Catalytic-doping on Intrinsic Amorphous Silicon Thin Films in Silicon Heterojunction Solar Cells

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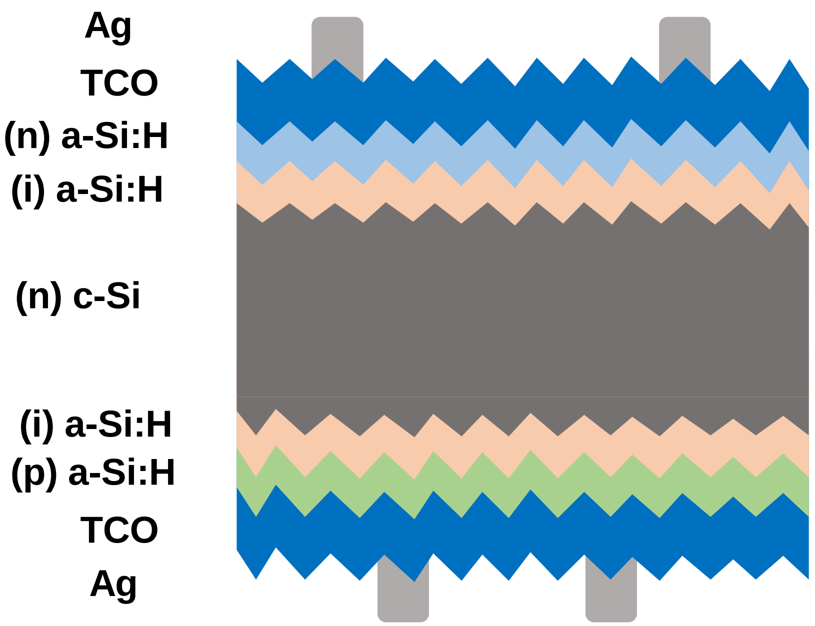
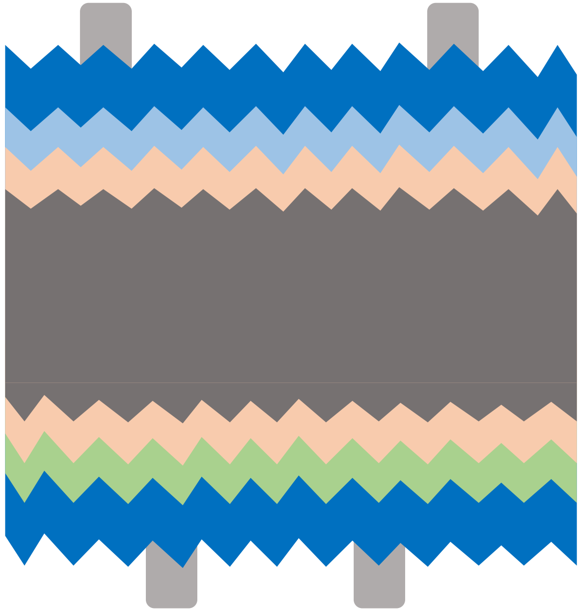
Features of SHJ Solar Cells



Schematic cross-section of a typical traditional silicon heterojunction (SHJ) solar cell

- High efficiency (record 26.5%).
- Mass production efficiency > 25%.
- Low thermal coefficient (< 0.3 %/°C).
- Simple processing (5 steps).
- Compatible with thinner wafers (< 100µm).
- High bifaciality (95%).
- Partner for tandem.

Efficiency Limitation of SHJ Solar Cells



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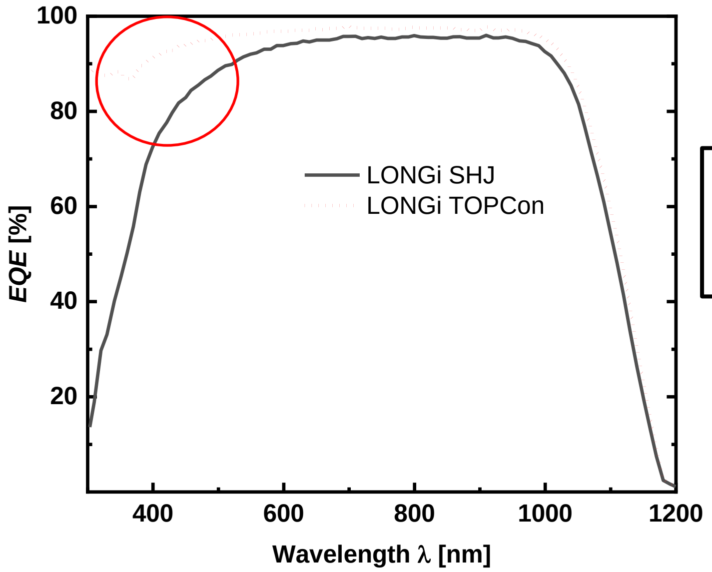


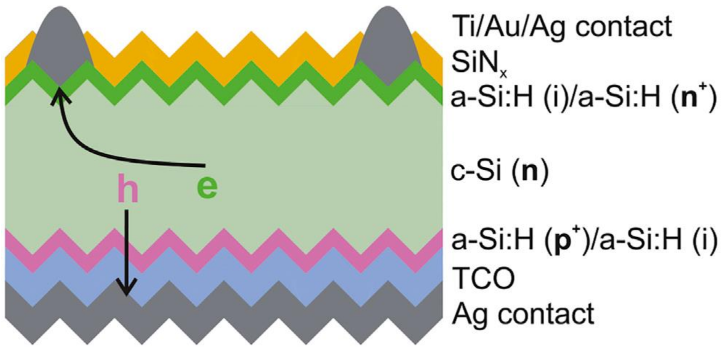
High parasitic absorption in TCO and silicon thin films!

Cell type	V_{oc} [mV]	J_{sc} [mA/cm^2]	*FF* [%]	Eff [%]	Area [cm^2]
LONGi SHJ	748.5	39.48	85.46	25.26	244.53
LONGi TOPCon	721.6	41.64	83.90	25.21	242.97

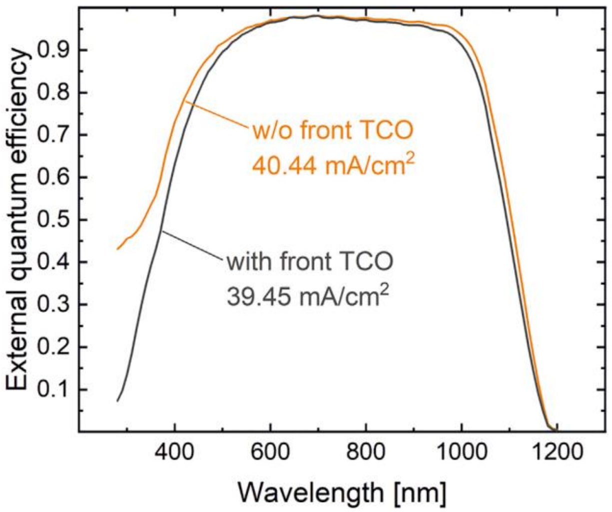
https://taiyangnews.info/technology/longi-claims-3-new-cell-conversion-efficiency-records/

J_{sc} Improvement of SHJ in Jülich

- TCO-free



Joule **5, 2021,1535-1547**



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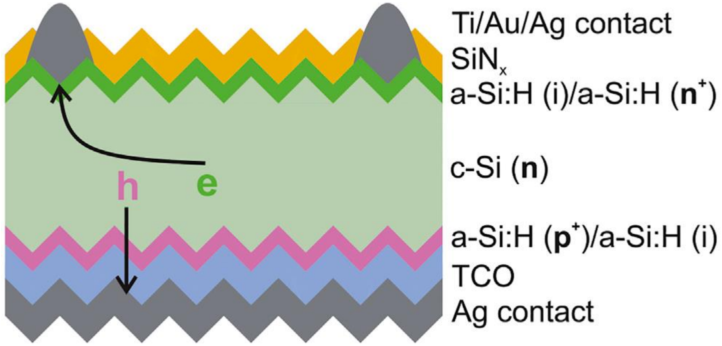

