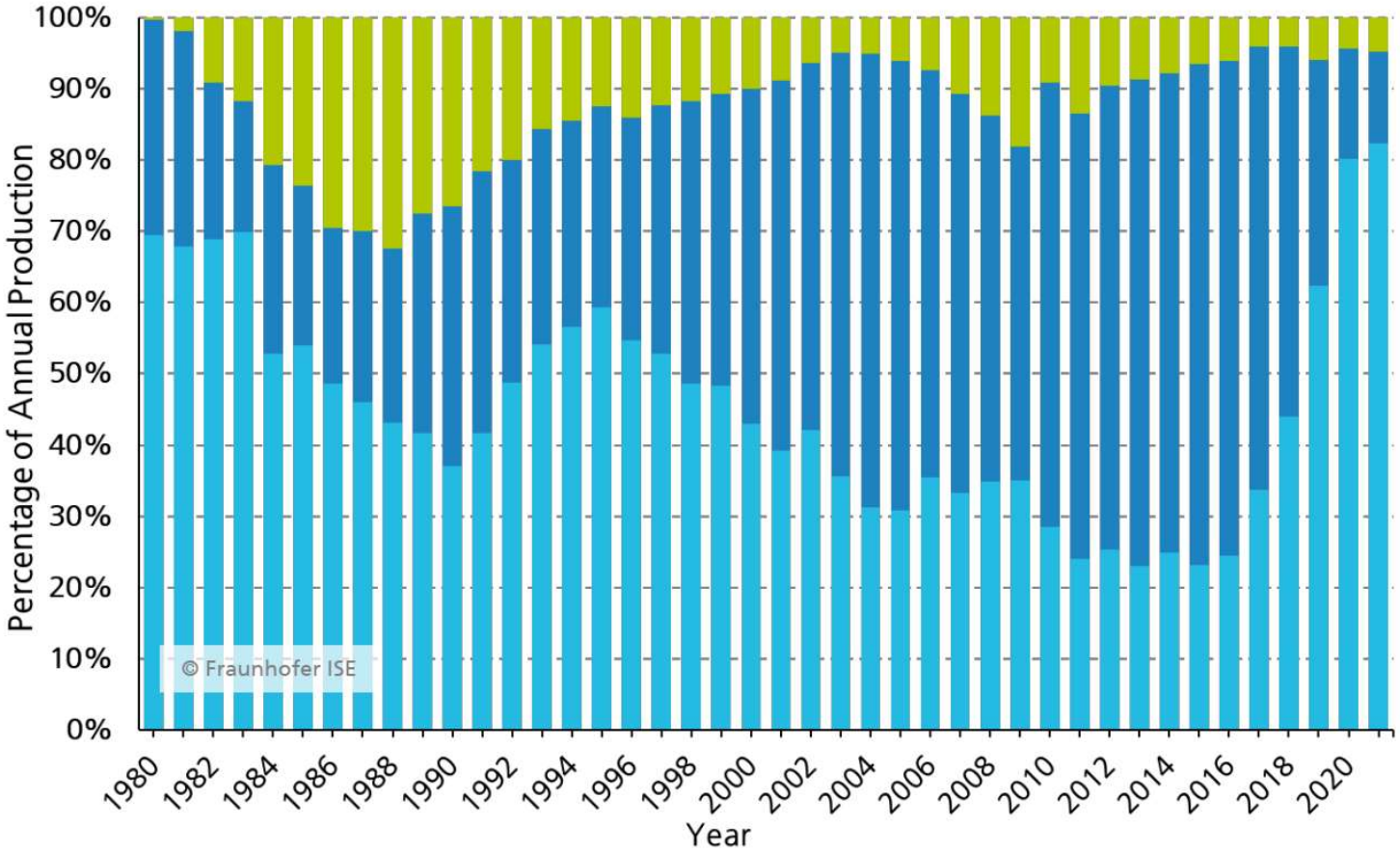
Introduction



Production 2021* (GWp)

Thin film	10
Multi-Si	20
Mono-Si	160

*estimated numbers

Data: from 2000 to 2009: Navigant; from 2010 to 2021 IHS Markit; from 2022 IEA. Graph: PSE 2022 . Date of data: July 2022

