

Semitransparent Organic Photovoltaics

Uli Würfel

PV-Dialog

Online, January 14th, 2026

www.ise.fraunhofer.de

Organic Photovoltaics – Introduction

Advantages

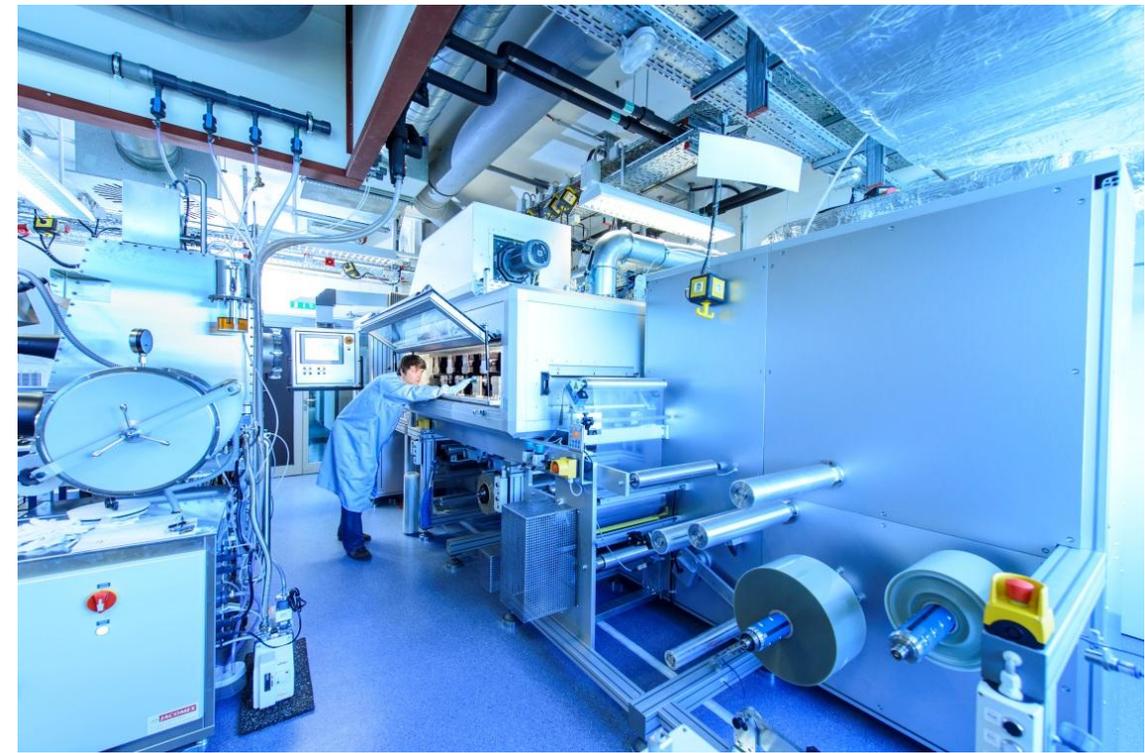
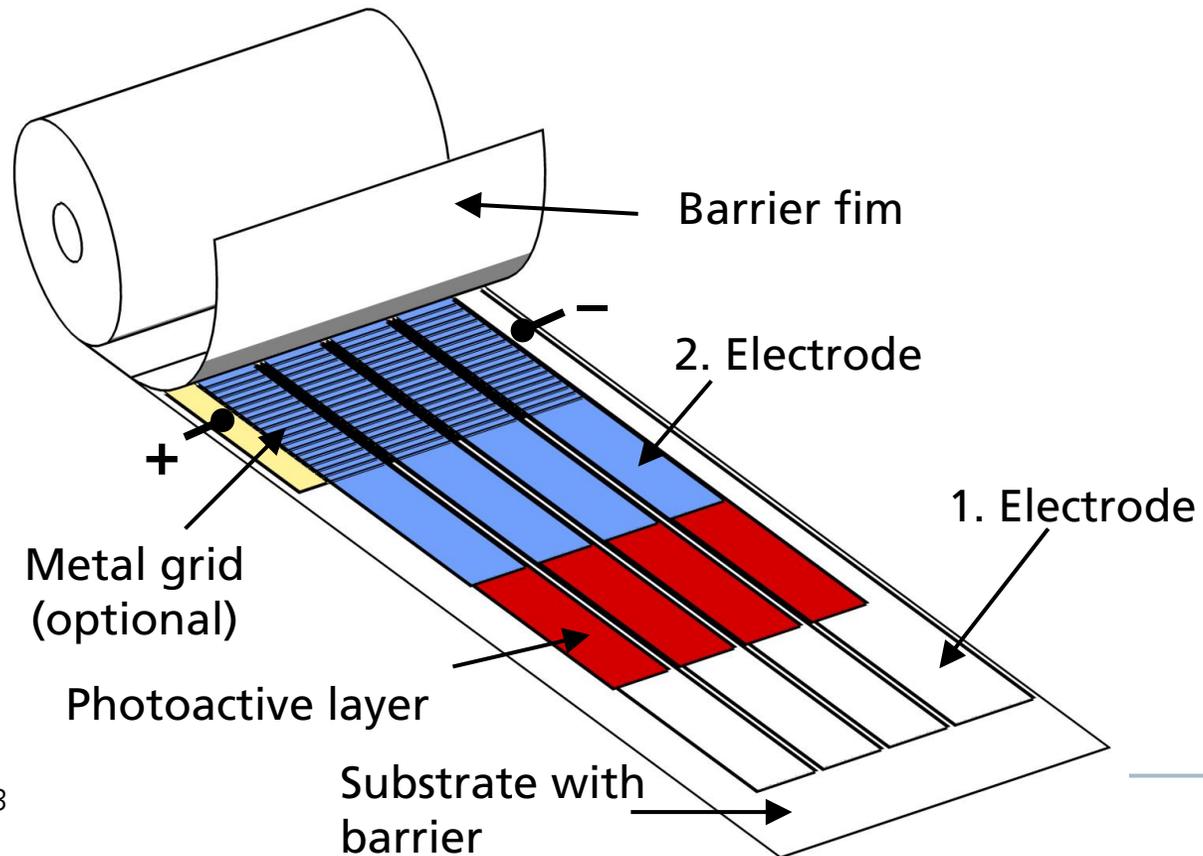
- Organic semiconductors can be processed from solution and deposited via different coating/printing technologies
- Drying takes place at rather low temperatures ($<130^{\circ}\text{C}$) \rightarrow enables the use of flexible substrates
- Very thin layers \rightarrow 1 g of absorber material sufficient for 10 m² module area
- No heavy metals or other critical materials required
- Very low energy input, therefore also very low CO₂-eq footprint

Challenges

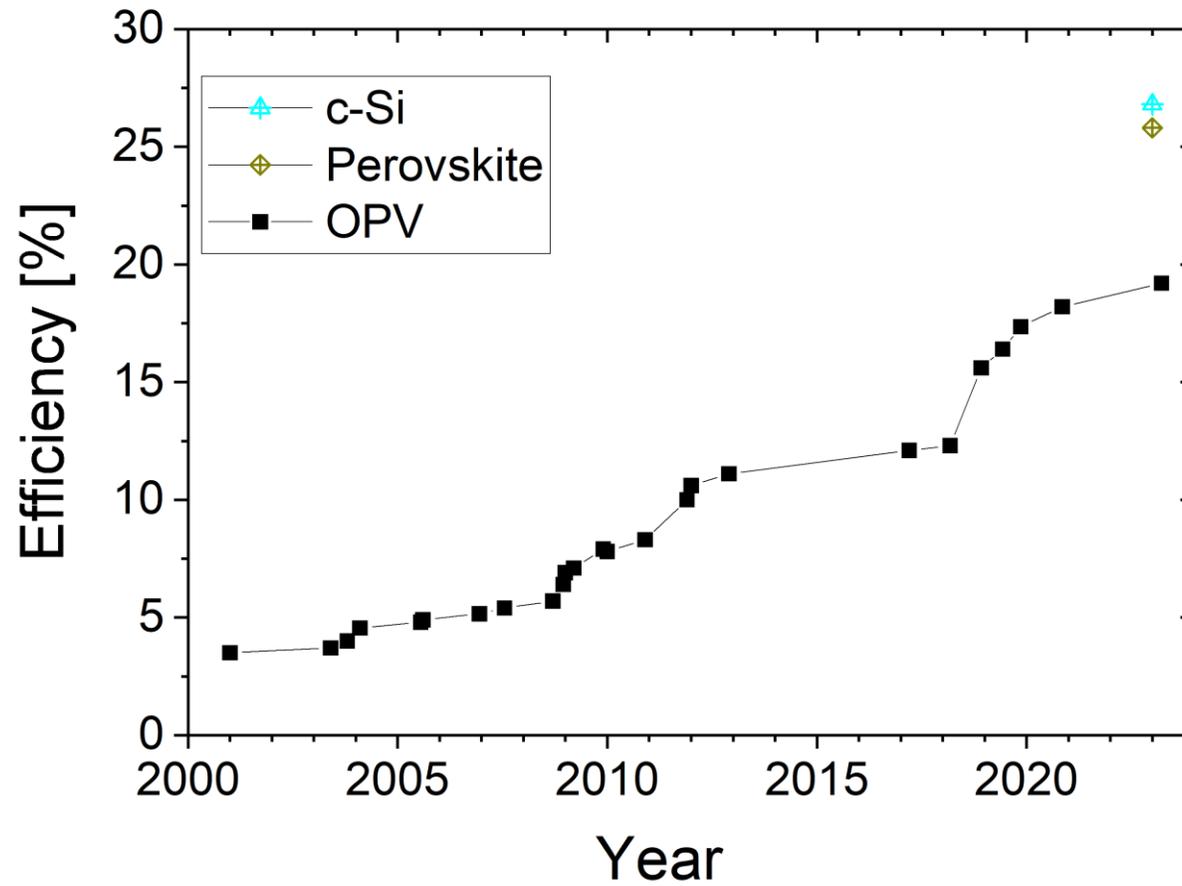
- Photoactive layer comprises two materials \rightarrow morphology becomes crucial
- Long-term stability
- Efficiency gap between small area lab cells and large area flexible modules is still large