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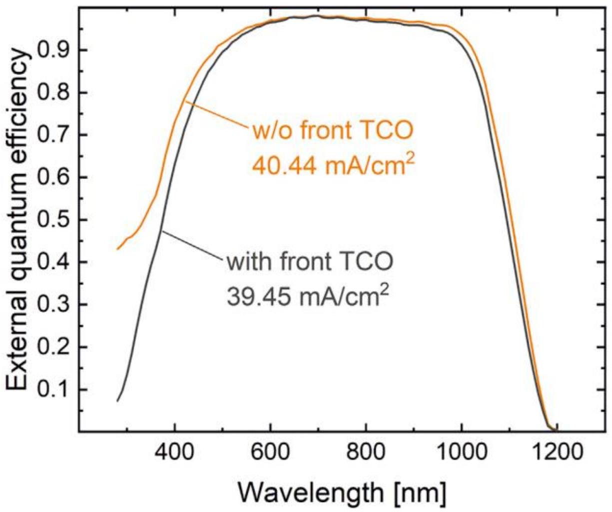
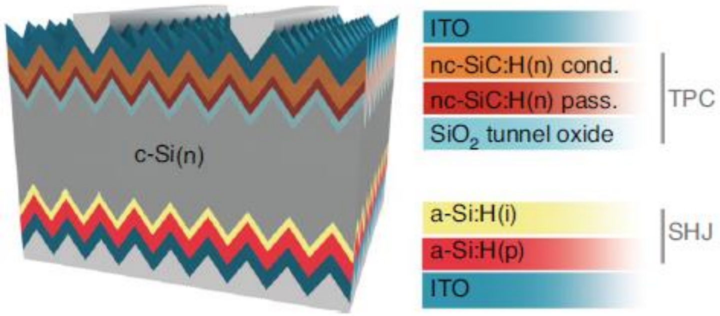
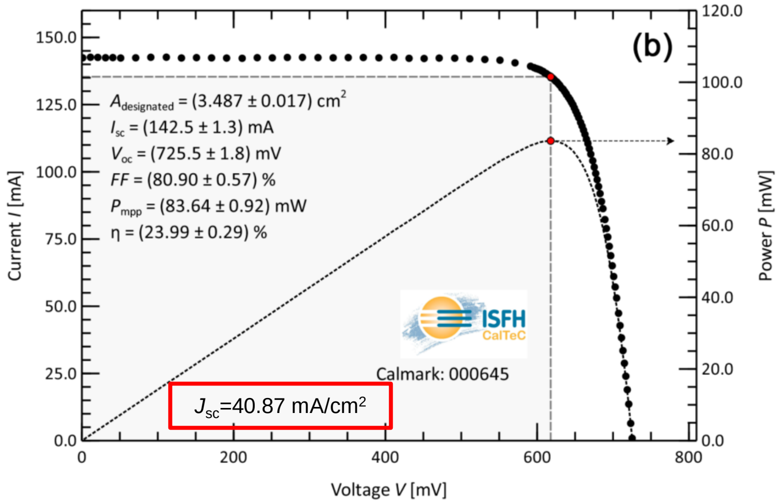


- Transparent passivating contact (TPC)



***Nature Energy* 6, 2021,529-537**



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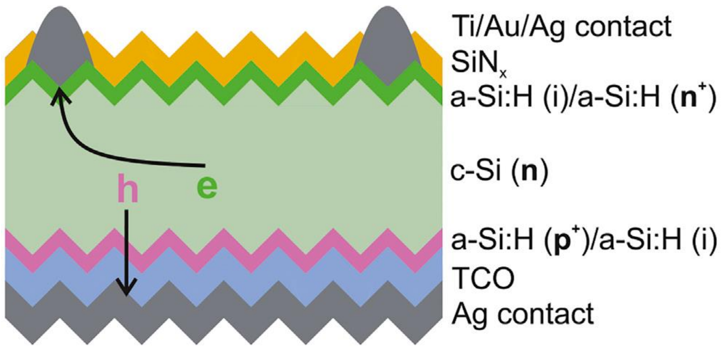

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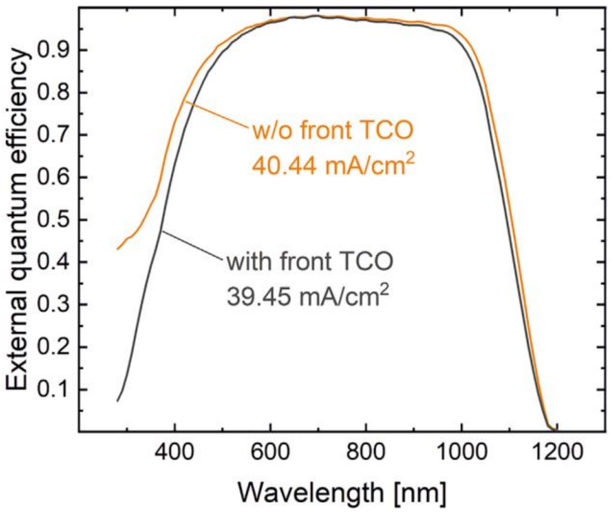

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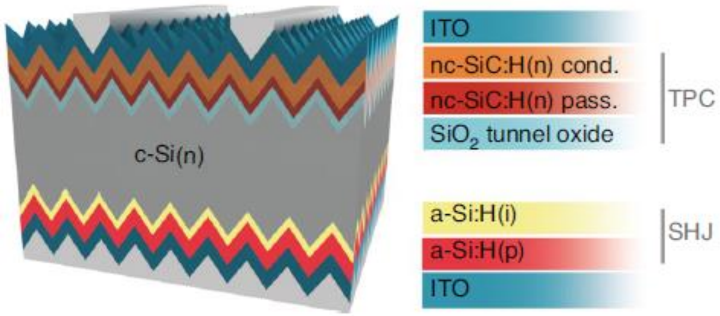

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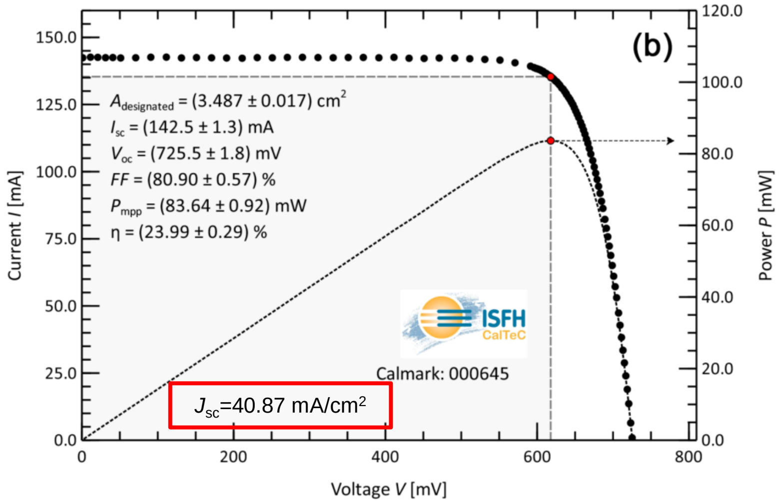
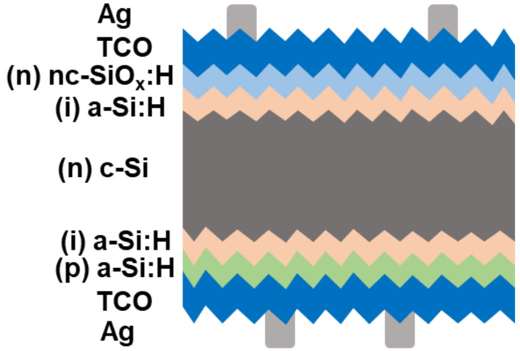
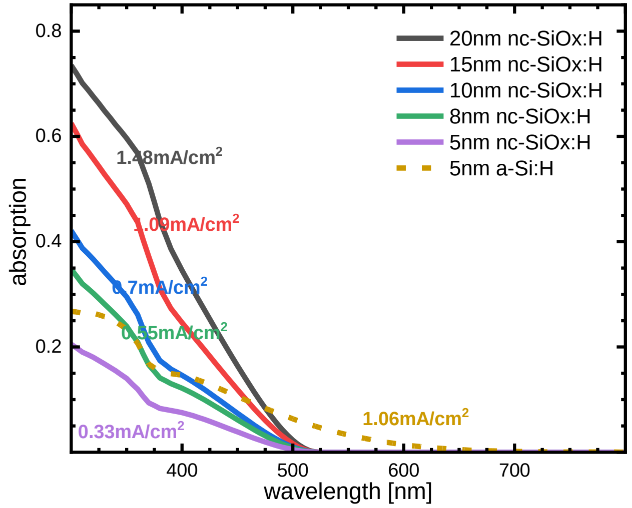