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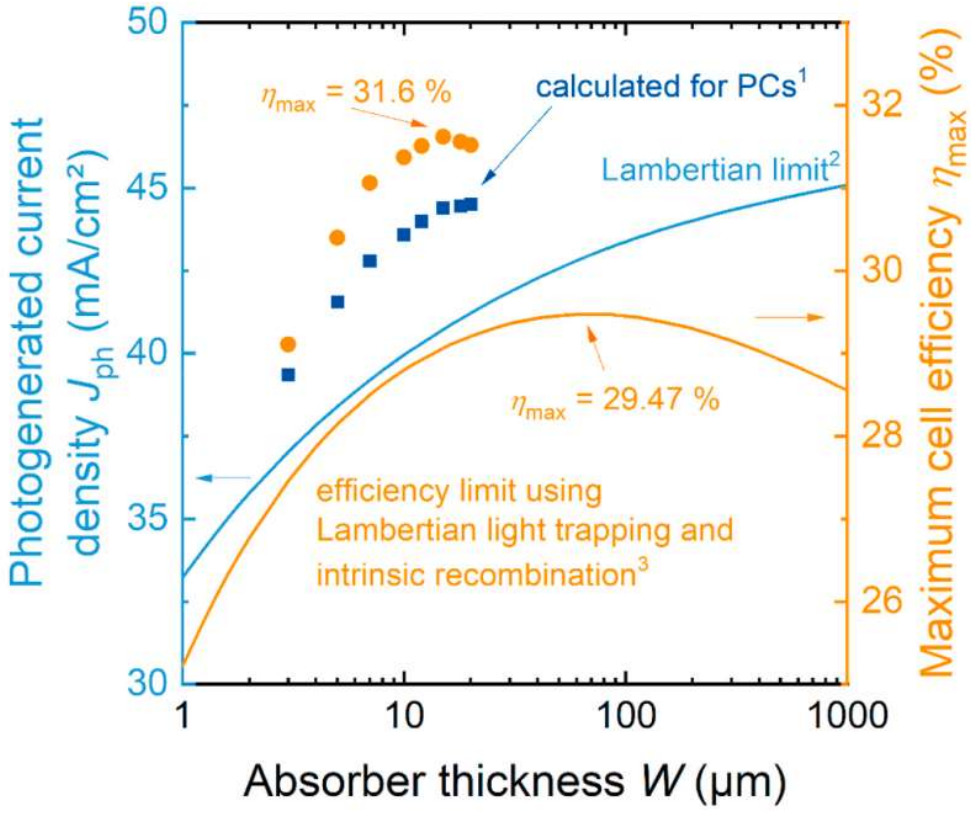
Records in Si solar cell efficiency

	Efficiency (%)	Cell area (cm^2)	V_{OC} (V)	J_{SC} (mA/cm^2)	FF (%)	Remark	Certified by
Si (crystalline cell)	**26.8 ± 0.4**	**274.4 (t)**	**0.7514**	**41.45**	**86.1**	LONGi, n-type HJT	ISFH (10/22)
Si (large)	26.6 ± 0.4	274.1 (t)	0.7513	41.30	85.6	LONGi, p-type HJT	ISFH (10/22)
Si (large)	25.3 ± 0.4	268.0 (t)	0.7214	42.07	83.4	Jinko, n-type TOPCon	ISFH (11/21)
Si (large)	24.0 ± 0.3	244.59 (t)	0.6940	41.58	83.3	LONGi, p-type PERC	ISFH (7/19)

Green, et al., Prog Photovolt Res Appl. 2023;31:651–663, DOI: 10.1002/pip.3726

Efficiency limit

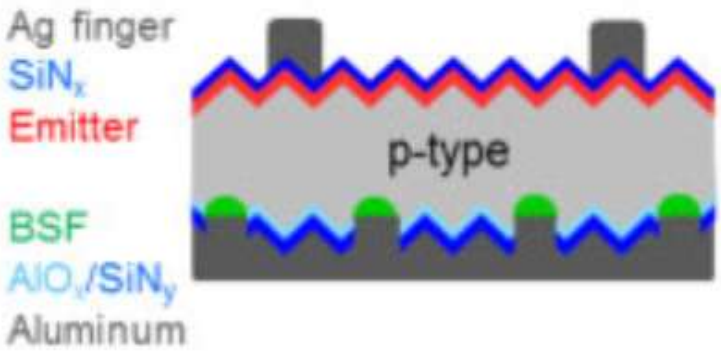


- All calculations neglect surface and Shockley-Read-Hall recombination.
- Photonic crystals allow efficiency 2% points higher than the Lambertian efficiency limit
- Increased light absorption of silicon absorbers using PCs compared to conventional Lambertian light trapping.
- Much thinner absorbers reduce the intrinsic recombination losses and thus increase the maximum achievable efficiency.