Roll-to-Roll Processing

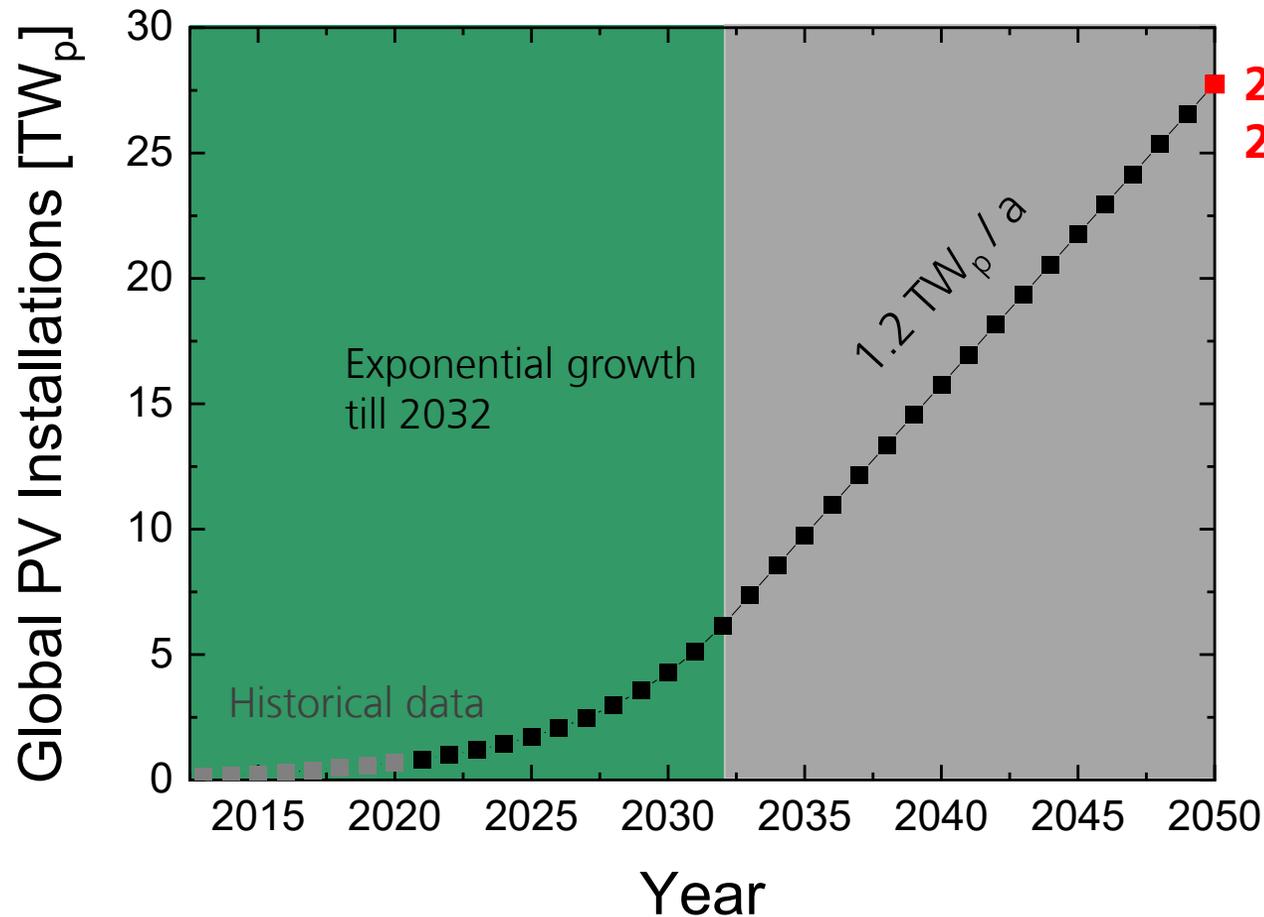
- High throughput rates
- Costs are determined almost exclusively by BOM



Evolution of Record Efficiencies



A LOT of PV Required: Scenario to Achieve the 2°C Aim



It's not only about technology and costs, but also about **acceptance!**

- BIPV is a must
- Climate change will require significantly more protected crops growing

(Semi-)Transparent Photovoltaics

- Attractive for BIPV
- Useful in agriculture
- Very probably beneficial for acceptance (aim of 50 – 75 TW_p by 2050)

(Semi-)Transparent Photovoltaics

Projekt Durchblick-PV: Entwicklung von organischen Solarmodulen mit hoher visueller Transparenz
Laufzeit: 01.04.2022 – 30.06.2025

