Organic solar cells based on small molecules

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   2. Types of organic solar cells (OSC): polymer, small molecules

2. **Small molecule OSC**
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   2. p-i-n concept
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   3. 6.07% certified efficiency

4. **Summary**

Fundamentals: Excitonic processes

Inorganic devices:

- light absorption leads to Wannier Mott excitons
- binding energy $E_B < k_B T \approx 26$ meV
- instantaneous creation of free electrons and holes

Organic photovoltaics (OPV):

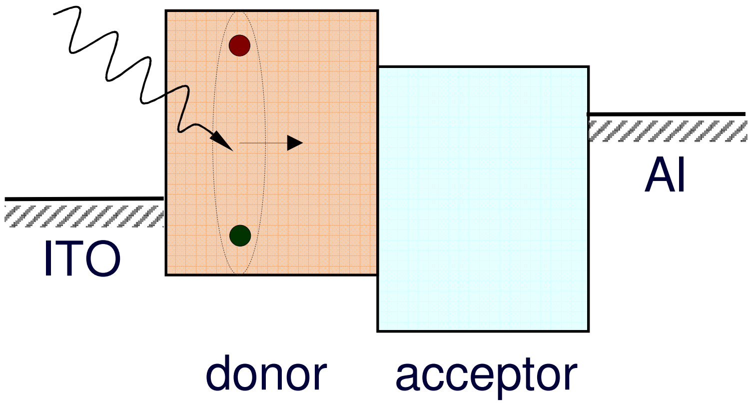
- light absorption results in strongly bound Frenkel excitons
- binding energy $E_B \approx 0.2 - 0.7$ eV
- suitable heterointerface necessary for charge carrier separation
- exciton diffusion length matters!

Advantages of OPV:

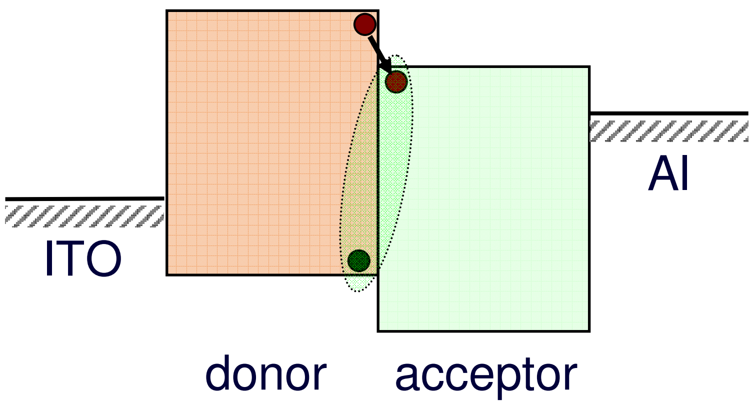
- Low weight
- Low material consumption
- Flexible
- Low price

Fundamentals: Excitonic processes

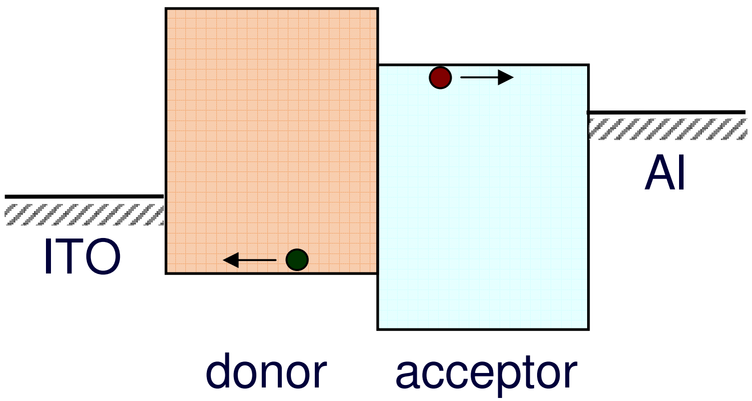
Generation of Frenkel exciton; Diffusion to heterojunction