J. Krügener et al., *Solar Energy Materials and Solar Cells 233 (2021) 111337.* DOI: 10.1016/j.solmat.2021.111337

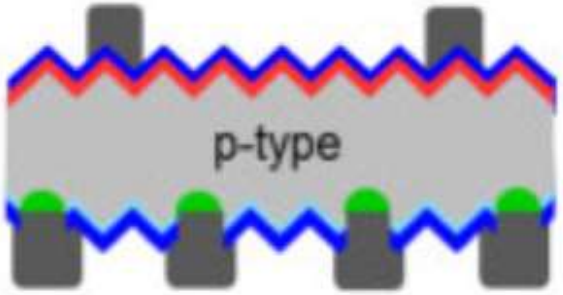
PERC – Passivated Emitter and Rear Cell

Monofacial



BSF: Back surface field

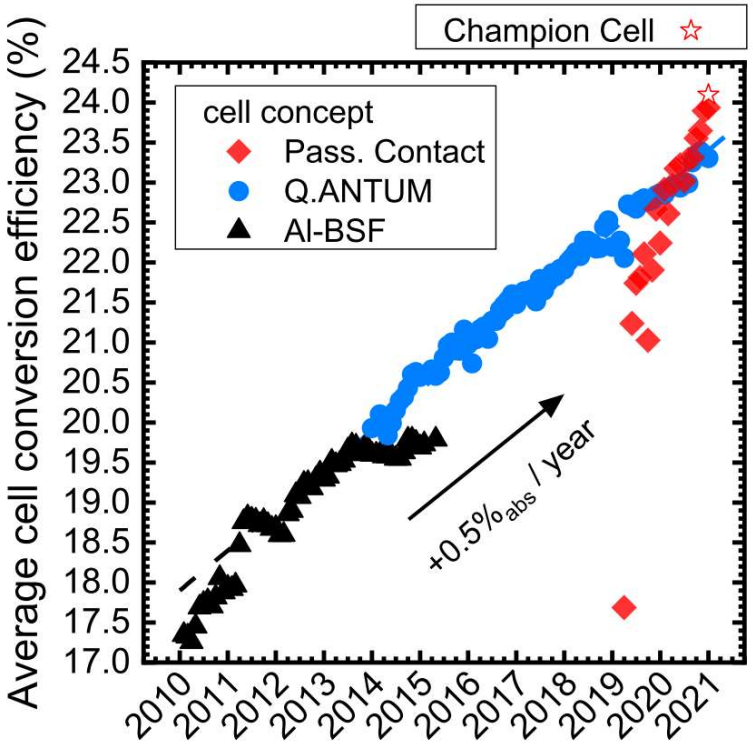
Bifacial



Improvement by selective emitter using laser doping

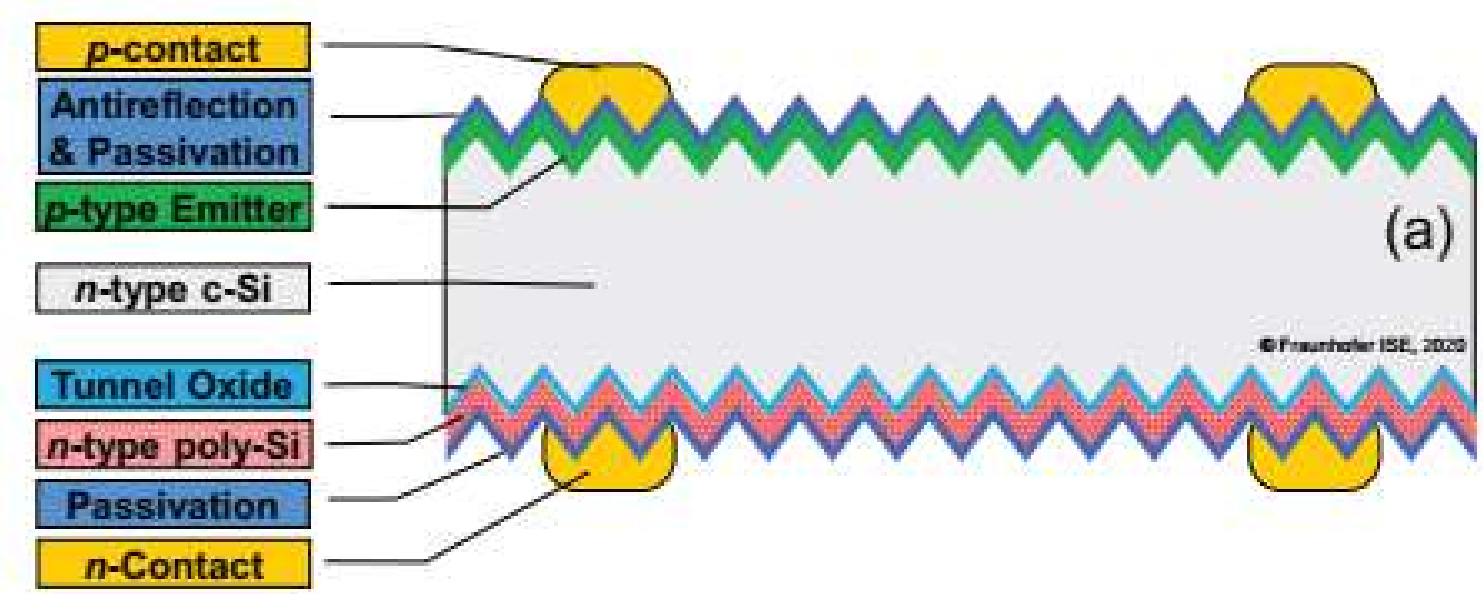