- 5 Partner: Heraeus, Rowo Coating, ASCA, Fraunhofer ISE, University of Freiburg

Heraeus

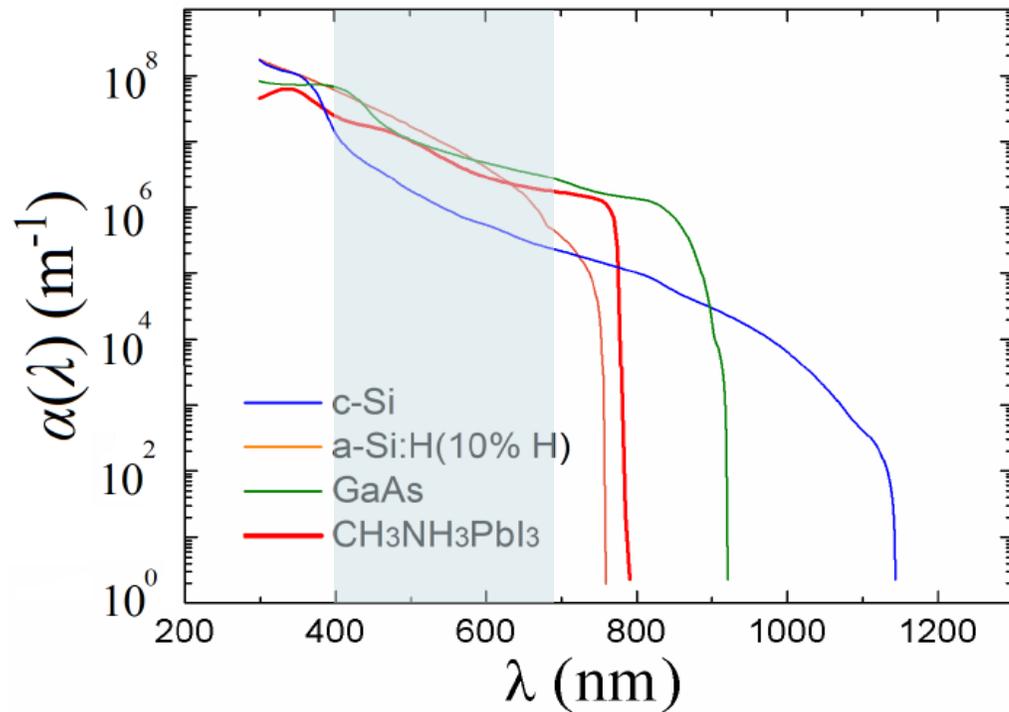


universität freiburg

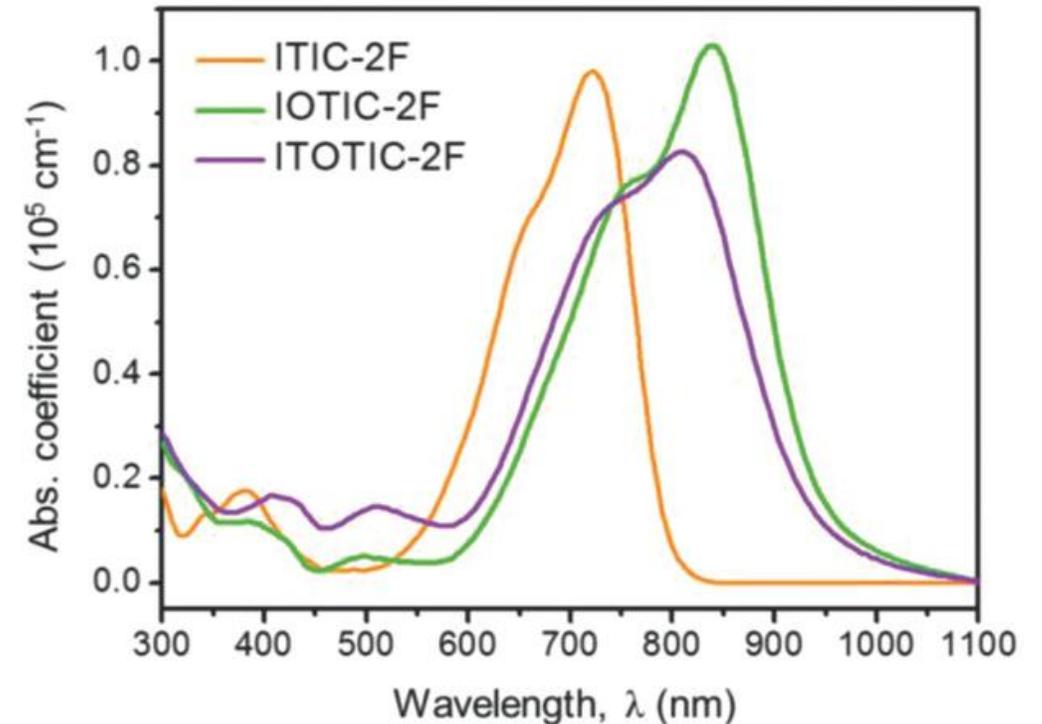


Transparent Solar Cells

Fundamental optical material properties



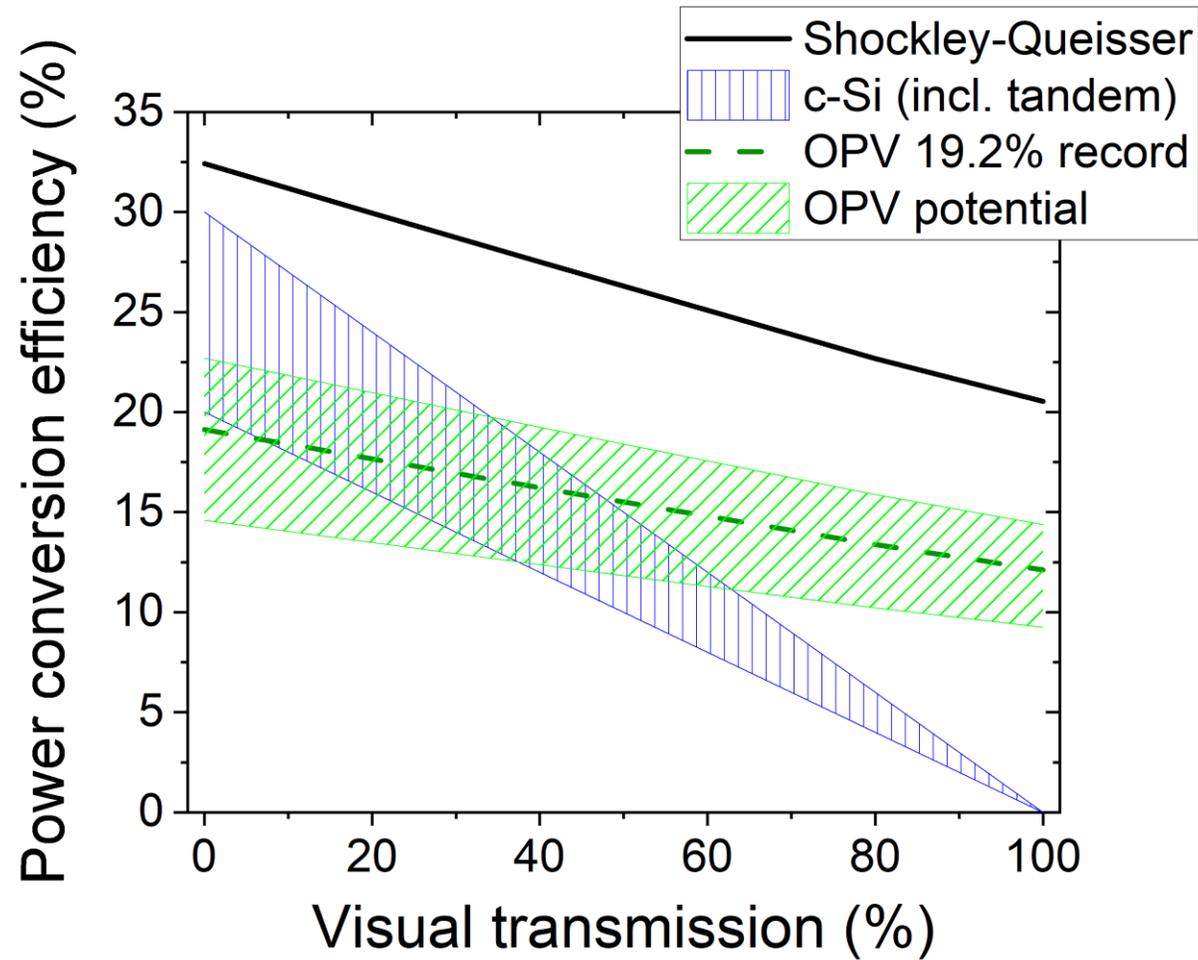
Inorganic (crystalline) semiconductors:
absorption coefficient increases towards
shorter wavelengths