- nc-SiO$_x$:H window layer



Solar Energy Materials & Solar Cells 209**, 2020, 110471**



J_{sc} Improvement by Reducing Silicon Thin Film Thickness

- Reduce n doped layer thickness
  → decrease selectivity

- Reduce front (i) a-Si:H thickness
  → decrease surface passivation

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- Reduce front (i) a-Si:H thickness
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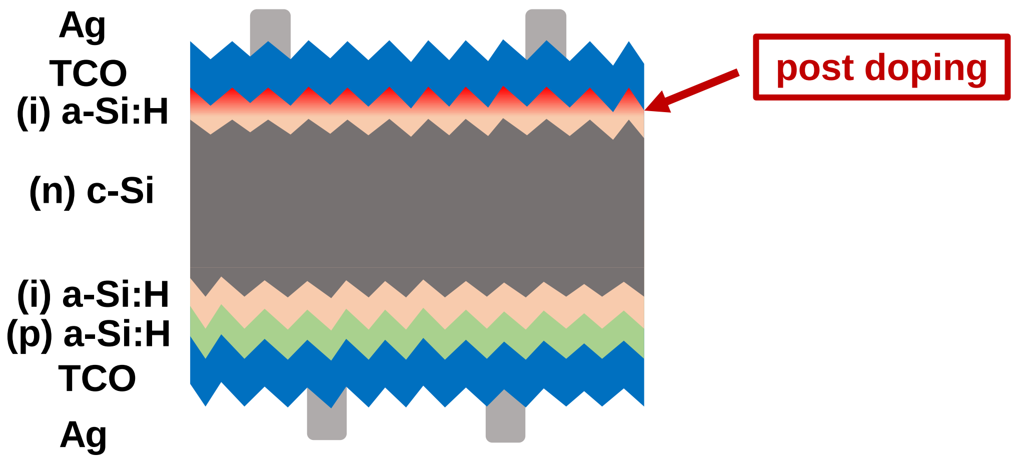
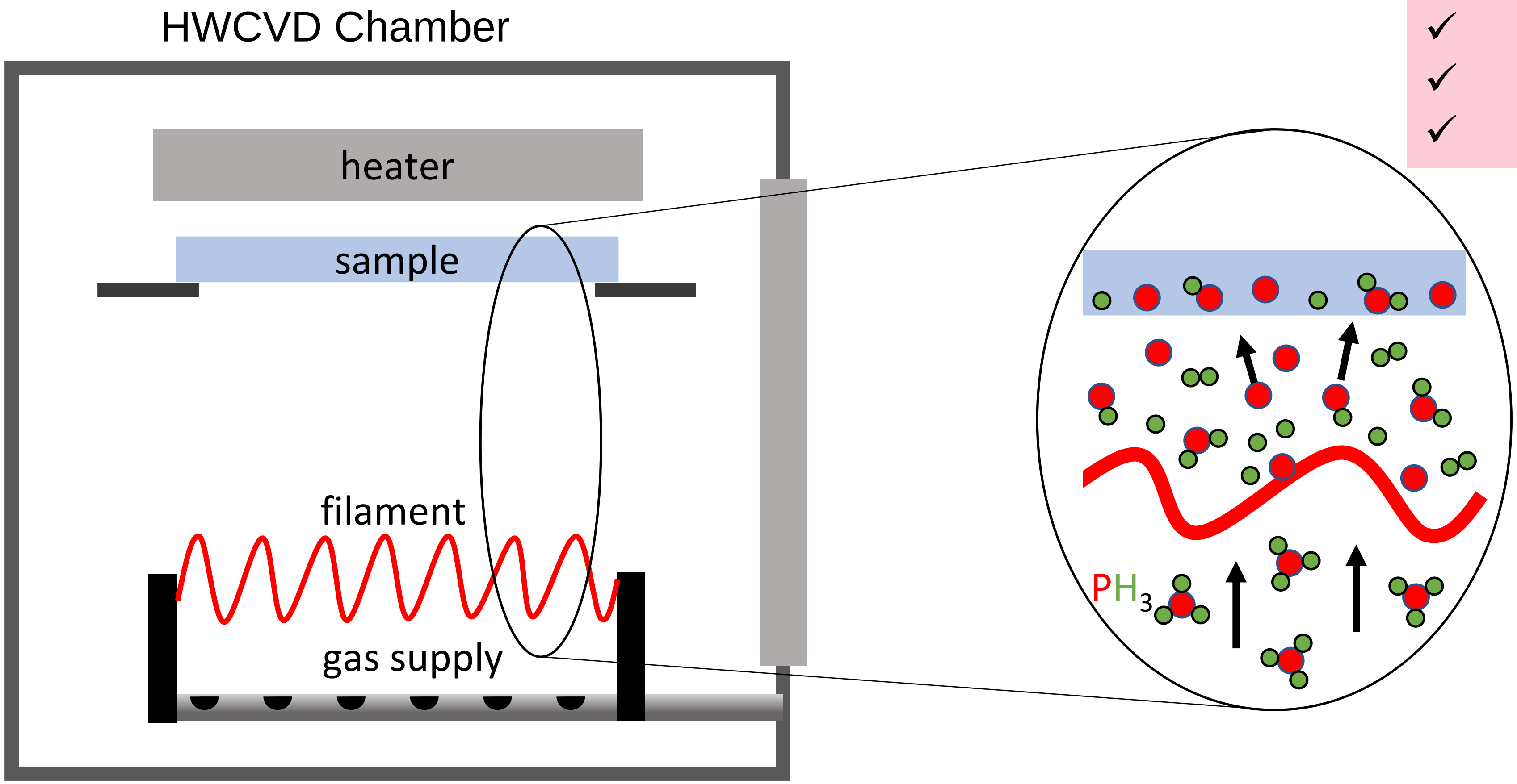
- Post dope on (i) a-Si:H
  →keep good surface passivation and selectivity



JÜLICH Forschungszentrum

Catalytic Doping (Cat-doping)

