Watching a Solar Cell Die
morphological degradation
in organic photovoltaics

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Challenges in Energy Supply

Some challenges of an ideal energy supply:

- **Versatility and applicability:**
  - large variety of applications
  - ease of application

- **Environmental impact and safety:**
  - reduce nuclear energy
  - reduce fossils
  - increase amount of renewables

- **Accessibility:**
  - microgrids
  - autonomous units
  - mobile power generation

- **Price:**
  - conserve energy

**Organic photovoltaics (OPV) as a versatile tool**
Want a free Sample?

plasticphotovoltaics.org
- a hub for OPV research
BMW i3

- consumption: 13 kWh/ 100 km
- a very rough estimation:
  - 4.5 m² covered surface
  - no significant weight of solar cells
  - 10% efficiency
  - 5 h sun/day
  - 17 km (2.3 kWh) per day
  - 6 l gas / week (14 kg CO₂)
  - for Munich: ~ 10000 t CO₂ / week
Energy in Motion

BMW i3

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new possibilities from OPV: architecture, electromotive, mobile applications, ...
Polymers

chemical definition:
poly (greek: “many“)
méros (greek: “part“)

monomer → polymer

polymer

daily “definition“:
plastics

organic electronics
conducting polymers

rieke
Wikipedia / meharris
Nobel prize 2000

organic p-type semiconductors:
• conduct positive charges
• example: polymers

• poly(3-hexylthiophene-2,5-diyl) (P3HT)

organic n-type semiconductors
• conduct negative charges
• example: polymers, mostly fullerenes

• phenyl C$_{61}$ butyric acid methyl ester (PCBM)
multilayer architecture

back contact
• aluminum, gold, silver, graphite, conducting polymers

active layer
• polymer:fullerene blends
• nanometer-scaled sponge-like structure from polymer, filled with fullerene

transparent conducting layer
• transparent conductors (ITO, FTO), conducting polymers

substrate
• glass, PET foils, ...
Fabrication of Polymer Based Solar Cells

fabrication on lab scale

substrate with transparent (ITO) electrode

thermal evaporation of metal cathodes (Al)

spin coating: thin film formation, micro phase separation

polymer:fullerene blend
Working Principle

- **electron donor (polymer)**
- **electron acceptor (fullerene)**

### Structure
- **metal contact**
- **active blend layer**
- **PEDOT:PSS**
- **ITO**
- **substrate**

### Processes
- **light absorption**
- **exciton generation**
- **exciton diffusion \((l_d \sim 10\ \text{nm})\)**
- **and splitting**
- **charge carrier transport and extraction**

### Note
- Structure length scales crucial for functioning coarsening → “**structural degradation**”
Evidencing Structural Degradation

- Time resolved I-V measurements
- Time resolved morphology probe
- In-situ X-ray scattering experiment (GISAXS)

Schaffer et al., Adv. Mater. 2013, 25 (46), 6760

Christoph Schaffer: Watching a Solar Cell Die christoph.schaffer@ph.tum.de
MiNaXS - Micro- and Nanofocused X-ray scattering
beamline P03, DESY, Hamburg
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Experimental Setup: P03


Special thanks to Christian Jendrzejewski for taking pictures.

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Morphological Degradation in OPV

electron donor (polymer)

electron acceptor (fullerene)

coadsening as pathway of degradation

- small polymer domains grow
- and “drift” apart
- overall loss of active area
  (small structures + interface)
- loss of short-circuit current $J_{SC}$

- loss of current fully explained by morphological degradation
- 1st direct evidence for morphological degradation
- main mechanism of degradation

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Summary and Outlook

OPV lifetime shortened by morphological degradation
⇒ need for morphological stabilization

potential routes towards elongated lifetimes
• cross linking of polymers
• processing additives
• hybrid solar cells / use of inorganic stabilizing materials

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