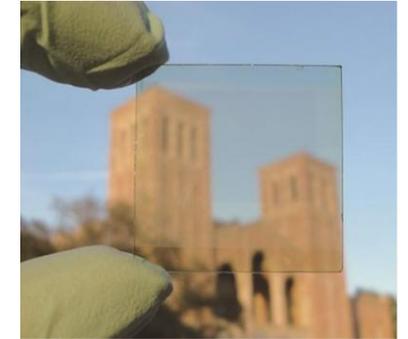
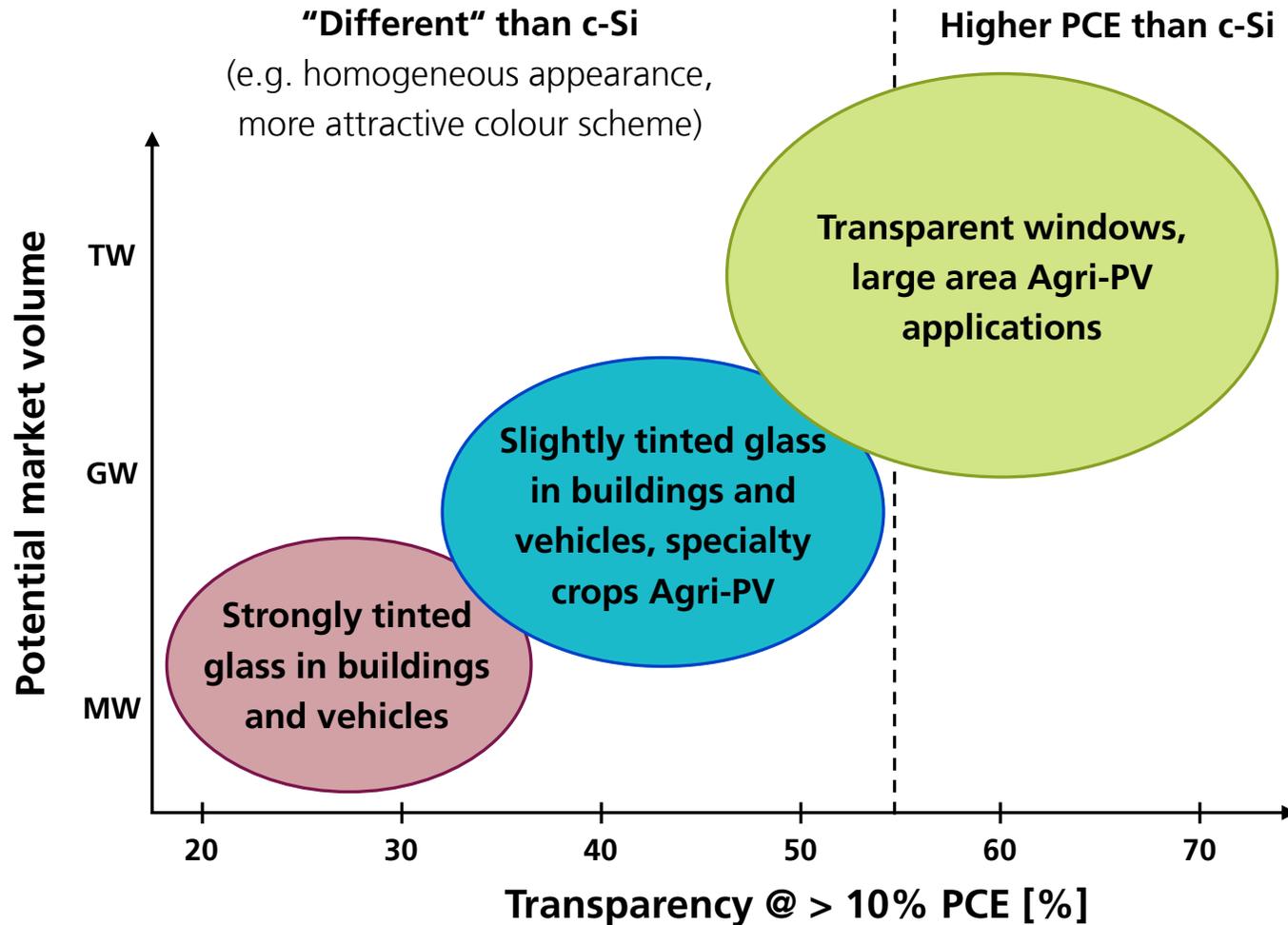
Organic semiconductor:
absorption only in certain spectral regions
→ **Spectral windows possible**

Transparent Photovoltaics

Estimation of realistic potential



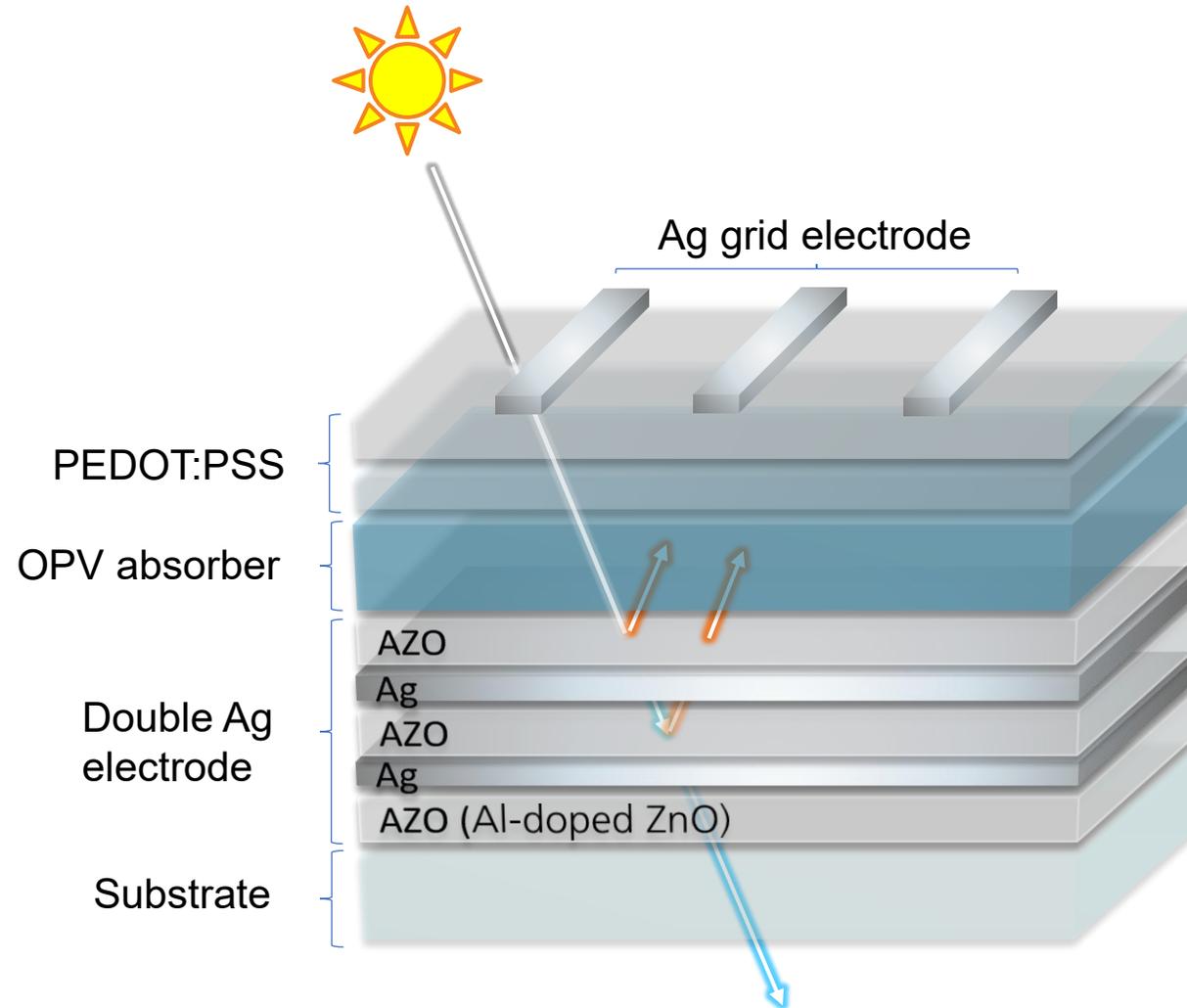
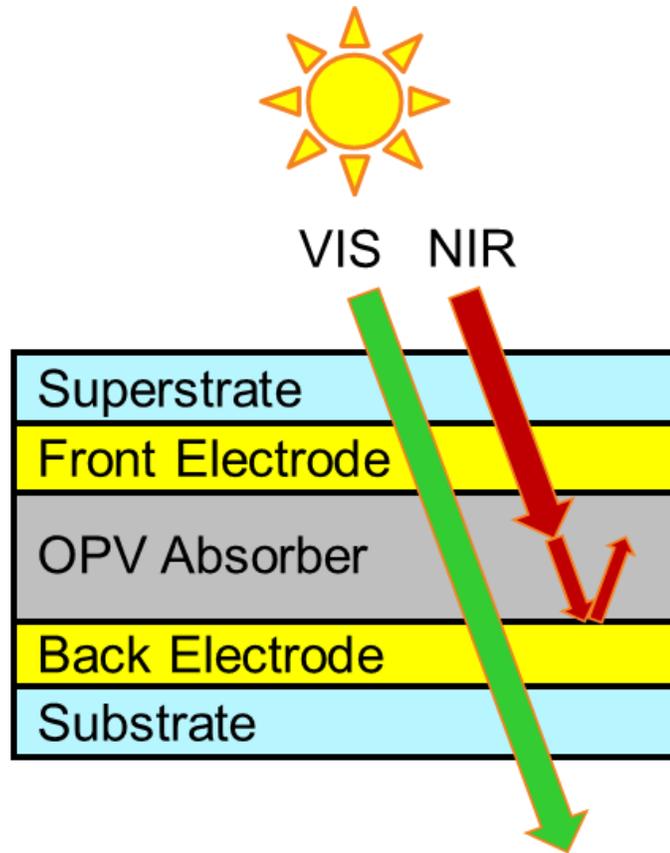
Transparent Photovoltaics



Organic photovoltaics is a promising technology for applications where a high visual transparency is demanded
→ large potential market