Dullweber et al., Japanese Journal of Applied Physics 57, 08RA01 (2018), https://doi.org/10.7567/JJAP.57.08RA01

Efficiency Increase per Year – New Solar Cell Concepts needed



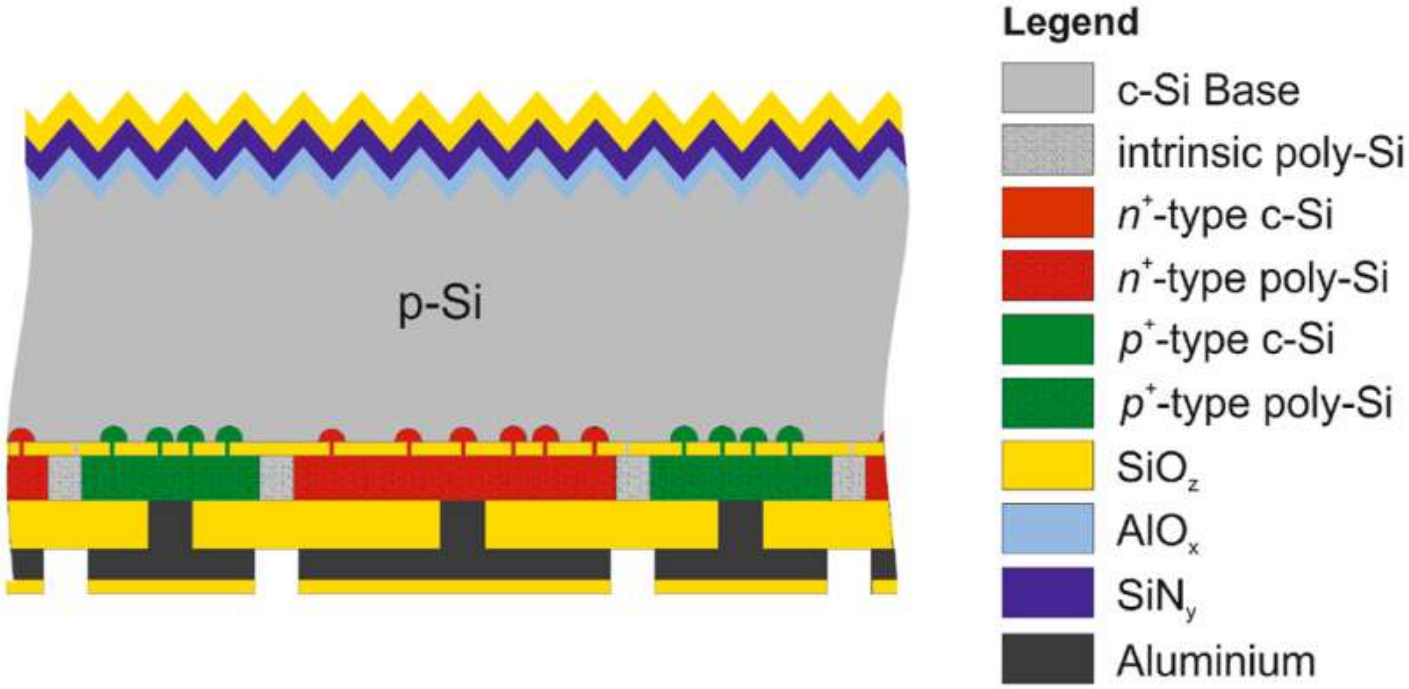
Fertig, Fabian (01.2022). "Q CELLS > 24% Silicon Solar Cells With Mass-Production Processes". IEEE journal of photovoltaics (2156-3381), 12 (1), S. 22. DOI: 10.1109/JPHOTOV.2021.3112122

