Overview c-Si & Perovskite/Silicon Tandem Solar Cells

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Schweizer PV Tagung, 22.03.2024

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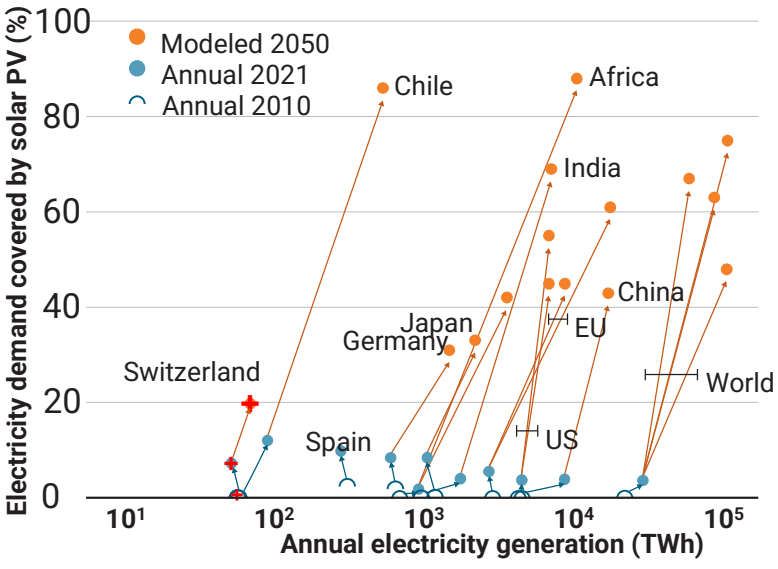
A Glimpse into the Crystal Ball

- We need more energy globally

70.000 (2020) ➔ 120.000 (2050) TWh

- Increasingly more electricity due to electrification in production and consumption

- Solar PV must play a significant role (20-80% of consumption depending on region)



Haegel et al. Science 2023, 380(6640), 39–42.
BFE Reports 2010-2021

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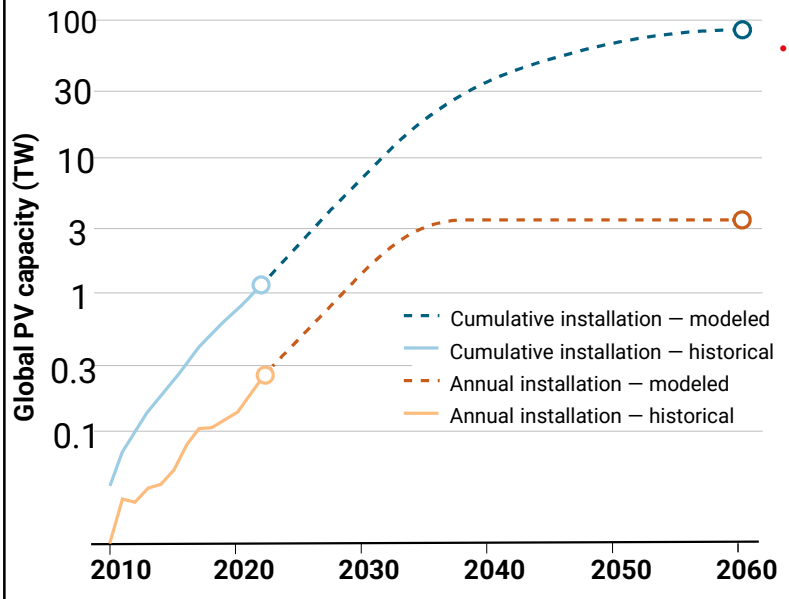
A Glimpse into the Crystal Ball – how to get there?



- **Exponential growth (25%) for the next decade in:**
  - **Supply chains**
  - **Deployment**
  - **Maintaince**
  - **Systems / Electricity net**
  - **Recycling**
- **3 TW / yr = 190 modules* / second**

Haegel et al. Science 2023, 380(6640), 39–42.