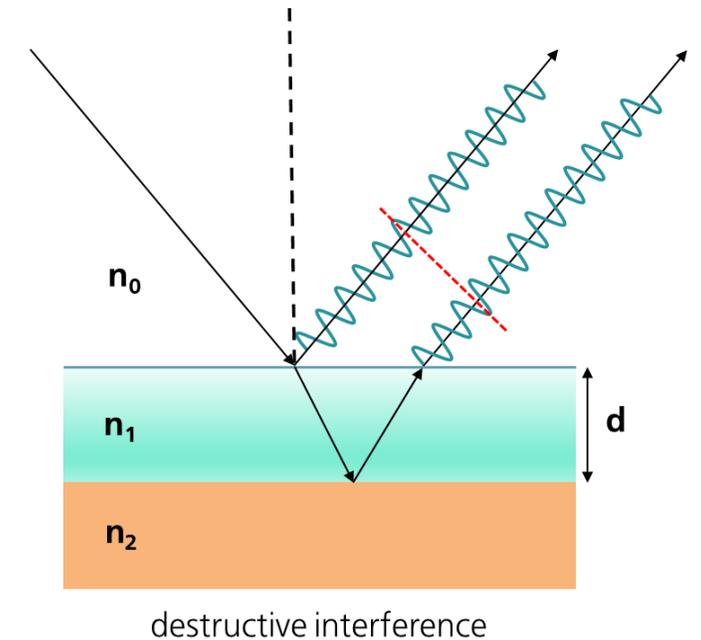
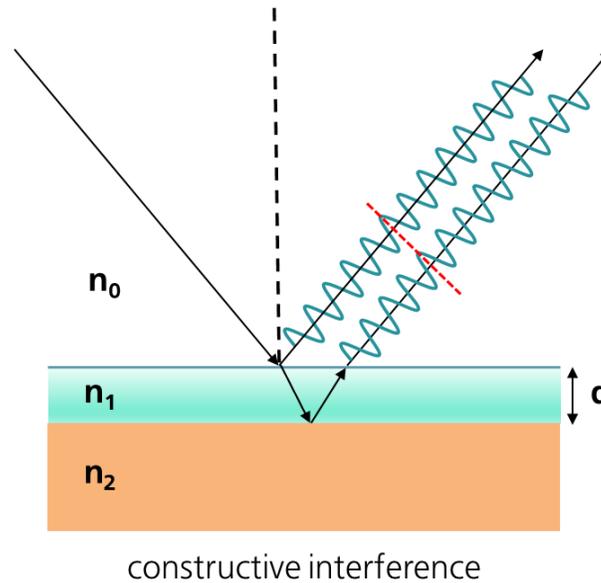
Requirements for Electrode Systems

Novel back electrode system



Evaluation of Optical “Potential”

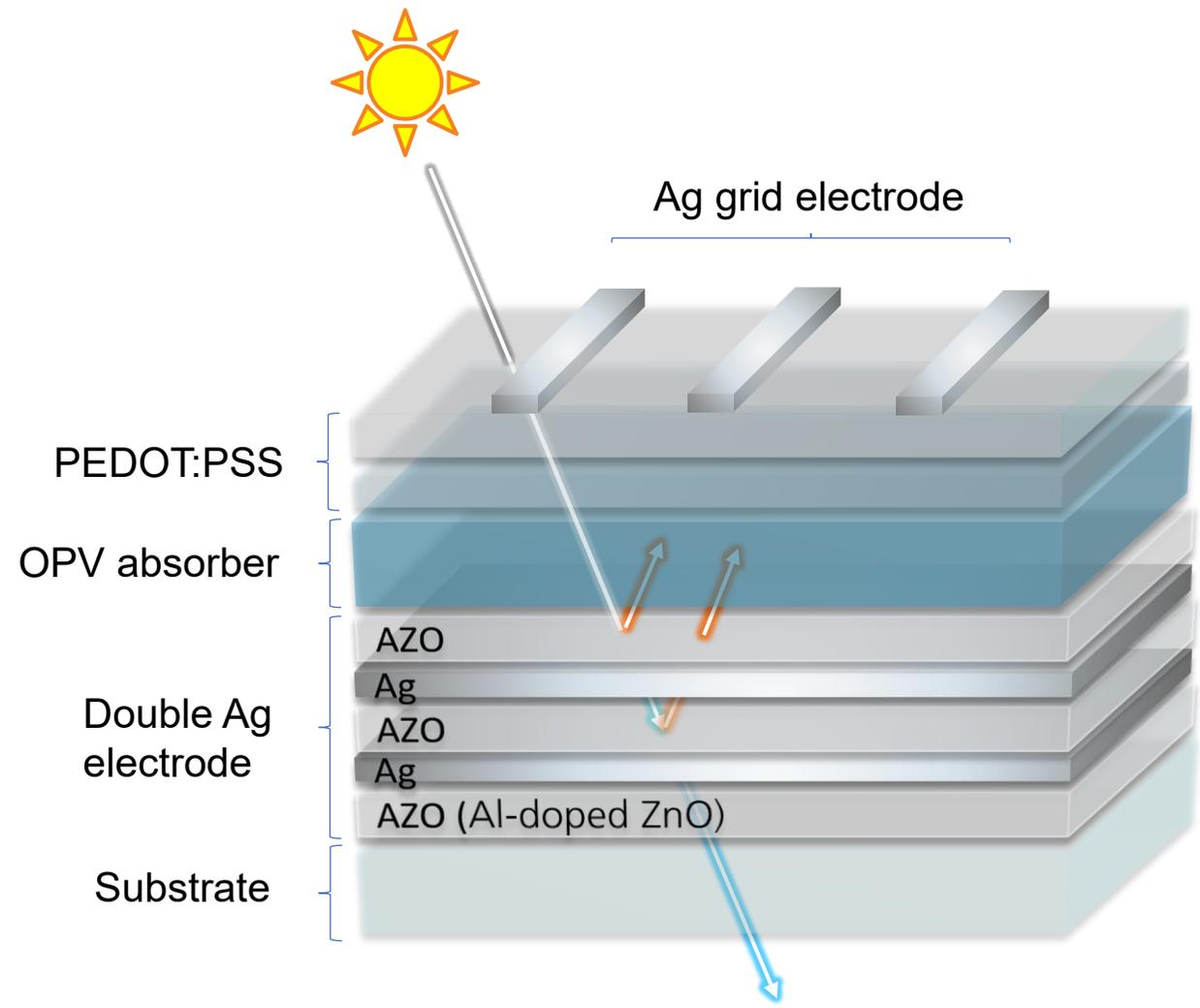
- Organic solar cells are thin film systems
- Thicknesses of the individual layers are below the wavelength of the light
- There are several interfaces with abrupt changes of the refractive index
 - Generation of a complex interference pattern
 - Use optical simulations to identify optimal layer thicknesses



Enhancing the Visual Transmission

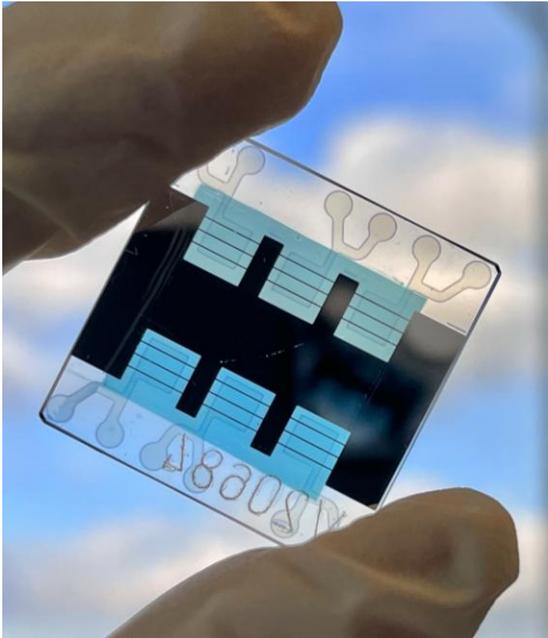
Metal-less front electrode

- Improved PEDOT:PSS with higher conductivity
- Allows grid-less architecture
- → higher transmission and generation