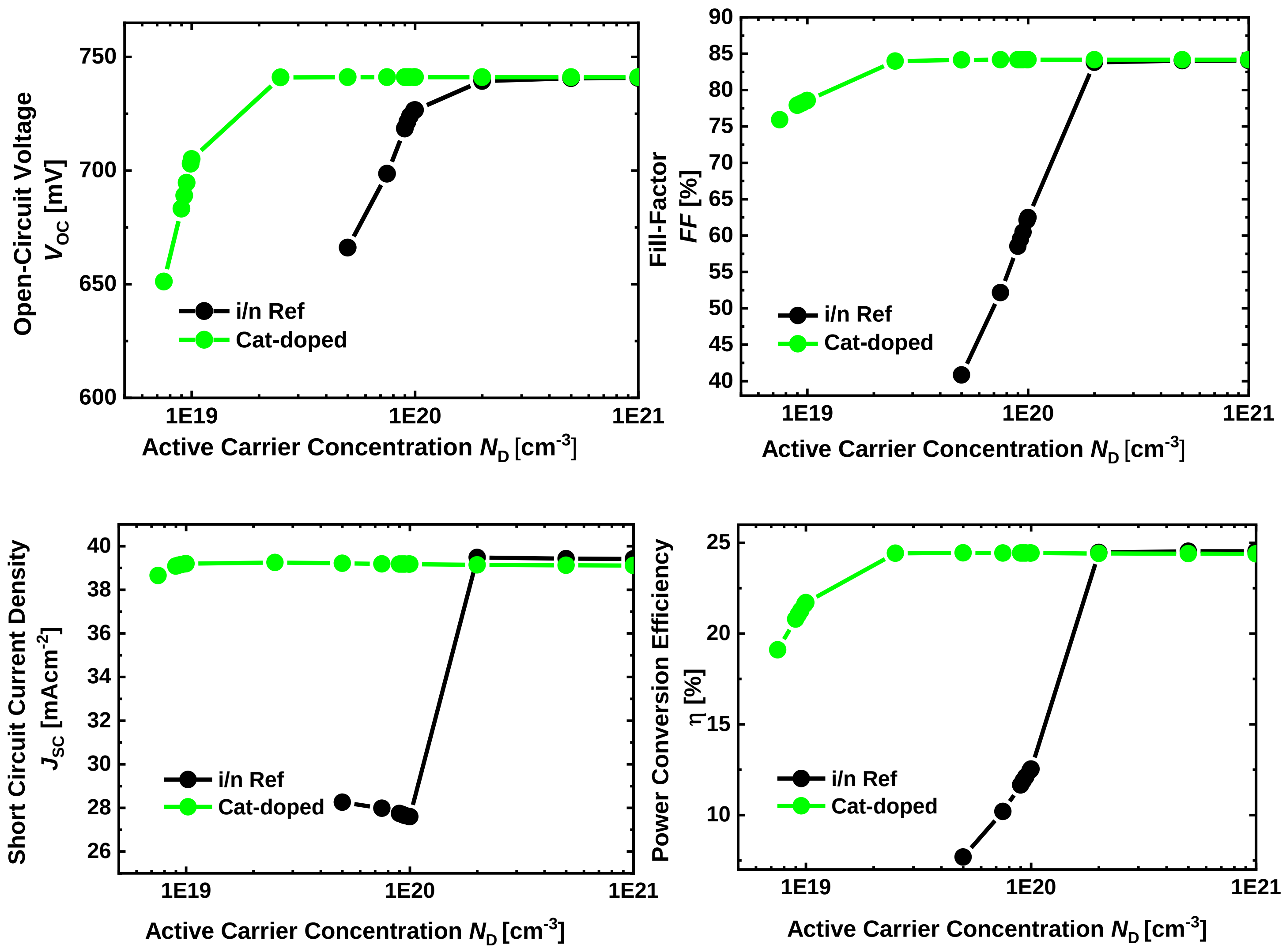


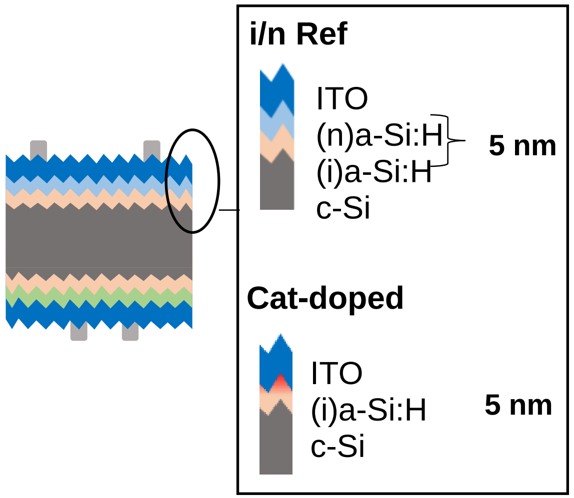
- ✓ low T_{sub} (<200 °C)
- ✓ No plasma damage
- ✓ shallow doping depth
- ✓ simple, efficient, up-scalable

effects:

- thermal annealing
- hydrogenation
- Carrier doping

Proof of Concept by Simulation



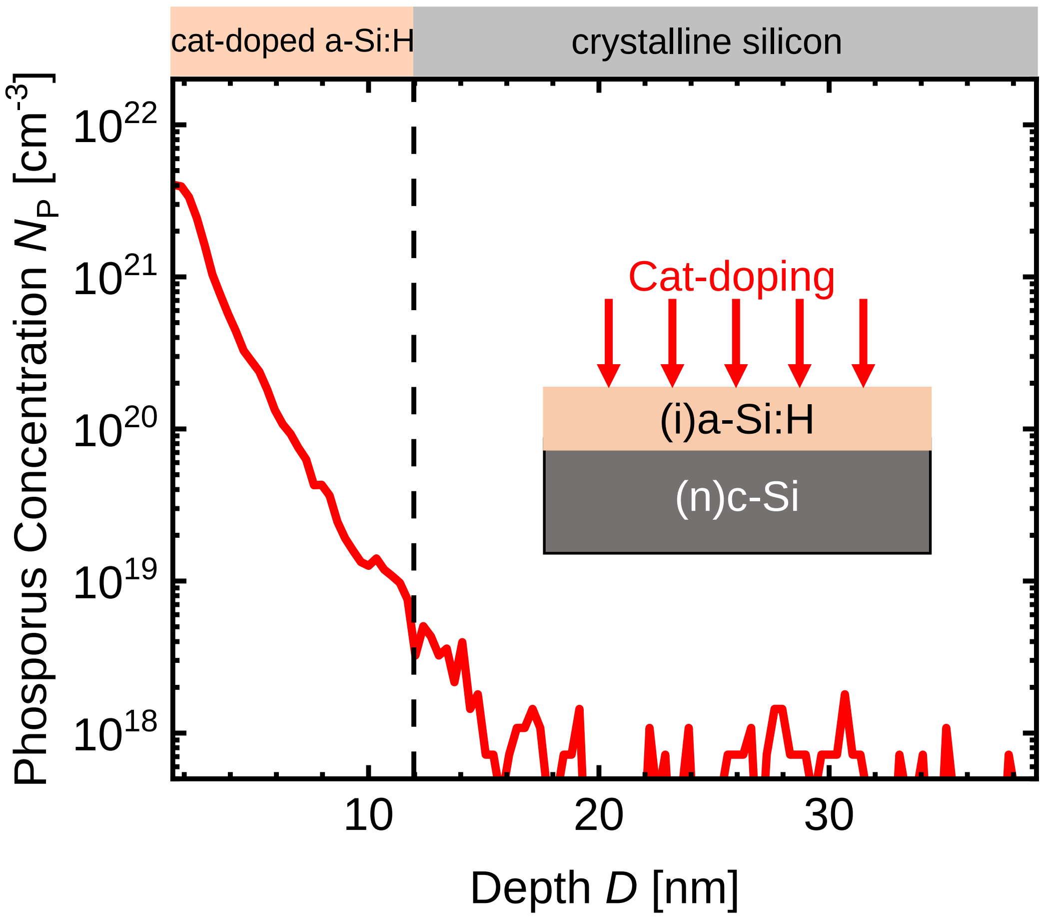


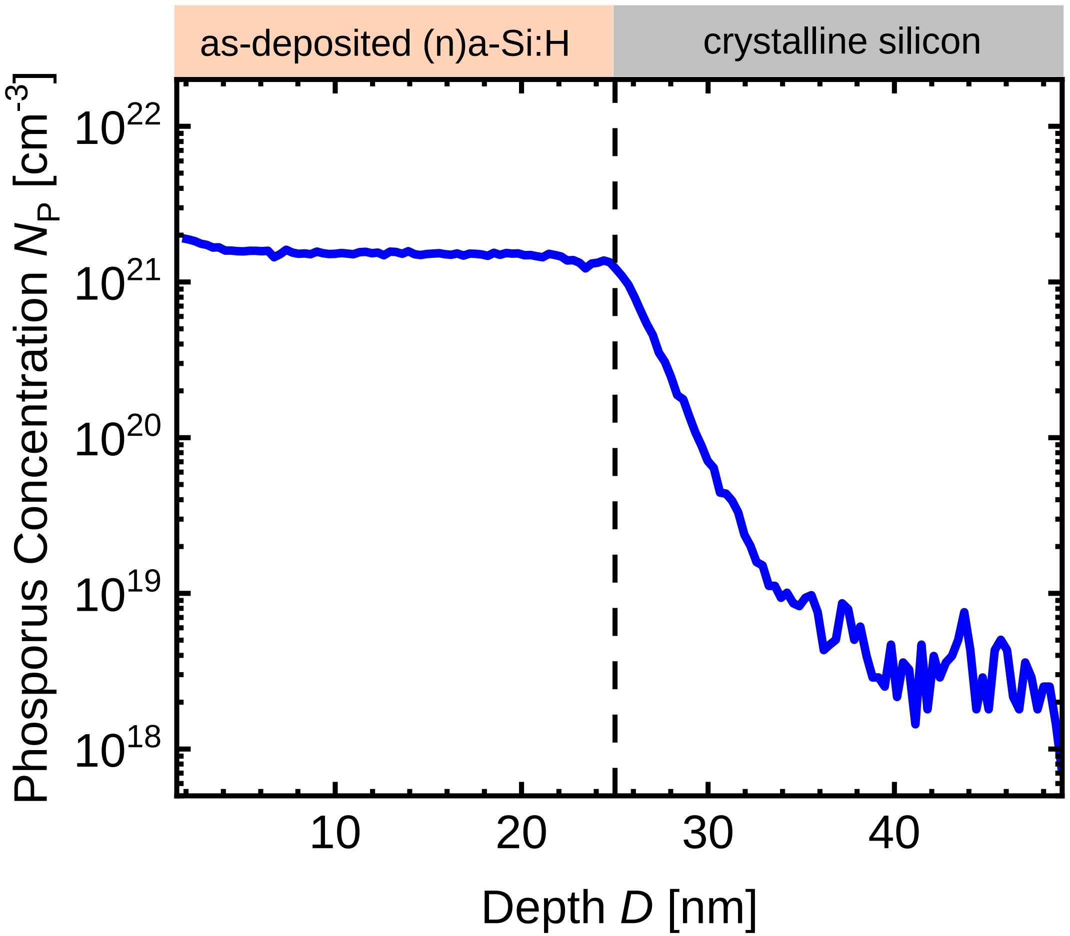
Low defects density in (i) a-Si:H

→Less requirement of active carrier concentration for selectivity!

Thin Film Characterization

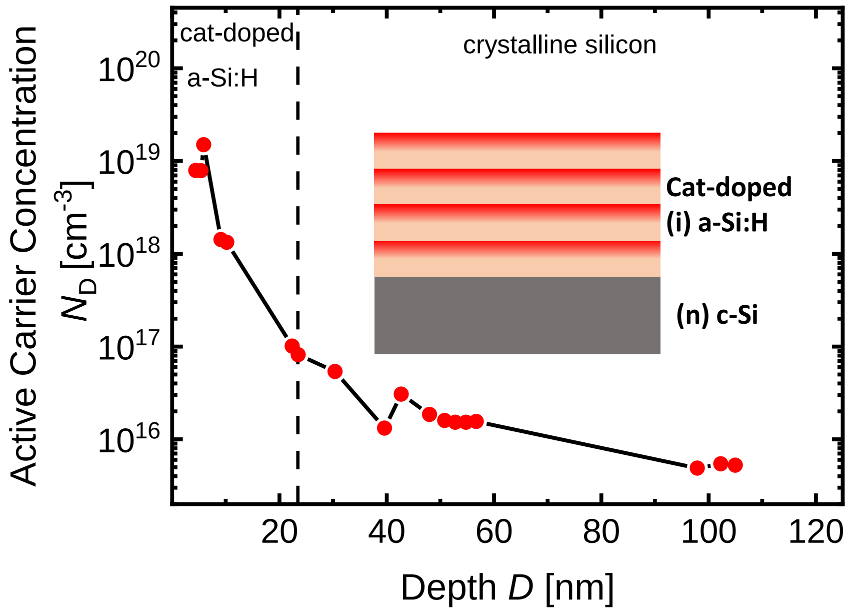
Secondary Ion Mass Spectrometry (SIMS) results