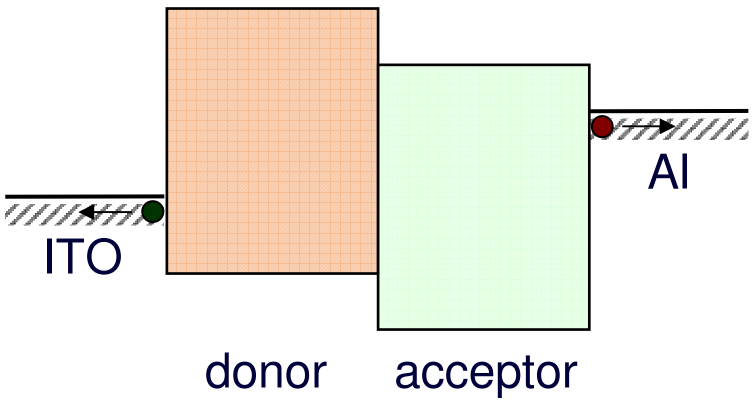
Dissociation and charge transfer



Charge carrier transport to electrodes



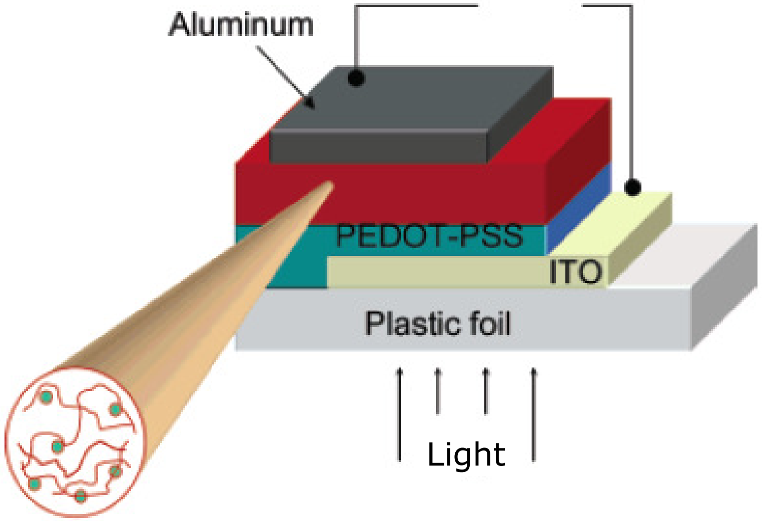
Extraction



Fundamentals: Types of OSC

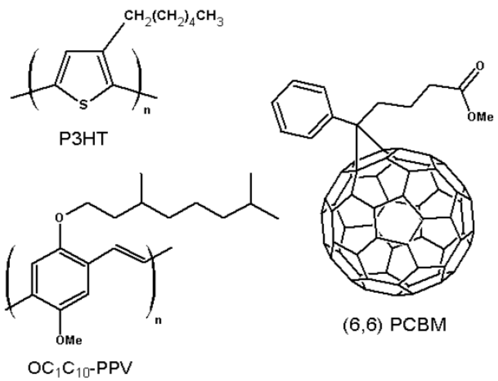
"Organic": contains **carbon-based** absorber materials