TOPCon - Tunnel Oxide Passivating Contact



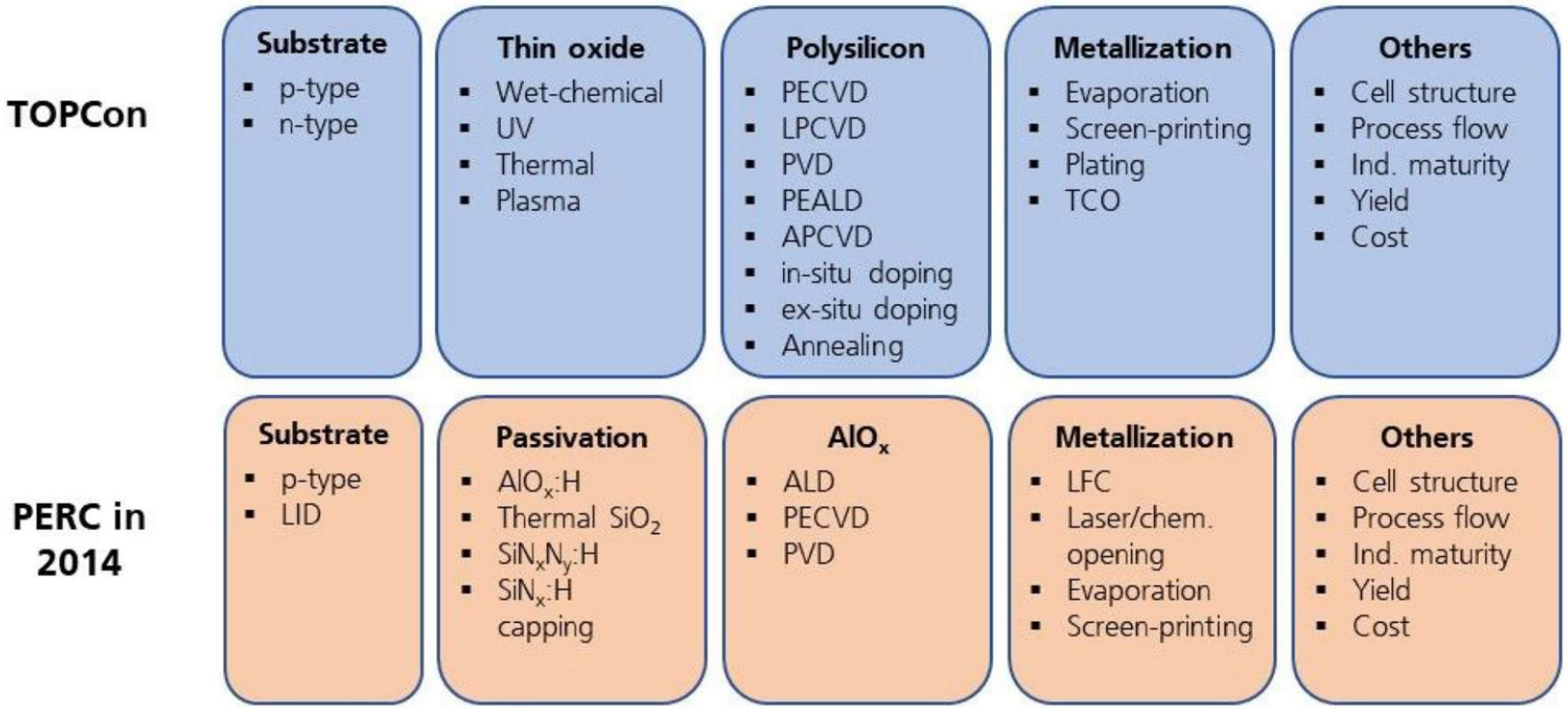
Wilson, Gregory M (12.2020). "The 2020 photovoltaic technologies roadmap". Journal of physics. D, Applied physics (0022-3727), 53 (49), S. 493001. DOI: 10.1088/1361-6463/ab9c6a