** 500 W_p modules*

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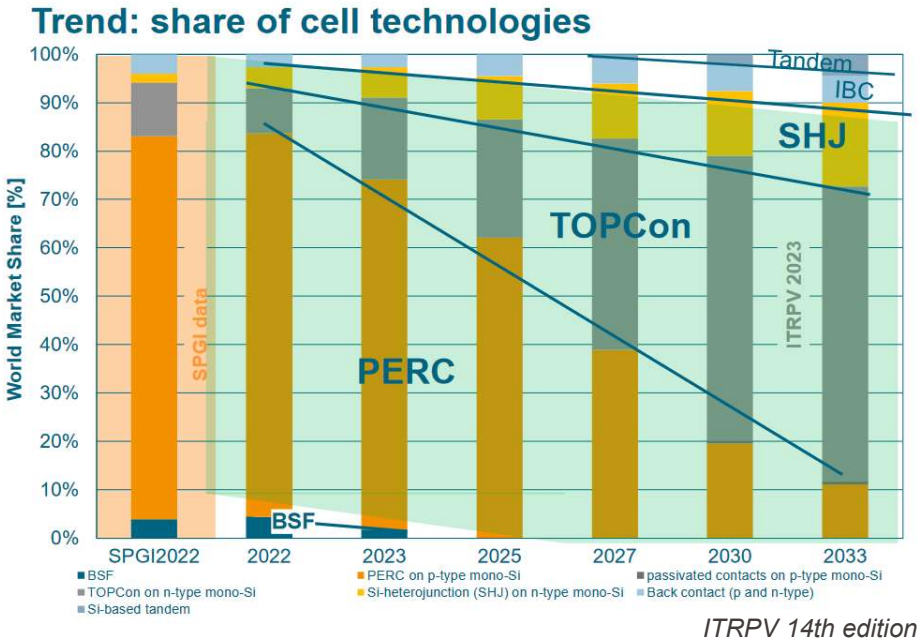
A Glimpse into the Crystal Ball – which technology ?

The photovoltaic market is dynamic:

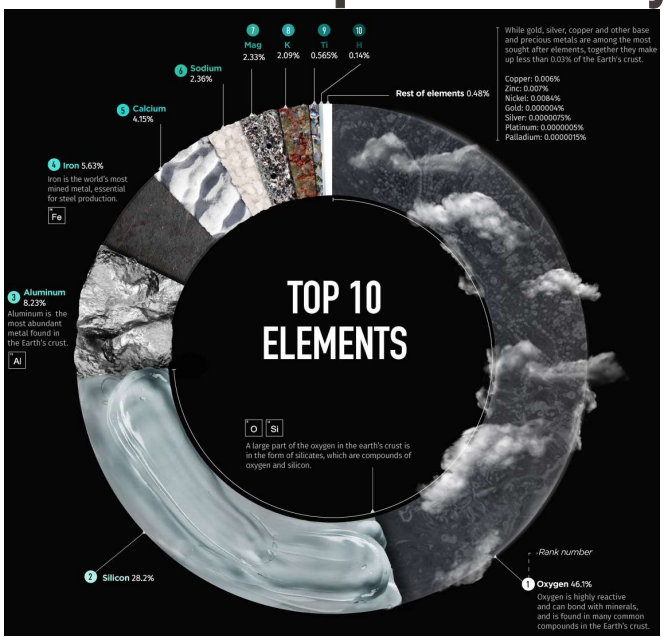
better technologies take over

BSF → PERC → TOPCon → SHJ → IBC (c-Si) → **Tandem Solar Cells**



ITRPV 14th edition

A Glimpse into the Crystal Ball – Material Demand



visualcapitalist.com

Solar cells require silicon, but also

- Boron
- Phosphor
- Silver
- Indium
- ….

At 3 TW : e.g.,

45.000 tons of silver, 15.000 tons of indium, ….

vs. 23.000 tons and 500 tons in 2023 ….

Developments from Neuchâtel

- Alternative materials
- Better energy yield = efficiency:
  - improvements in c-Si
  - Tandem solar cells

➔ rough estimate:

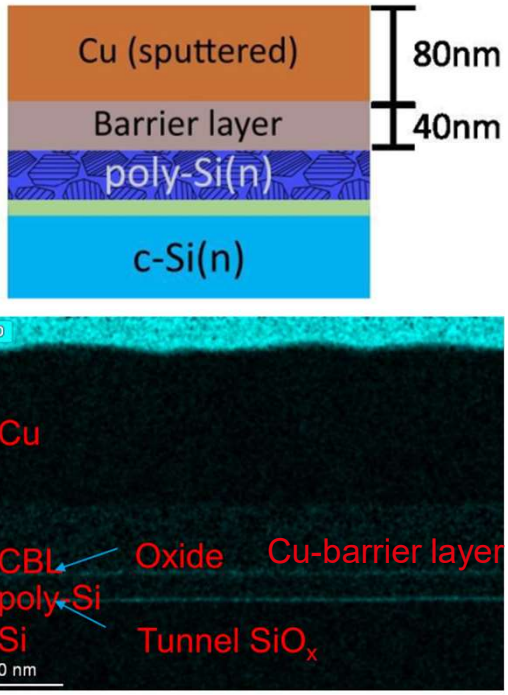
Tandem provides 3x voltage, ½ current

~ 50 % more energy per m^2

~ 50 % less indium and silver needed

Silver-«free» metallization

- Cu-sputtering/plating to replace silver
- Interaction between Cu & poly-Si(n) layer studied via microscopy & chemical analysis
- Comparably low sputter damage, acceptable contact resistance, needs better-controlled stripping of oxides



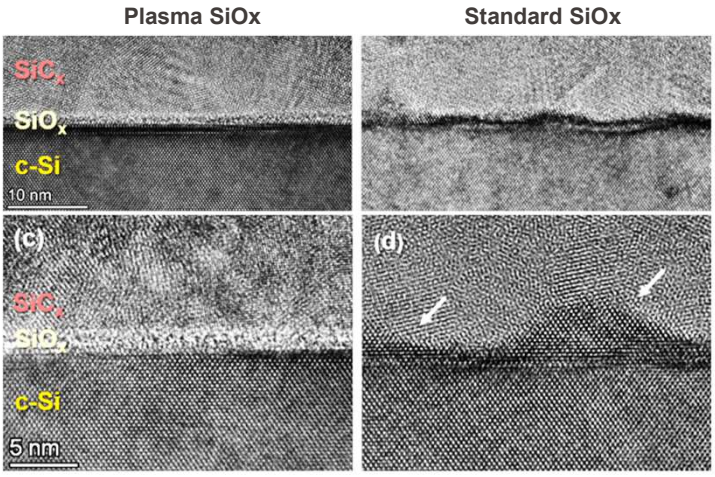
Solar-Era-Net, OFEN, «COMET»

Improved poly-Si surface passivation

plasma-assisted SiOx growth mode enables compact layer with:

- Continuos and crystalline morphology
- Better passivation
- Higher tolerance to post-processing

Offers to improve TOPCon resilience



Libraro et al., in prep.

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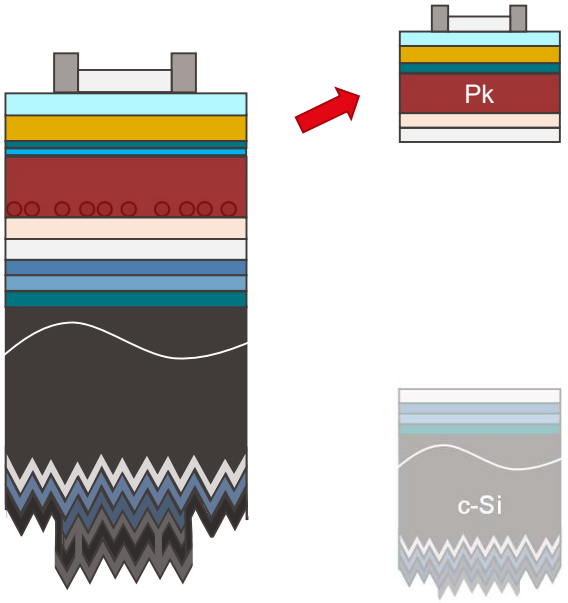
Improved perovskite-Si tandems – top-cell



What's the optimal contact layers for perovskite top-cell?

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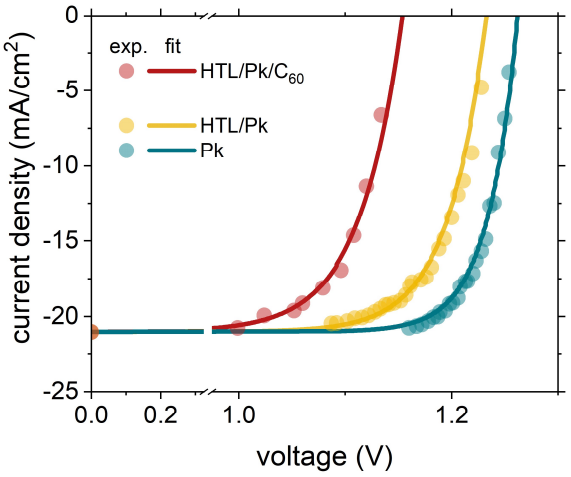
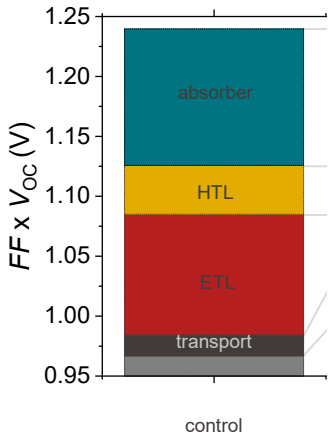
Photoluminescence-based loss-breakdown