Polymer-based OSC

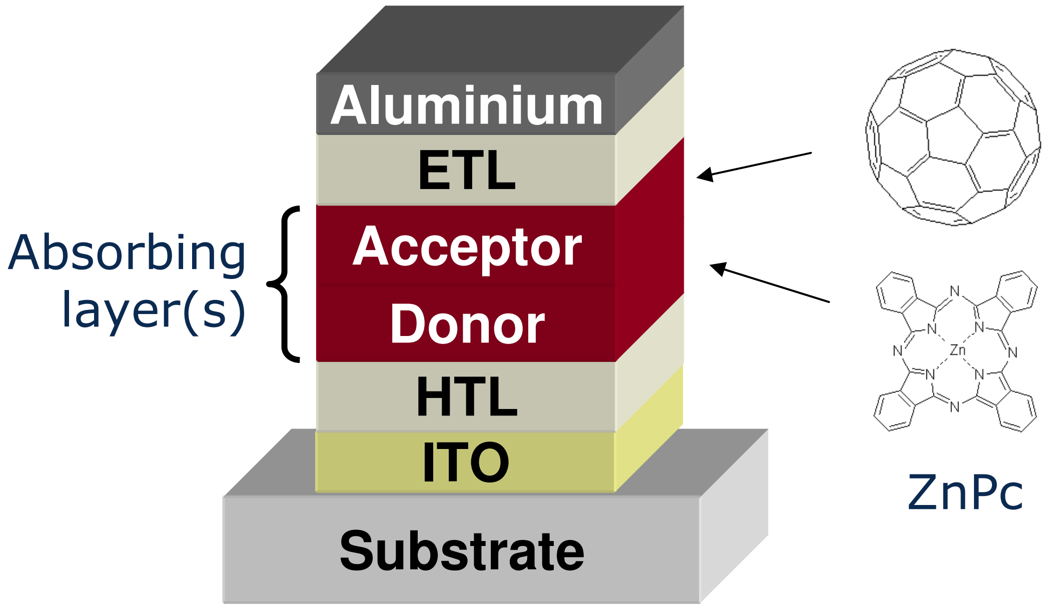


MDMO-PPV
PCBM

Guenes, Neugebauer, Sariciftci, Chem. Rev. 107, 1324-1338 (2007)



Small molecule-based OSC

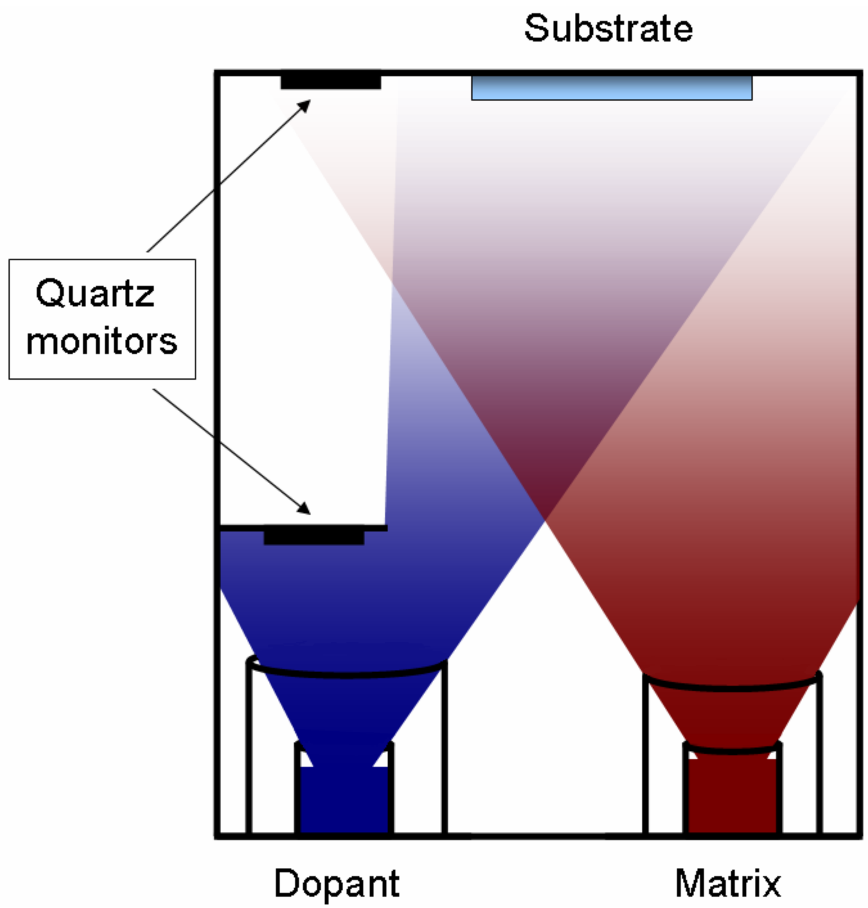


- Dry vacuum processes
- Thermal evaporation
- Easy in-line production

Small molecule OSC: Processing

- Thermal vacuum evaporation
- Simultaneous evaporation of several materials (→ doping)