TOPCon / POLO IBC



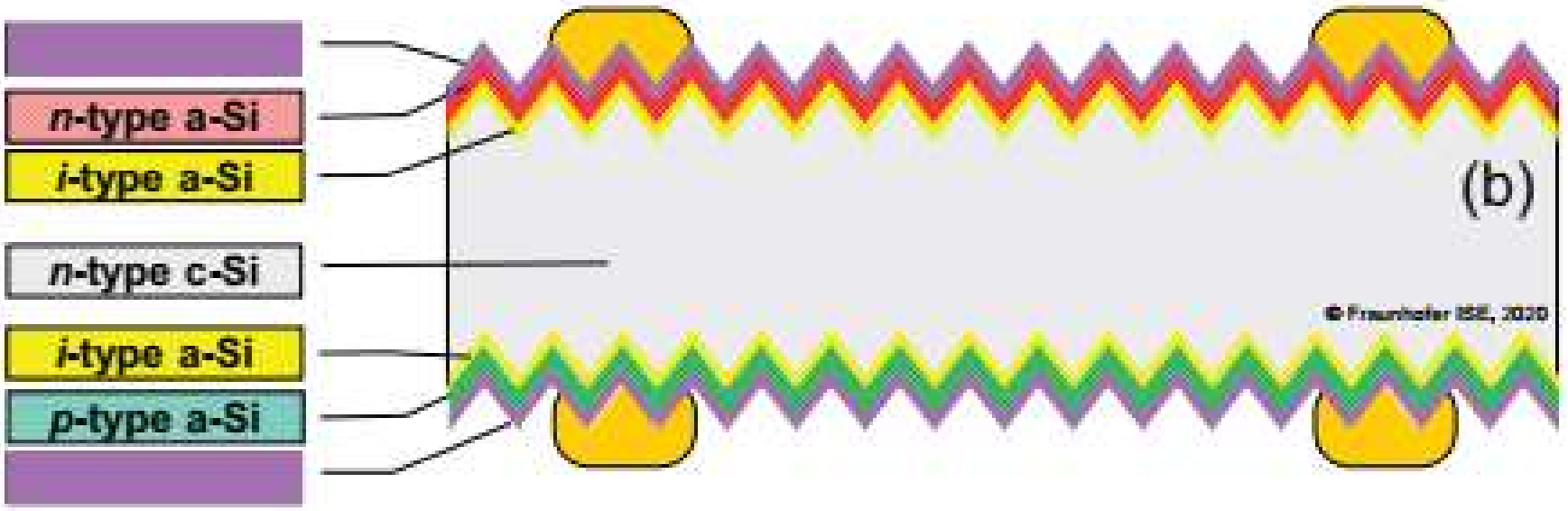
Peibst, R. (05.2022). "Towards 28 %-efficient Si single-junction solar cells with better passivating POLO junctions and photonic crystals". Solar Energy Materials and Solar Cells (0927-0248), 238, S. 111560. DOI: 10.1016/j.solmat.2021.111560