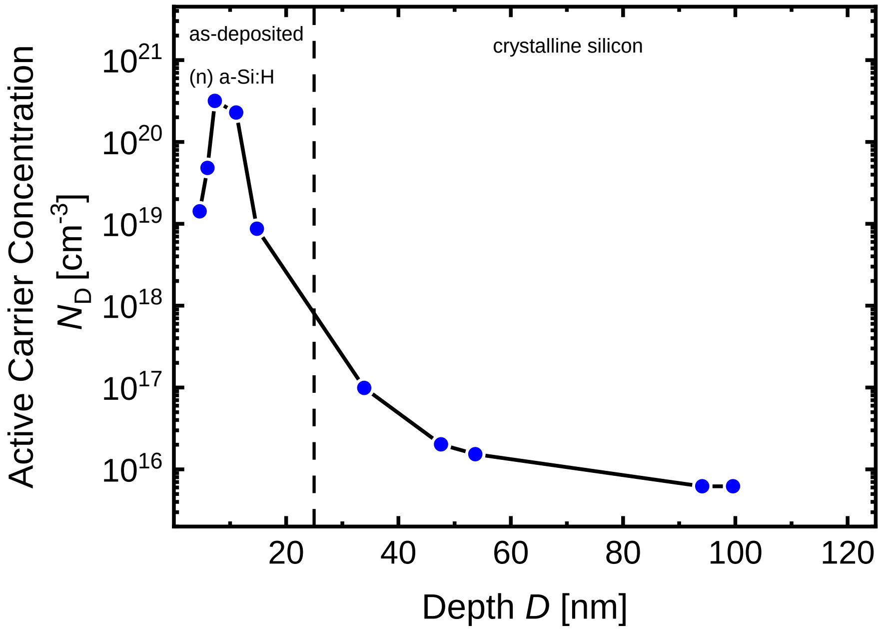




Thin Film Characterization

Electrochemical Capacitance-Voltage Measurement (eCV) and conductivity results





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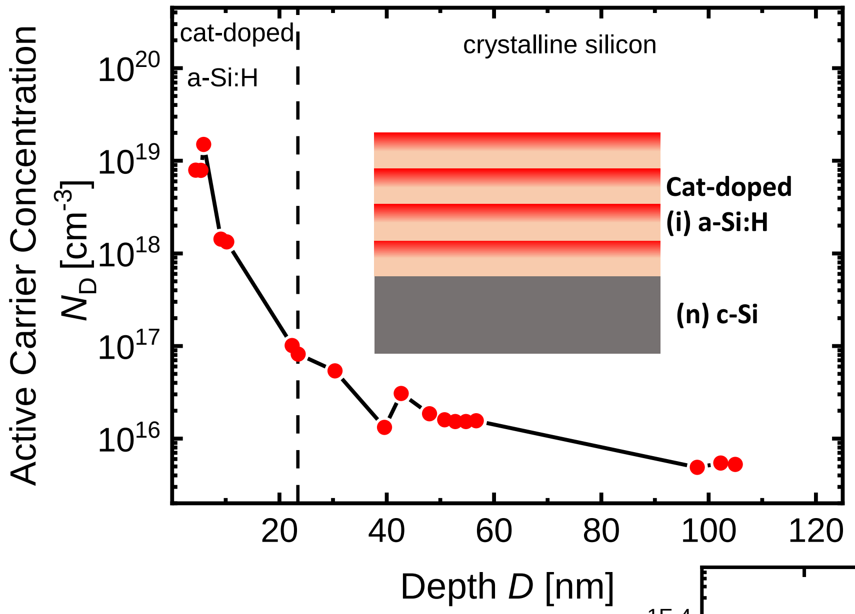
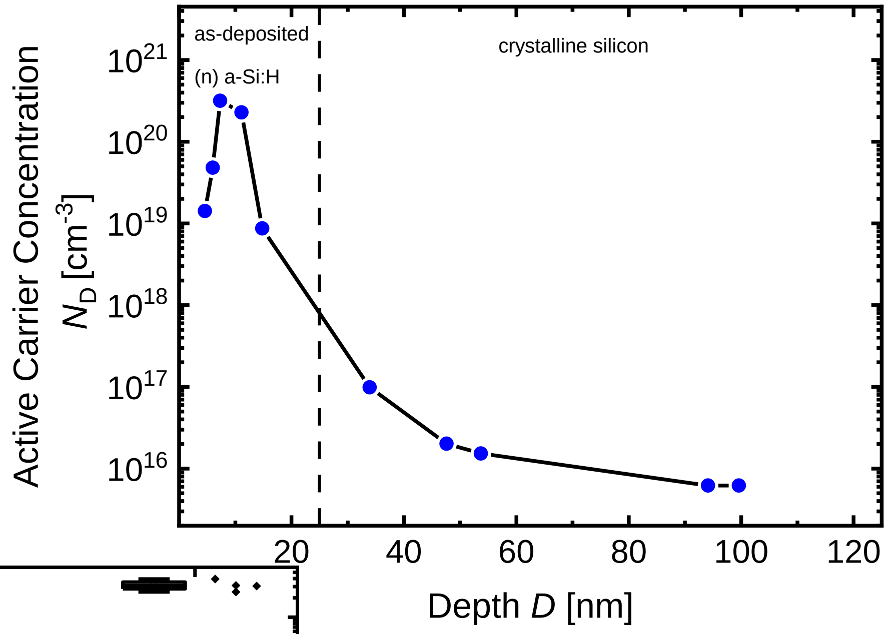
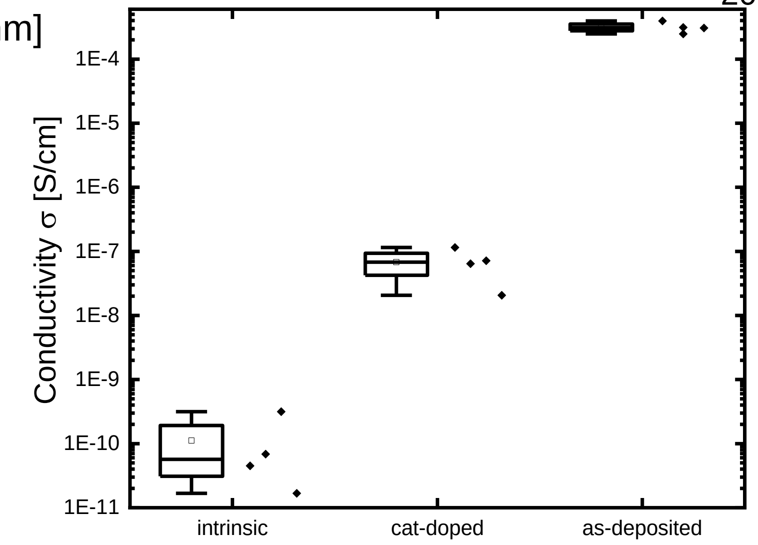
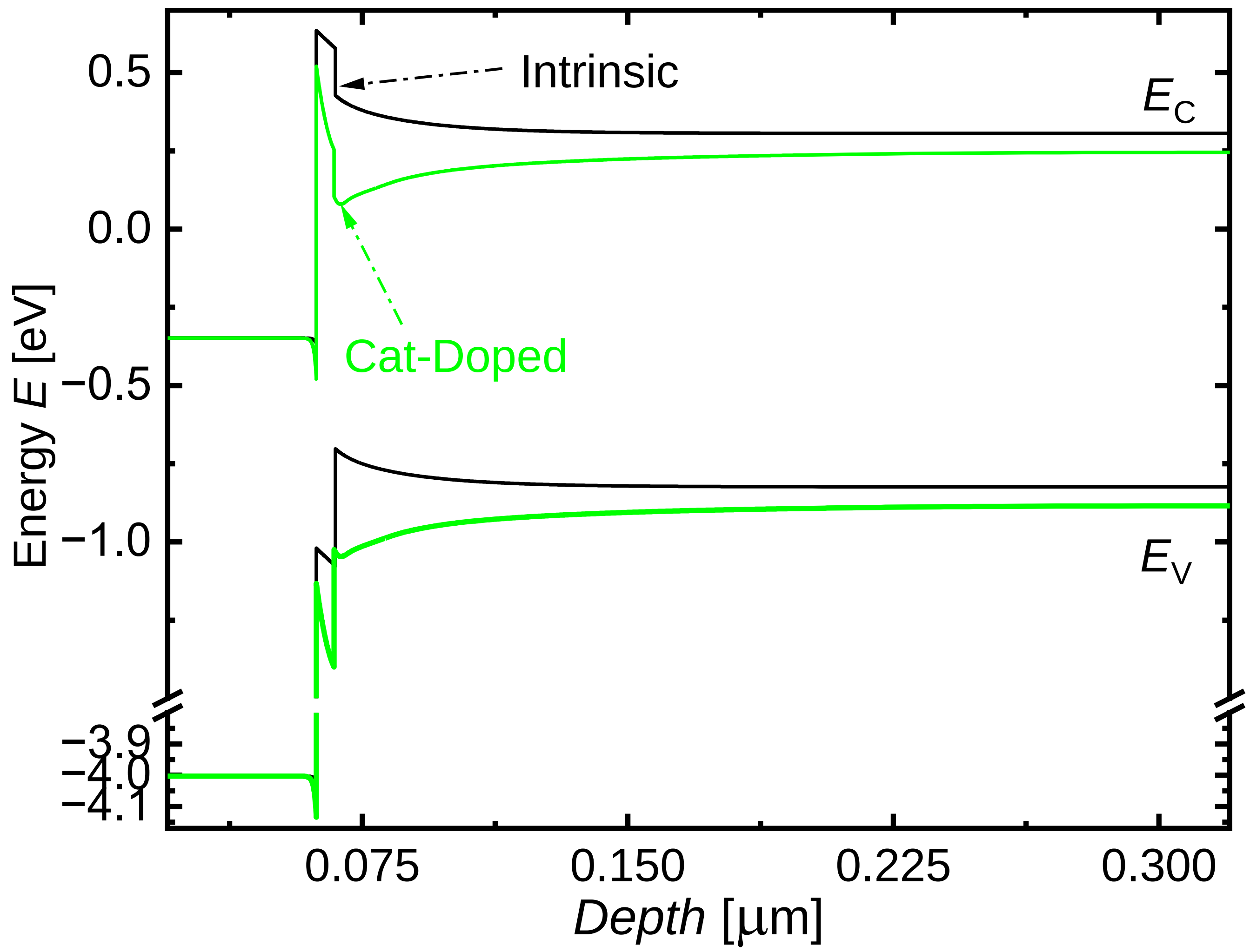