- Optical assessment of efficiency through pseudo-JV curves
- Aluminium oxide interlayer at n-contact improves the FF x V_{OC} product





Artuk et al., Adv. Mater. 2024

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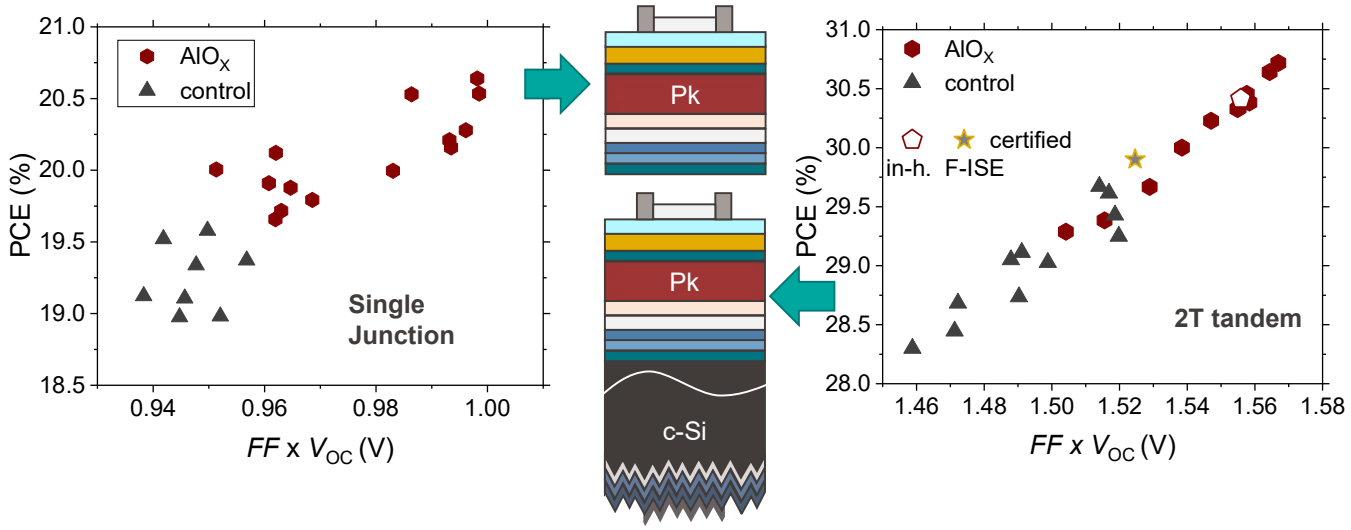
Improved top-cell drives tandem efficiency



AlOx interlayer improves the *FF* x V_{OC} product through an improved *iFF* & iV_{OC}, but introduces a small transport loss

Artuk et al., Adv. Mater. 2024

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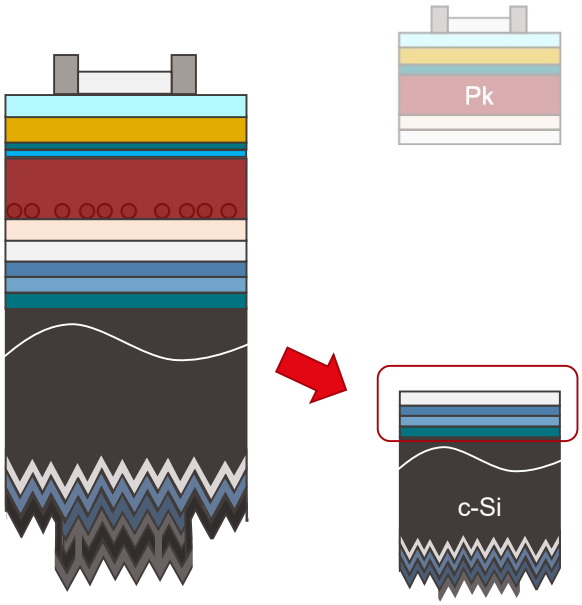
Improved perovskite-Si tandems – bottom-cell



What's the ideal interconnection?

