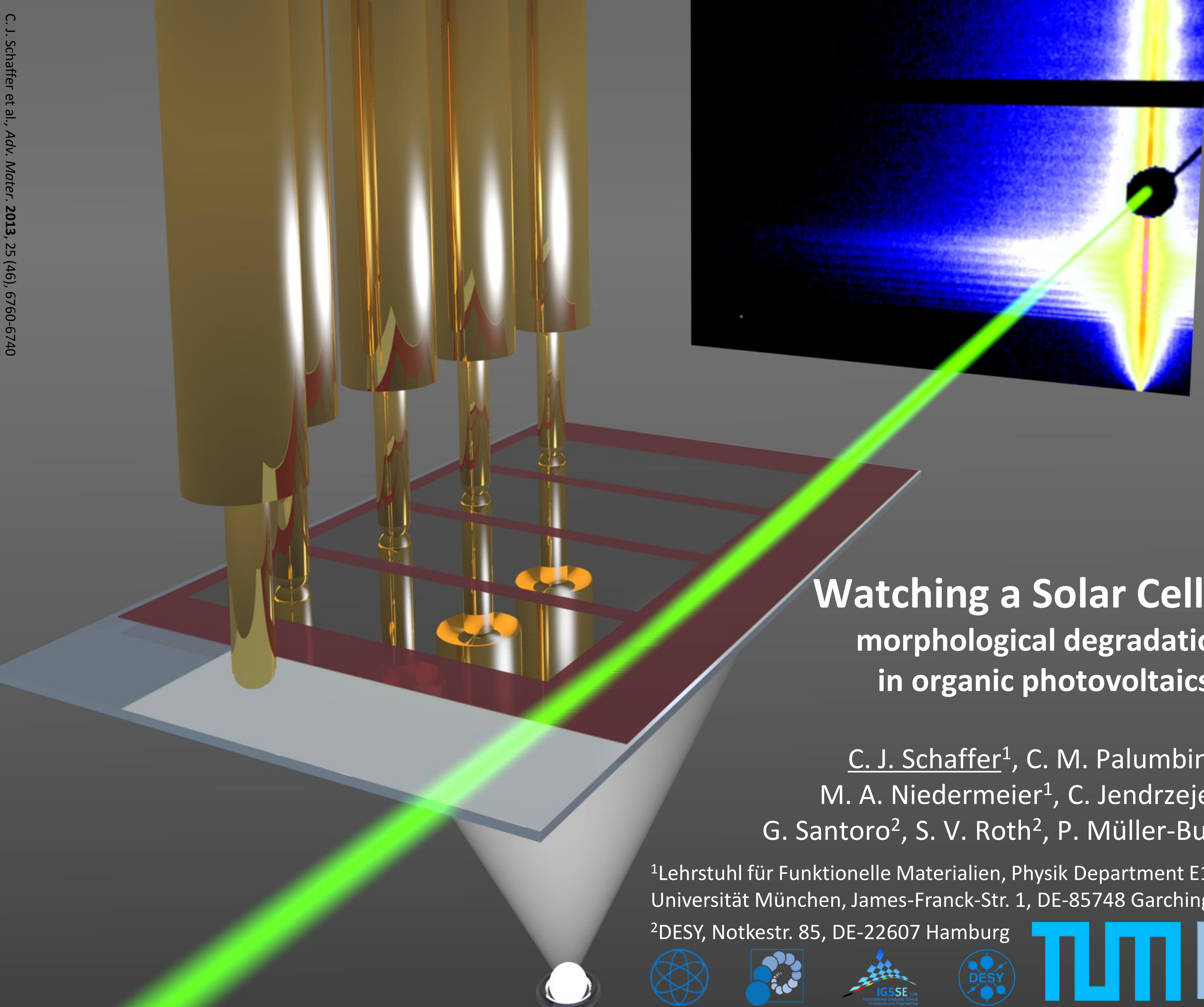
C. J. Schaffer et al., *Adv. Mater.* **2013**, 25 (46), 6760-6740