TOPCon - Tunnel Oxide Passivating Contact



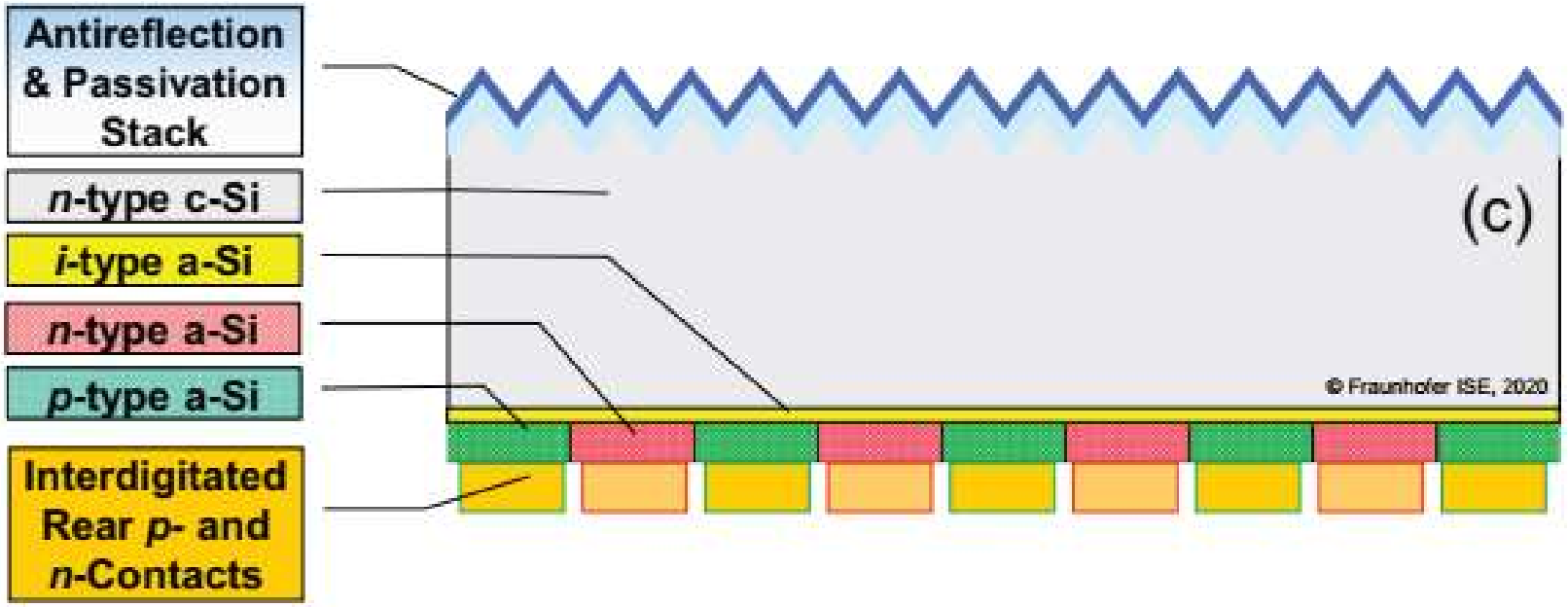
Glunz, Stefan W. (04.2023). "Silicon-based passivating contacts: The TOPCon route". Progress in photovoltaics (1062-7995), 31 (4), S. 341. DOI: 10.1002/pip.3522

Silicon Heterojunction



Wilson, Gregory M (12.2020). "The 2020 photovoltaic technologies roadmap". Journal of physics. D, Applied physics (0022-3727), 53 (49), S. 493001. DOI: 10.1088/1361-6463/ab9c6a

Silicon Heterojunction IBC



Wilson, Gregory M (12.2020). "The 2020 photovoltaic technologies roadmap". Journal of physics. D, Applied physics (0022-3727), 53 (49), S. 493001. DOI: 10.1088/1361-6463/ab9c6a

Summary

- TOPCon (POLO) and HJT come into production
- Cell concepts are applicable as both sides contacted or IBC
- HJT show an appealing simple solar cell process
- However, cost of ownership is higher for HJT than TOPCon (10 GW factory[1])

[1]Reichle et al., presented at EU PVSEC, Lisbon, 2023

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Thank you very much for your attention

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