- Layers 1-100 nm thick; complete device < 300 nm thick (excl. substrate)
- Material consumption for 100 nm layer:
  $10^2 \times 10^2 \times 10^{-5}$ cm³ = 0.1 cm³
  → Total material for device ≈ **1 g/m²**
- Aim: **500 g/m²** incl. substrate

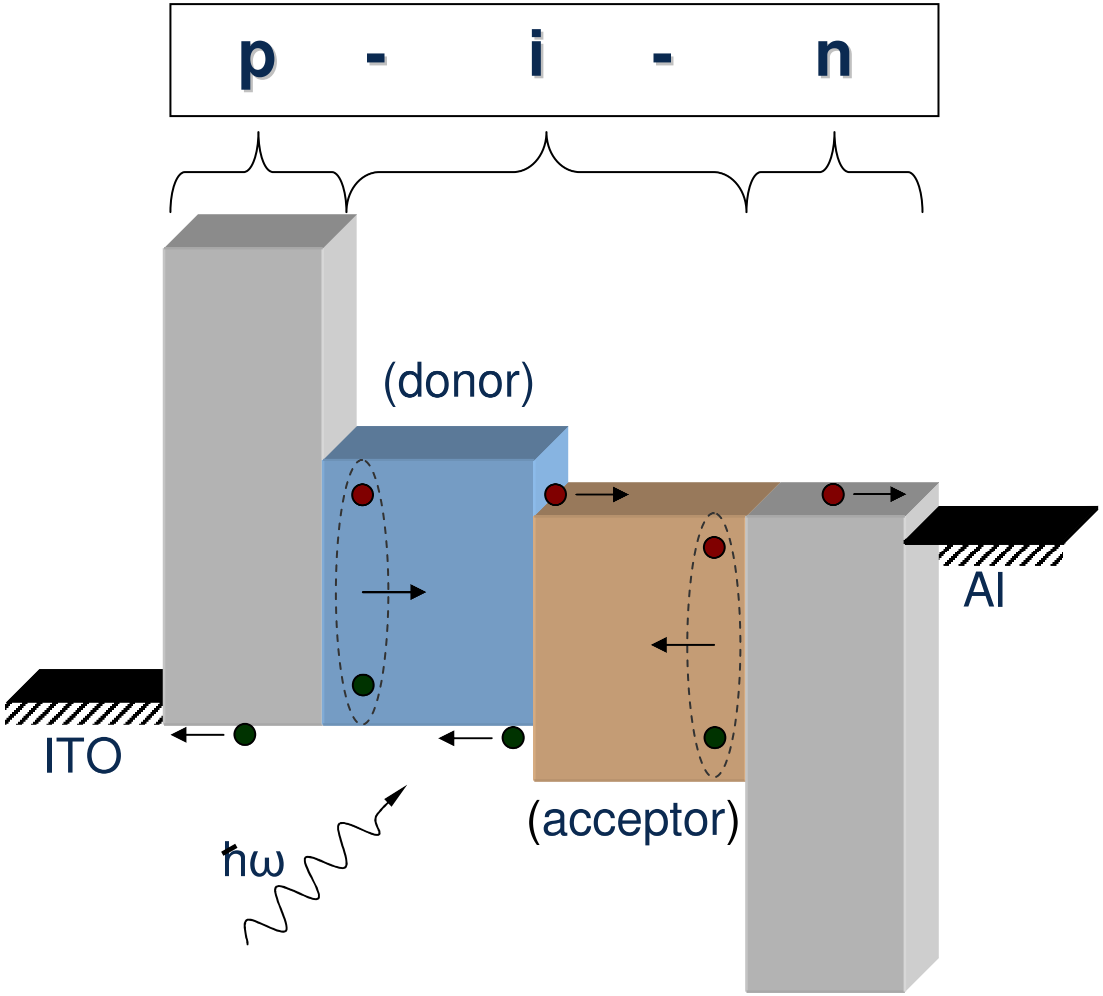


➔ low-cost, low-weight
➔ Large commercial potential

Small molecule OSC: p-i-n concept

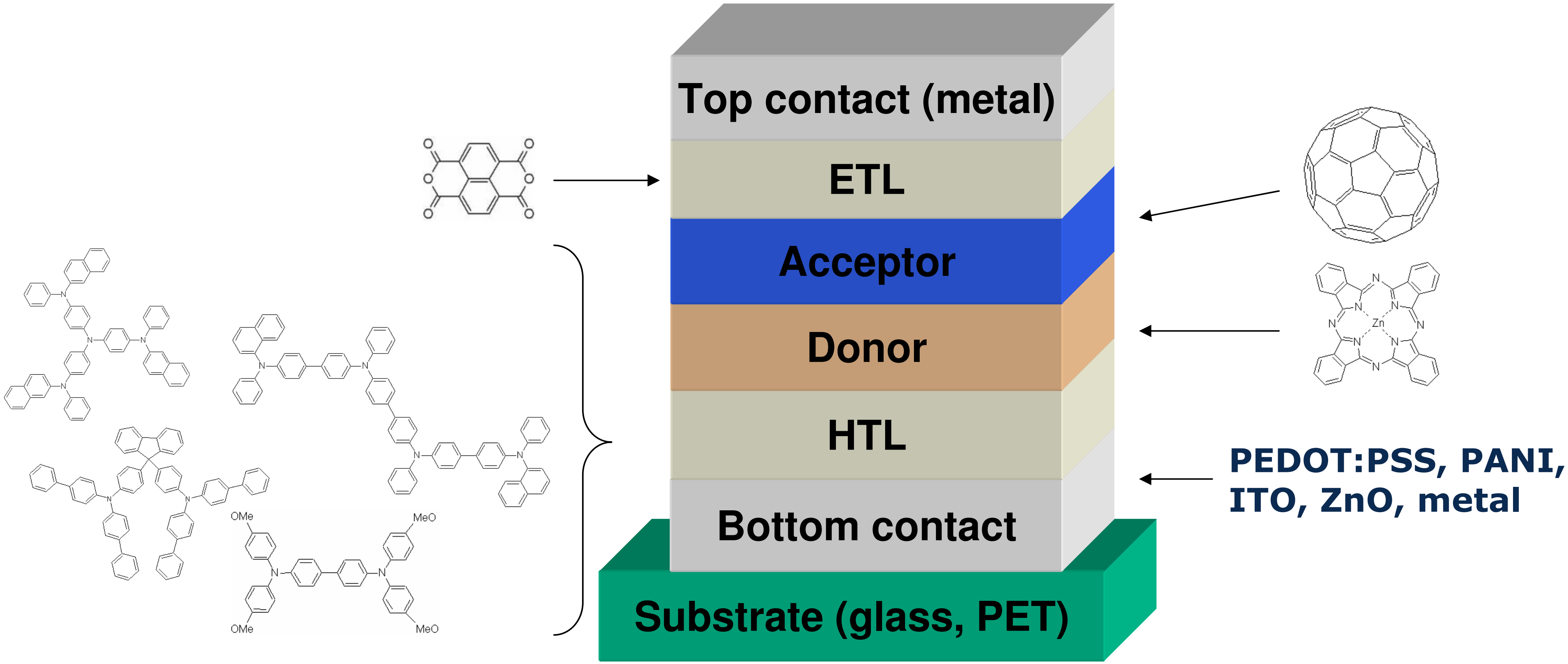
Doping of organic hosts by guest dopant materials (1-10 wt%)

- Increases conductivity
- Ohmic contacts between layers
- Concept of semipermeable membranes
- Transparent transport layers (→ interference effects)



K. Walzer *et al.*, Chem. Rev. **107**, 1233 (2007)
B. Maennig *et al.*, Appl. Phys. A **79**, 1 (2004)

Small molecule OSC: Materials



Additional building blocks:

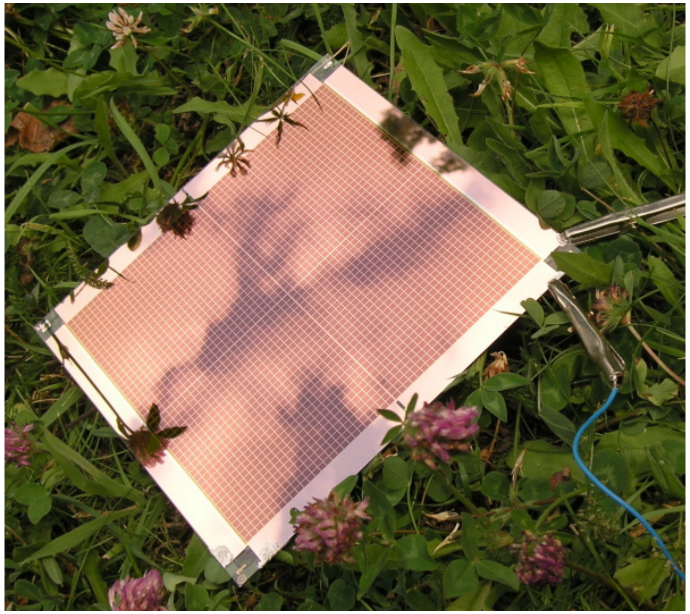
- capping layers for light incoupling,
- exciton blocking layers,
- bulk heterojunctions

➔ **Very high versatility**
➔ **devices can be tailored**

Work at IAPP

Main challenges:

- Excitonic processes
- Narrow absorption bands
- Morphology



15x15cm² OSC Module made in collaboration with Fraunhofer IPMS and Helitatek GmbH

Optical and electrical **modelling**

Charge Separation in D-A systems

Improving the device **characteri-sation**

Understanding mechanism of **doping**

Development of **device concepts**

Characterisation of **new materials**

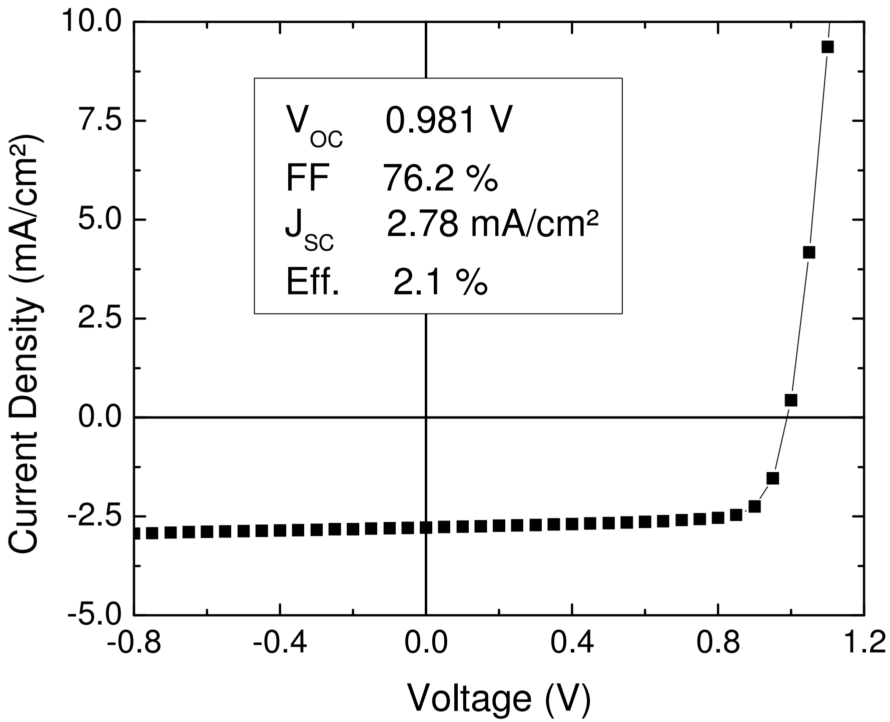
Investigation of the basic **degradation mechanisms**

Highly efficient and long-living organic solar cells

Outstanding results: High fill factors

- Novel green donor materials tested at IAPP
- With suitable dopants and p-i-n concept, fill factors > 76% possible
- Extremely good transport properties

➢ Building block for tandem devices?