Watching a Solar Cell Die

morphological degradation in organic photovoltaics

C. J. Schaffer[1], C. M. Palumbiny[1], M. A. Niedermeier[1], C. Jendrzejewsi[1], G. Santoro[2], S. V. Roth[2], P. Müller-Buschbaum[1]

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[2]DESY, Notkestr. 85, DE-22607 Hamburg

Challenges in Energy Supply

some challenges of an ideal energy supply

versatility & applicability

neubers.eu

no environmental impact

inma.org

safety

accessible for everybody

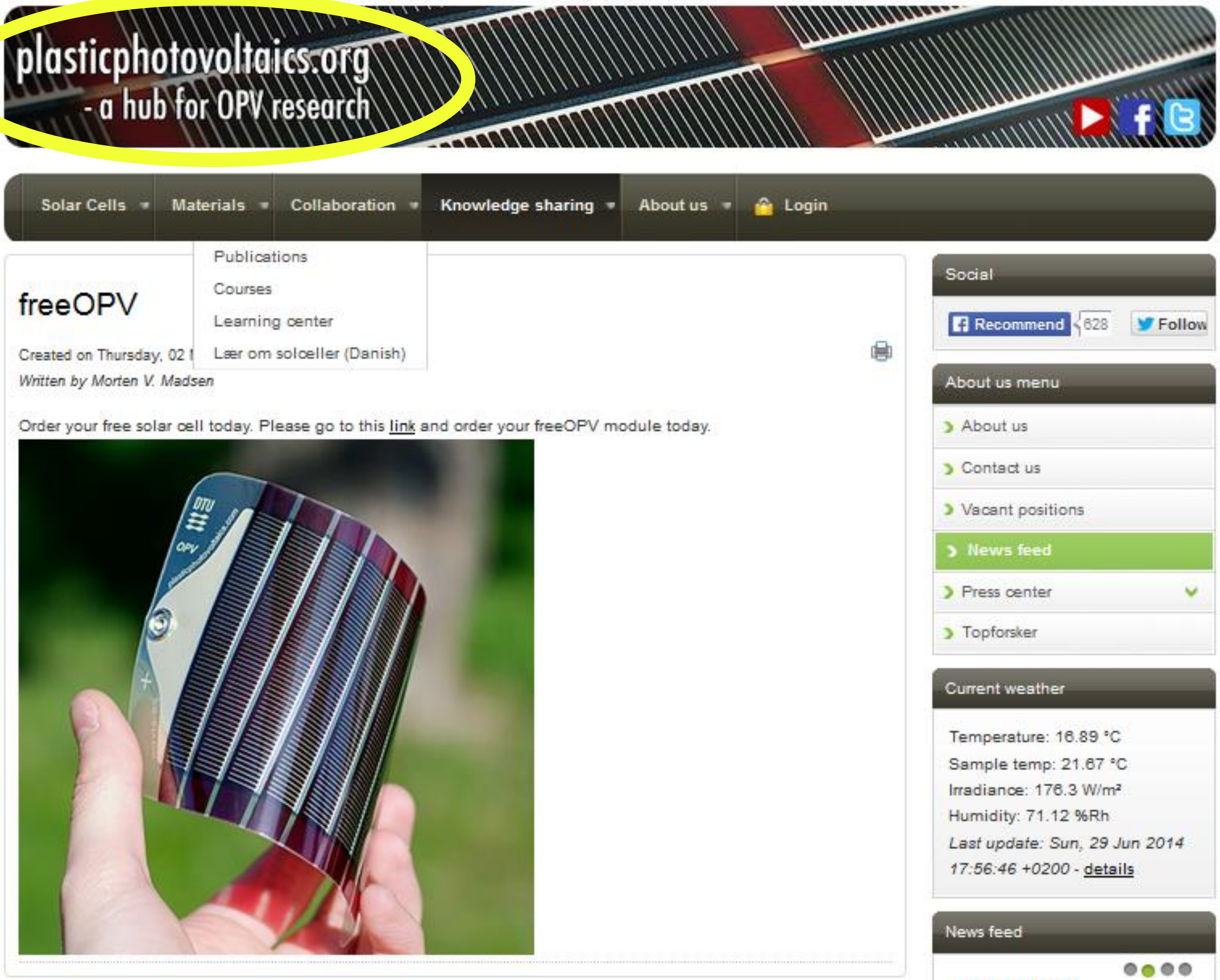
eight19.com

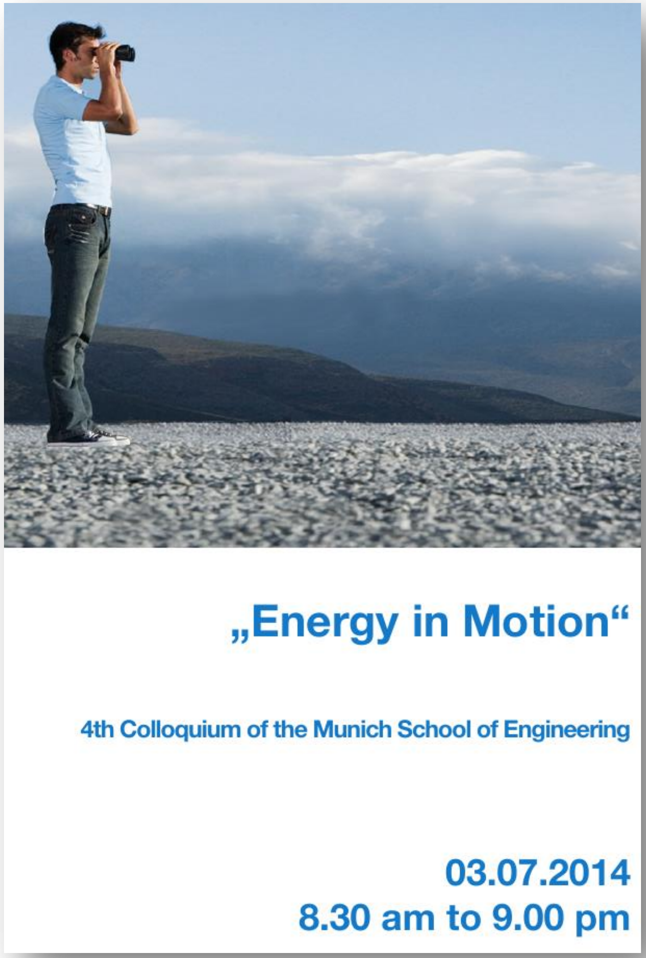
cheap

organic photovoltaics (OPV) as a versatile tool

- versatility and applicability:
  - large variety of applications