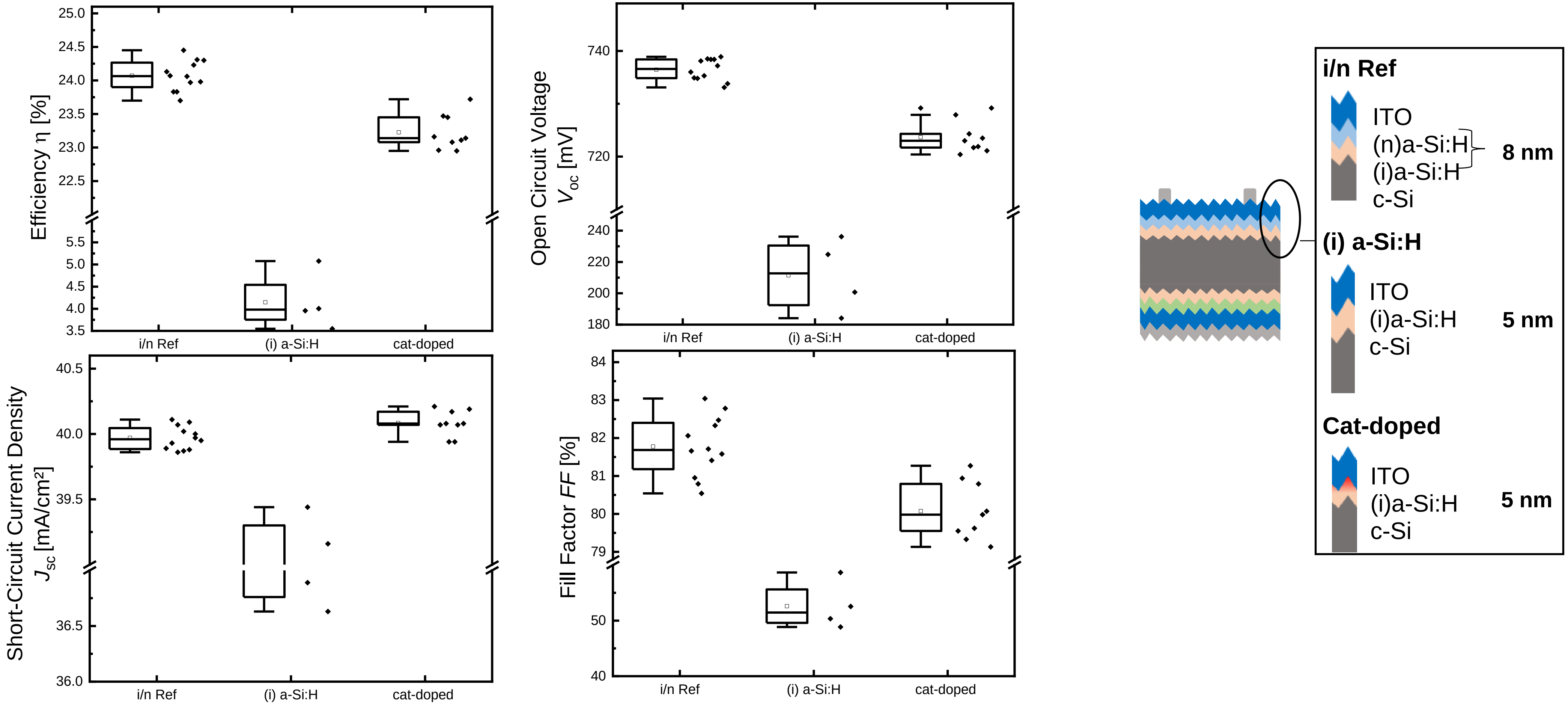
Passivation Enhancement with Cat-doping

Band diagram of (i) a-Si:H vs cat-doped (i) a-Si:H at the same biasing voltage near MPP



- Cat-doping can result in band bending in c-Si near the surface! It is beneficial for carrier selectivity and passivation.

Solar Cell results



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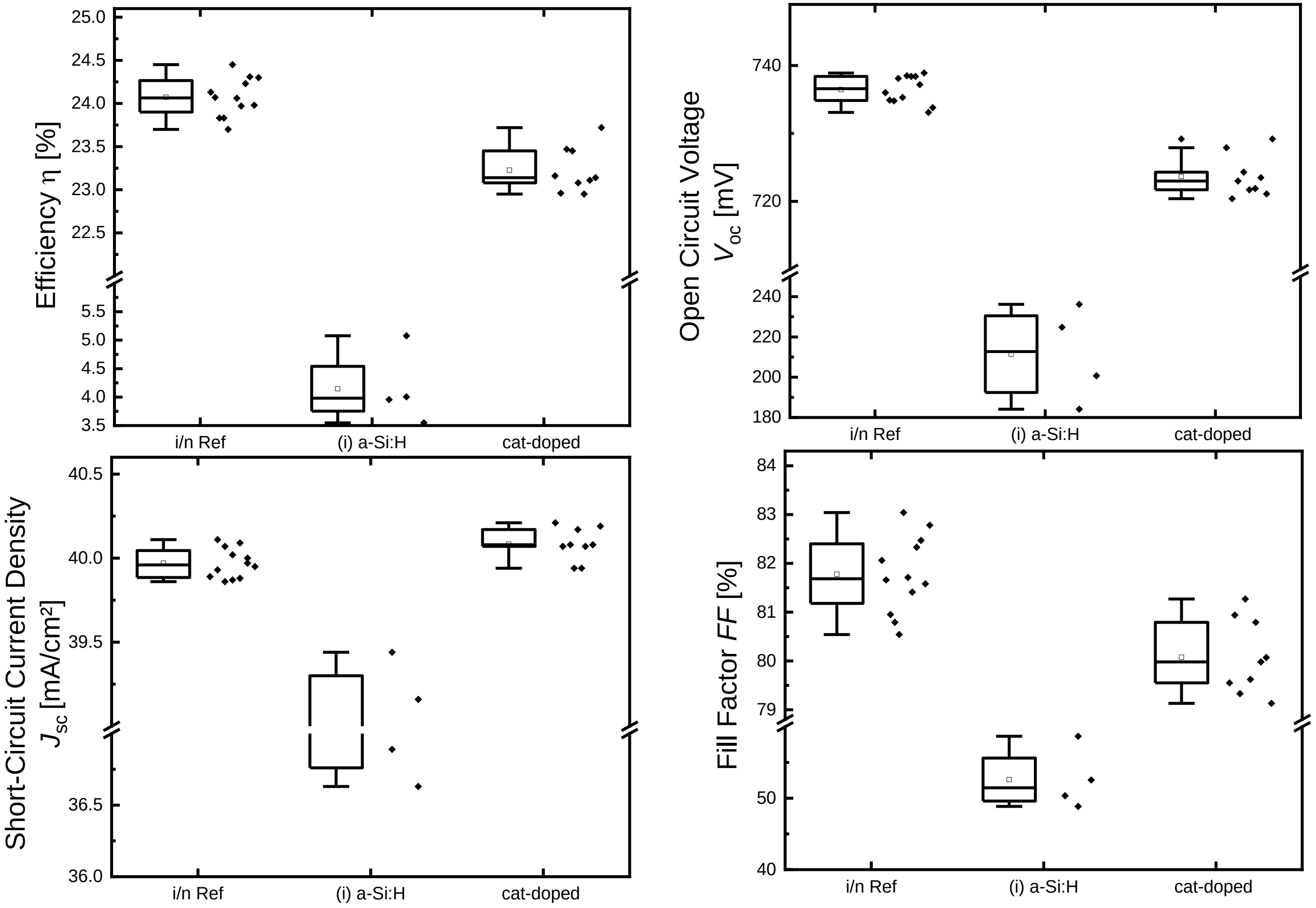
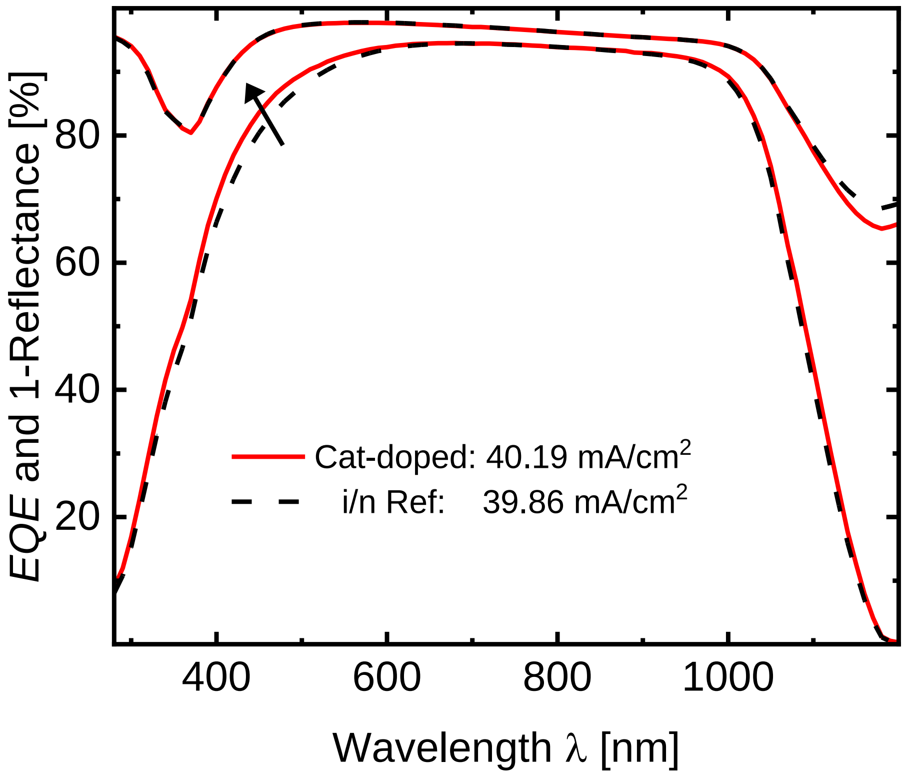
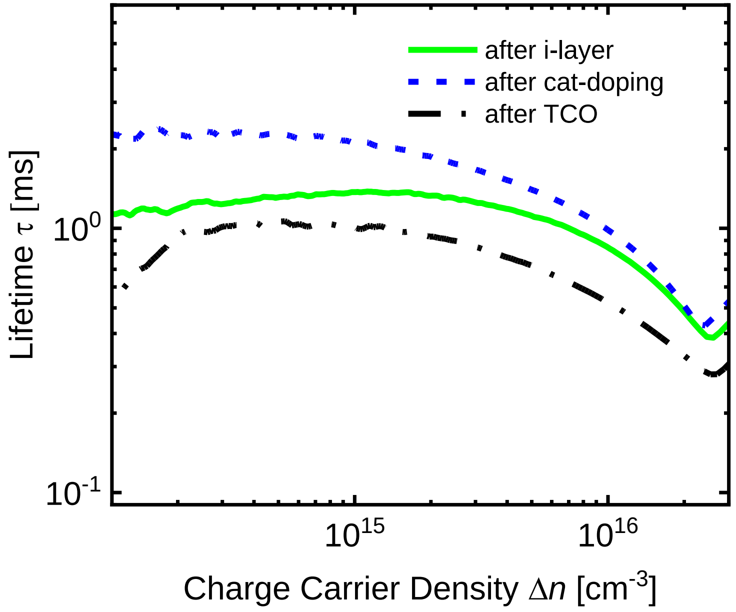