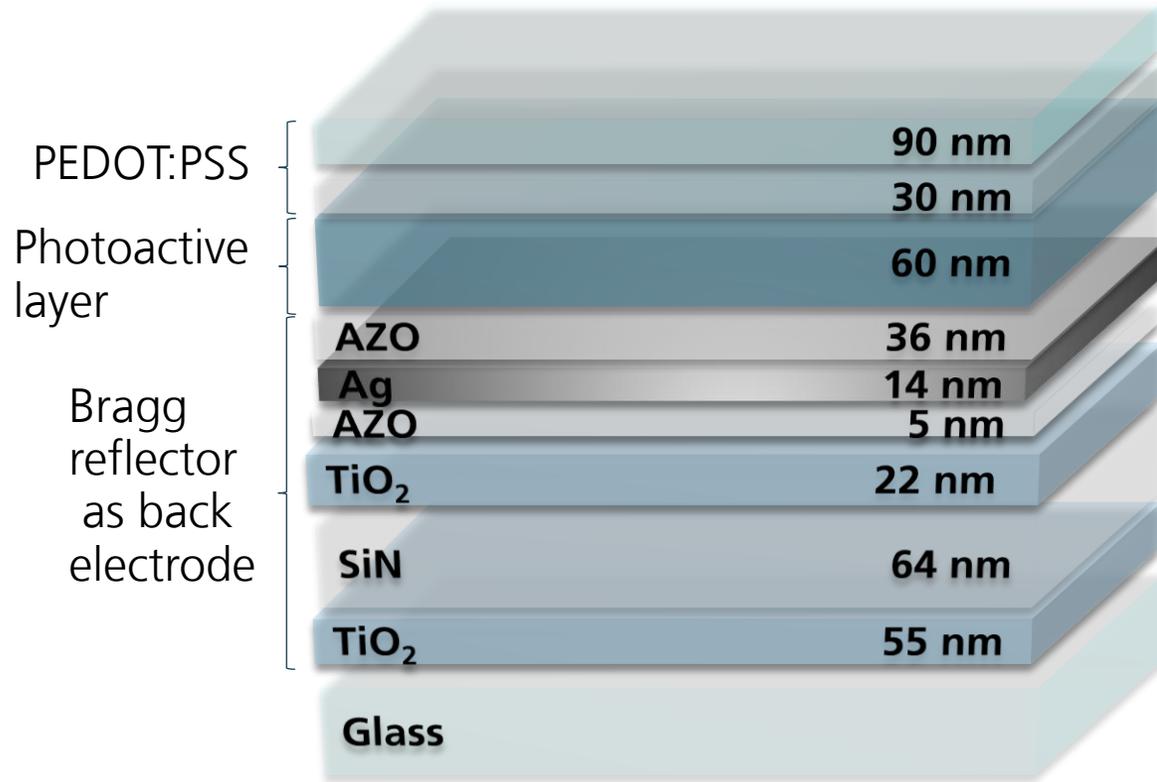
Transparent Organic PV

Examples for cells with and without Ag-grid in top-electrode

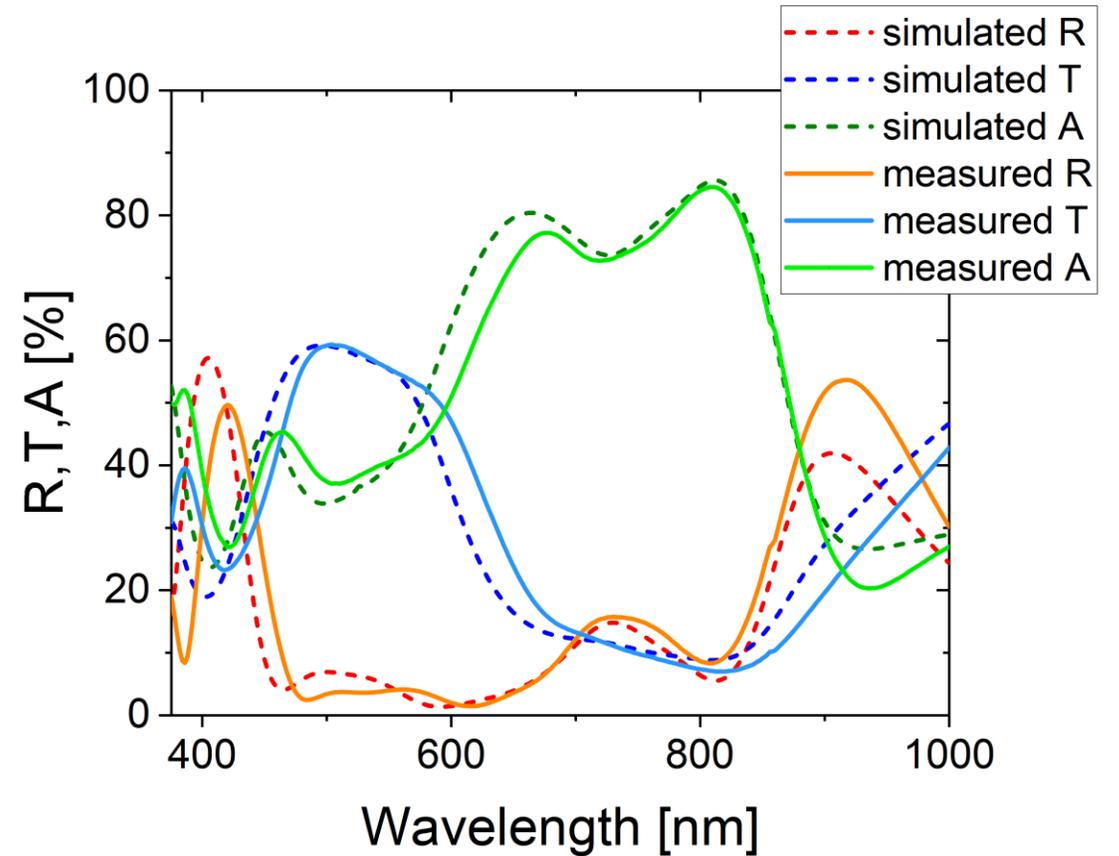


Transparent Organic PV

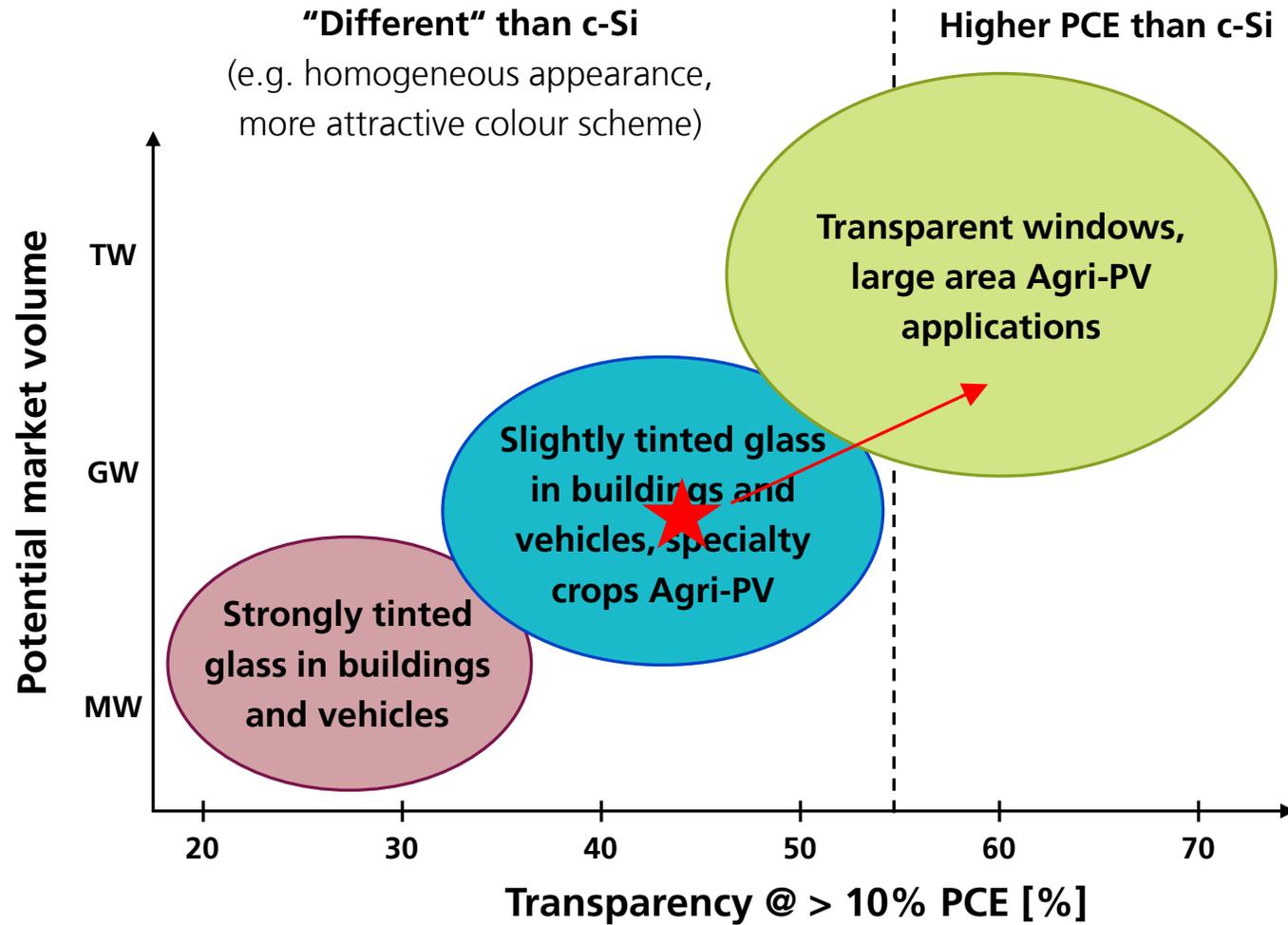
Enhanced NIR reflection through Bragg reflector