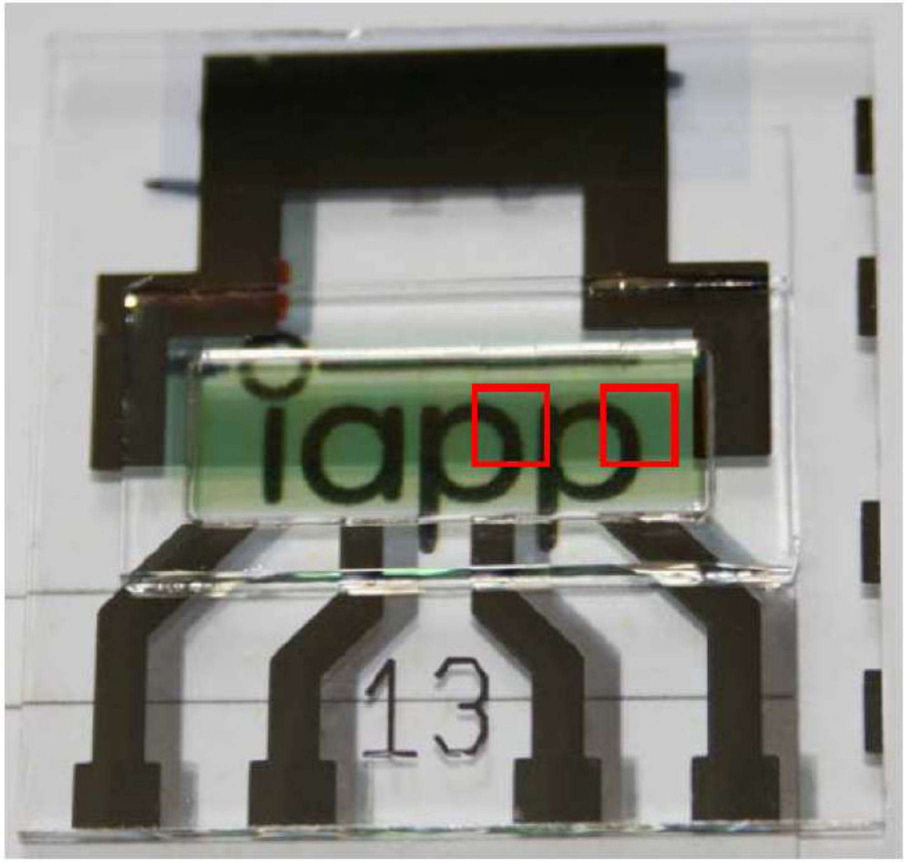


J. Meiss *et al., in preparation*

Outstanding results: Semitransparent devices

- Huge market for building-integrated “power windows“
- Using advanced device concepts: 2% efficiency at 30-50% transmission;

  close to 4% with tandem devices (< 20% transmission)