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improving wetting & increasing R_{shunt}

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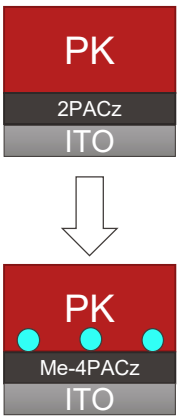

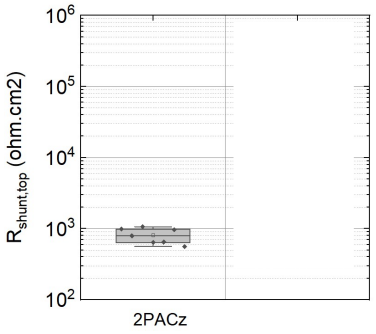

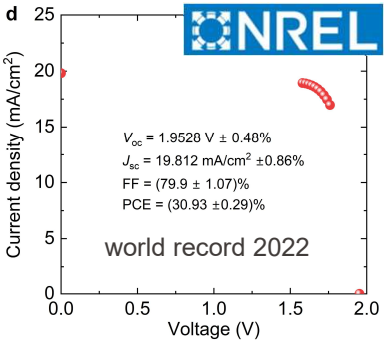

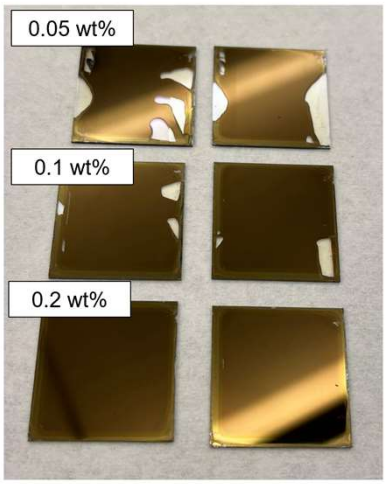

Perovskite on Me-4PACz/SiO2-NP

Novel bilayer p-contact with:

- better process yield
- higher performance

Turkay *et al., submitted*

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Combined efforts – tandem solar cells > 30%

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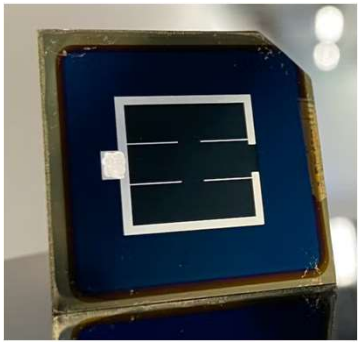

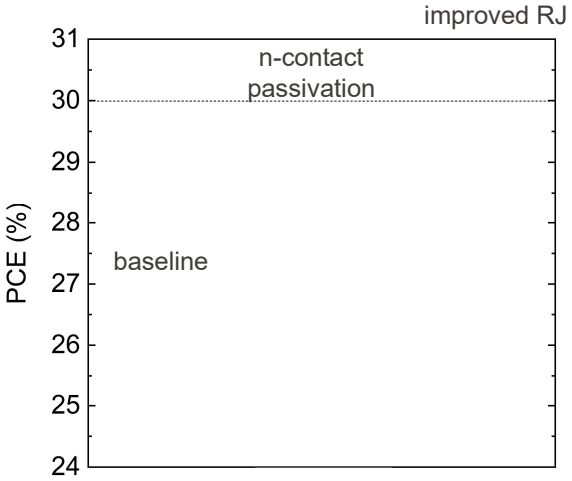

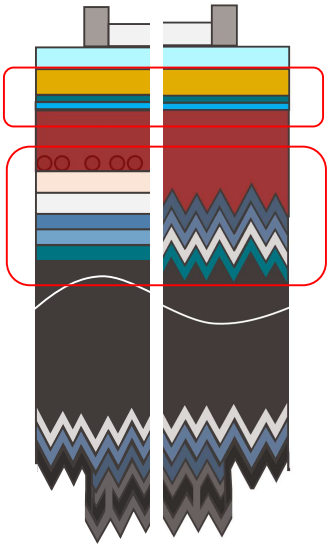

Chin et al., Science, 2023
Artuk et al., Adv. Mater. 2024
Turkay et al., submitted

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Contributors & Acknowledgements

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