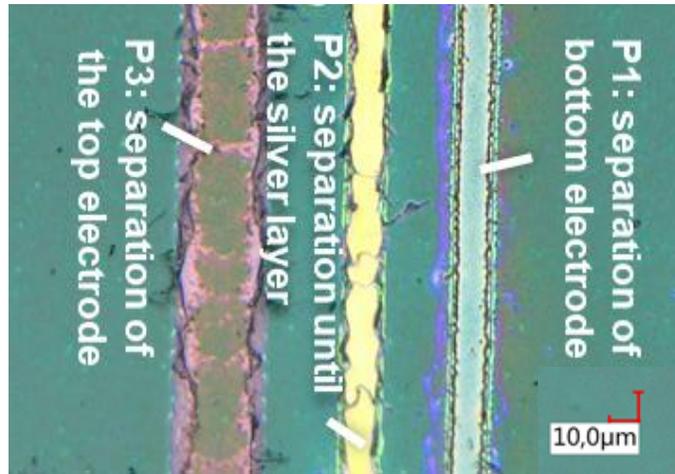
AVT: 52% @ PCE: 8.6%
→ LUE: 4.5%



Transparent Photovoltaics



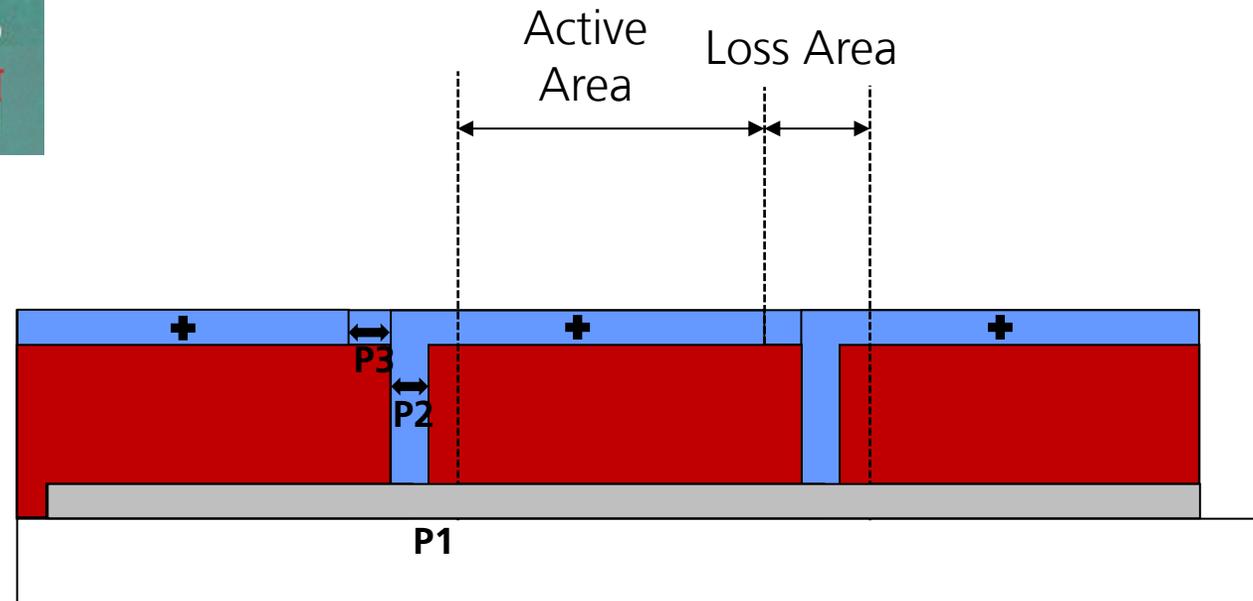
Production of Semitransparent OPV-Modules



P3 P2 P1

Laser structuring

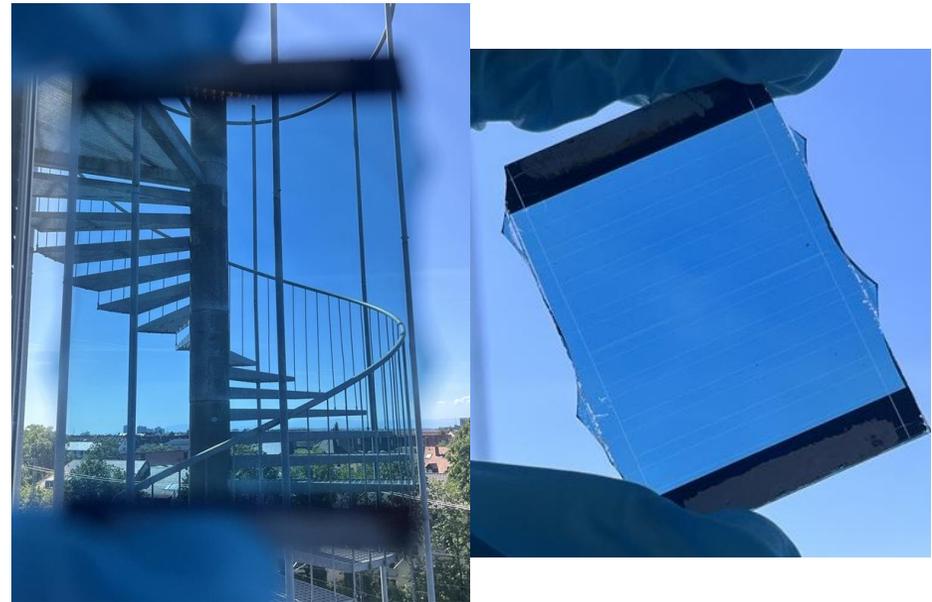
- very small area loss
- enables use of narrow sub-cells
- low current
- renders PEDOT:PSS sufficiently conductive



Top Electrode
Absorber + Interlayers
Bottom Electrode
Substrate

Transparent Organic Solar Modules

ITO back electrode and top electrode metal free interconnection



Transparent Organic Photovoltaics on ITO

Modules: Series interconnection with metal-less top electrode

- Module area 210 cm²; all layers deposited from solution (ETL, Absorber, PEDOT:PSS) via slot-die-coating
- High coating quality, very good yield