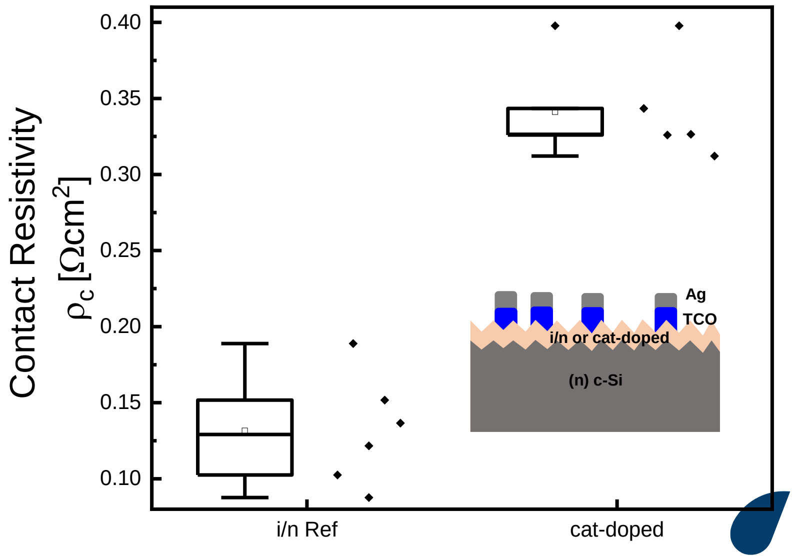
	Eff [%]	V_{oc} [mV]	J_{sc} [mA/cm²]	FF [%]	PFF [%]
i/n Ref	24.45	738.5	39.86	83.04	83.70
Cat-doped	23.72	729.2	40.19	80.94	83.20

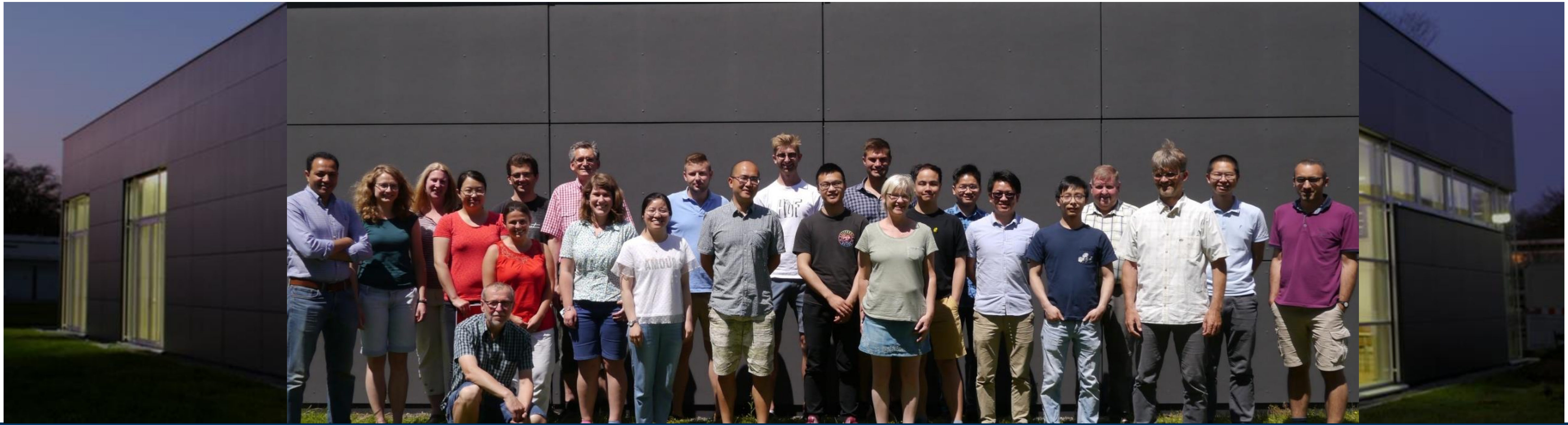
Directions for Further Improvement

- Reduce TCO sputter damage
  - soft TCO depositions
  - denser (i) a-Si:H



- Reduce contact resistance between TCO/cat-doped layer
  - optimization of cat-doping process
  - microstructure variation of (i) a-Si:H





THANK YOU FOR YOUR ATTENTION

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