In cooperation with heliatek GmbH

heliatek
Organic based Photovoltaics

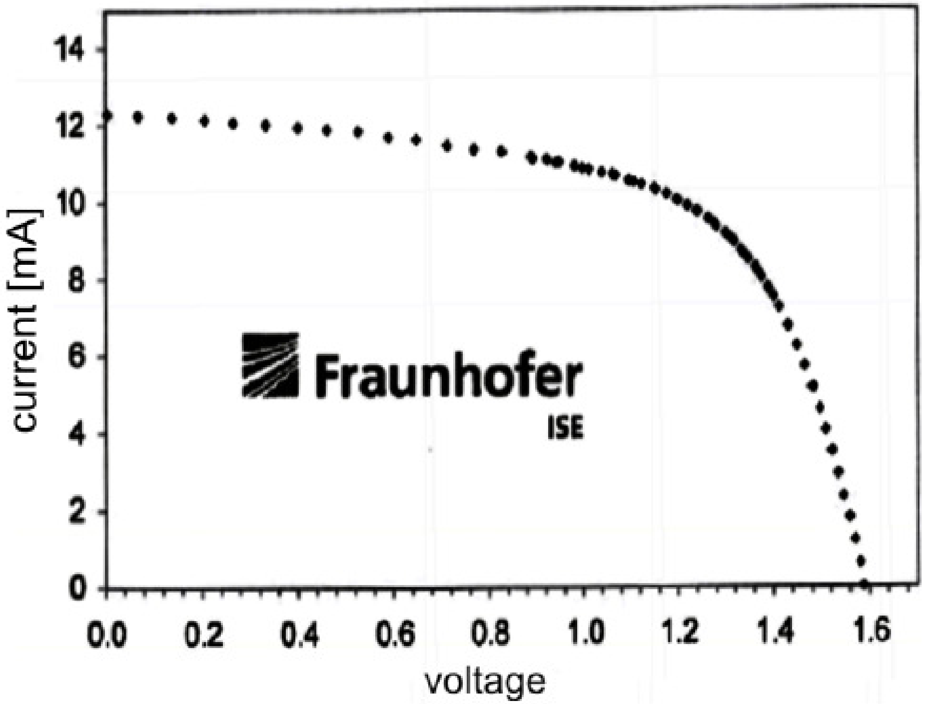
J. Meiss, K. Leo, M. Riede, C. Uhrich, Stefan Sonntag, W.-M. Gnehr, and M. Pfeiffer, Appl. Phys. Lett. 95(21), 213306 (2009)

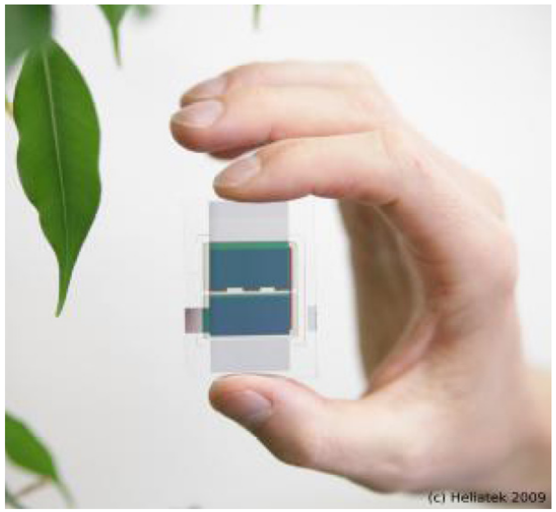
Outstanding results: Certified world-record OPV efficiency

heliatek
Organic based Photovoltaics

- Cooperation of heliatek, IAPP and BASF
- Dopants by Novaled
- 6.07% on large-area OSC (2 cm²), certified by ISE Freiburg:

  V_{oc} = 1.59 V
  J_{sc} = 6.18 mA/cm²
  FF = 61.9 %
  η = 6.07 %
- Notable exception for polymers: 7.9% on ≈ 4 mm² (Solarmer)





M. A. Green et al., Prog. Photovolt: Res. Appl. 18, 144 (2010).
R. Timmreck et al., Proc. EU PVSEC 24, 89-92 (2009).

Summary

- Small molecule-OSC
  - Vacuum processing
  - Low material consumption
  - Potentially very low costs

- Still basic research. Young field, not many small-molecule groups
- Highly interdisciplinary (materials science, chemistry)
- Promising efficiencies show potential; 10-15% possible

- Chance for cutting-edge technology in Germany
- Economic potential
- heliatek is planning pilot production facility in Dresden

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INNOPROFILE

UNTERNEHMEN REGION

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Organic based Photovoltaics

- Spin-off of IAPP
- Financing by BASF, Bosch, Wellington Partners, Technologiegründerfonds Sachsen
- CEO: Dr. Andreas Rückemann
- CTO: Dr. Martin Pfeiffer
- Recent financing round: 18 Mio. €
- Close cooperation with IAPP
- Plans to set up pilot processing line