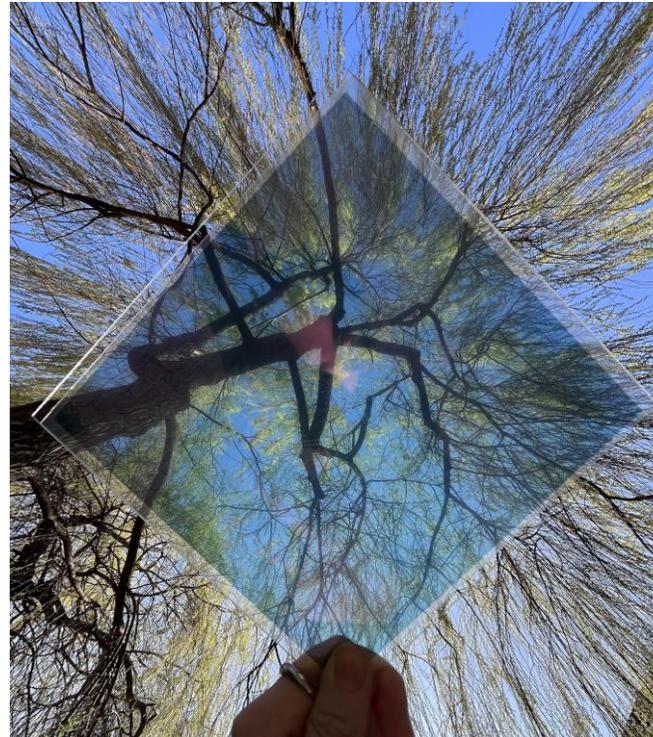


Figure of merit $LUE = AVT \times PCE$

Results

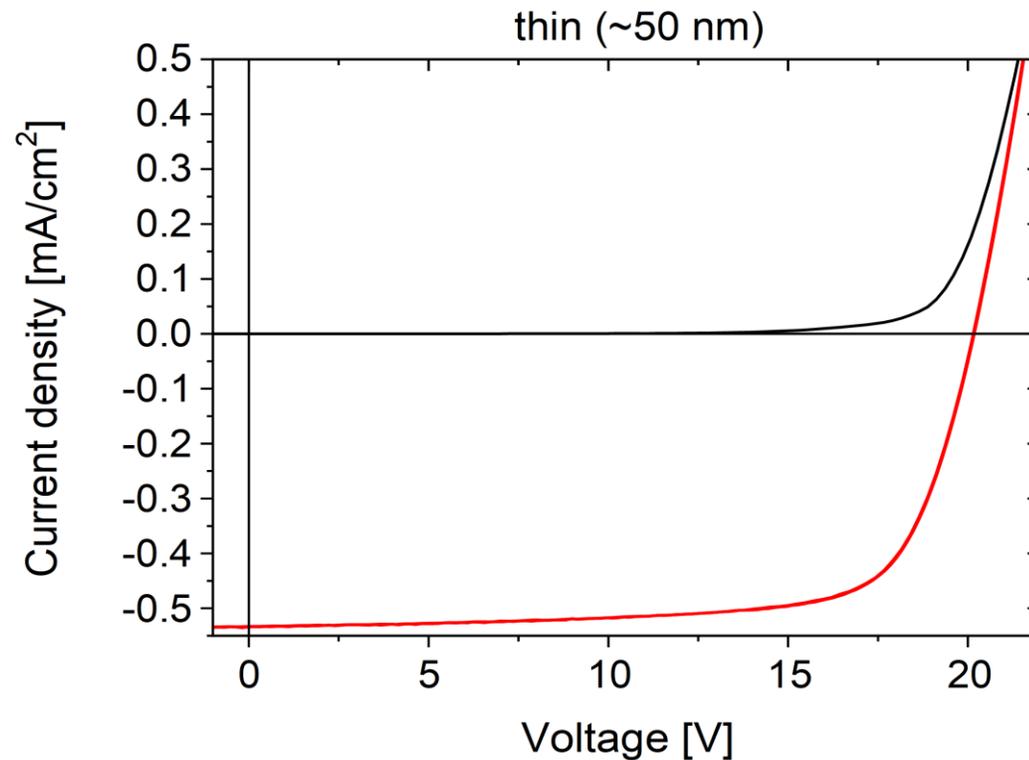
AVT: 44%; PCE: 8%; LUE: 3.5%

- Next steps: realize this with thin Ag-based NIR reflective back electrode and increase LUE

Transparent Organic Photovoltaics

Modules: Series interconnection with metal-less top electrode

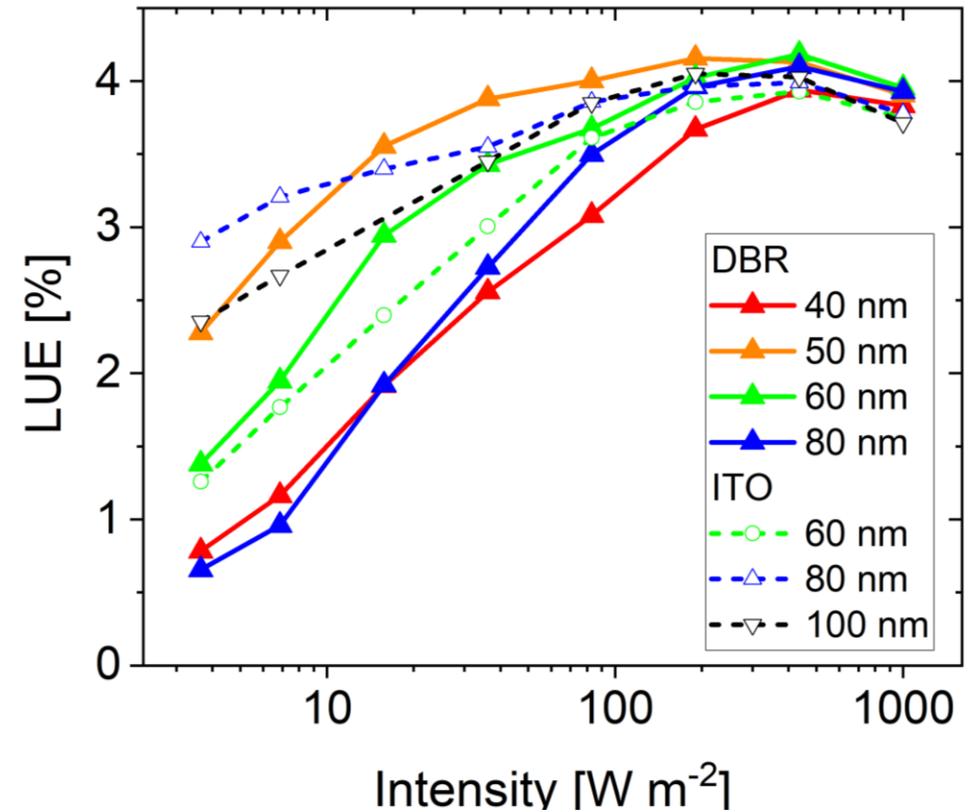
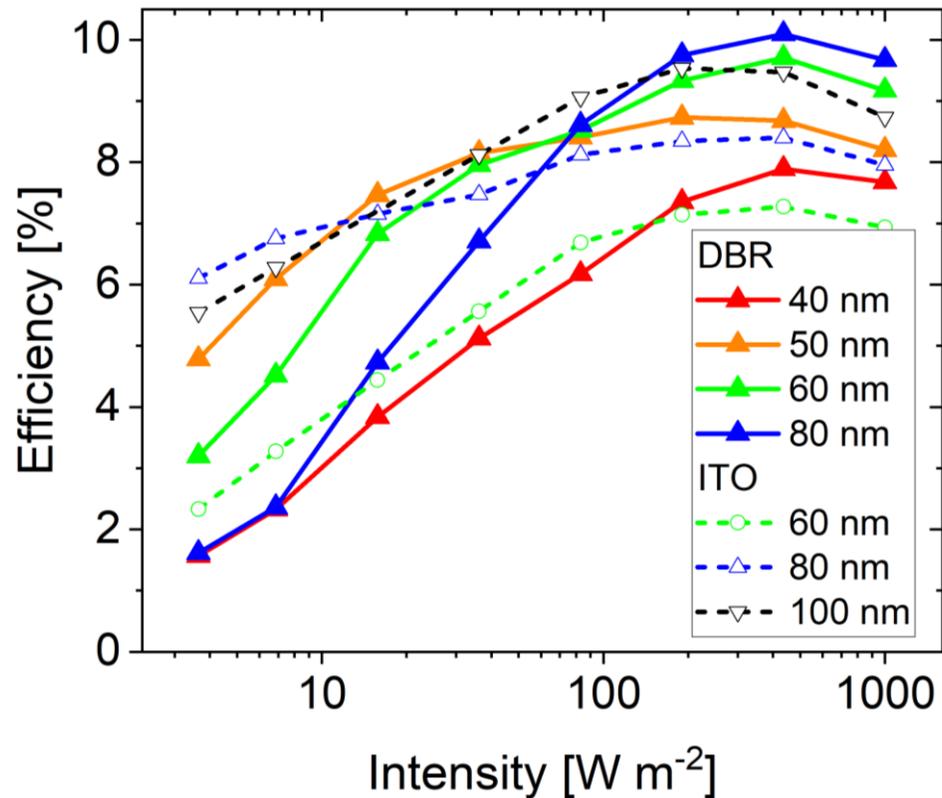
- New generation of transparent mini-modules with metal-less top electrodes and double Ag back electrode
- Cell stripe width 1.25 mm



AVT: 50.8%; PCE: 7.9%; LUE: 4.0%

Transparent Organic Photovoltaics on ITO vs on DBR Electrode

Module area 210 cm²: series interconnection with metal-less top electrode



Transparent Organic Photovoltaics on ITO vs on DBR Electrode



Summary & Conclusion

- OPV is the technology with the largest potential for applications requiring a high degree of visual transparency
- For this to be successful further progress regarding efficiency and lifetime is needed



Thank You for Your Attention!

Uli Würfel

Organic and Perovskite Photovoltaics

uli.wuerfel@ise.fraunhofer.de

Fraunhofer ISE

Heidenhofstraße 2

79110 Freiburg

www.ise.fraunhofer.de

Supported by:



Federal Ministry
for Economic Affairs
and Energy

on the basis of a decision
by the German Bundestag



Funded by
the European Union