  - ease of application
- environmental impact and safety:
  - reduce nuclear energy
  - reduce fossils
  - increase amount of renewables
- accessibilty:
  - microgrids
  - autonomous units
  - mobile power generation
- price
  - conserve energy

Want a free Sample?





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 CO_2)
➢ for Munich: ~ 10000 t CO_2 / week

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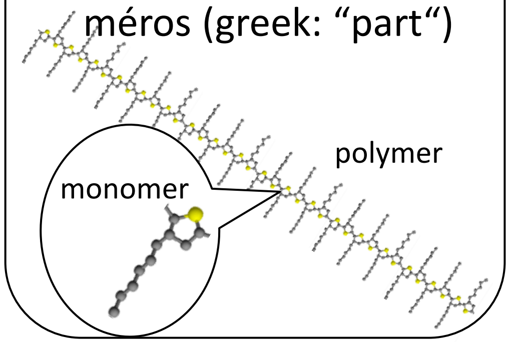
new possibilities from OPV: architecture, electromotive, mobile applications, …

Polymers

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

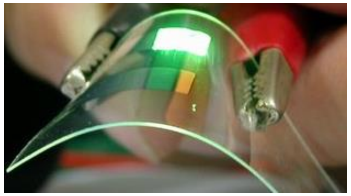


daily “definition“:
plastics



organic electronics
conducting polymers

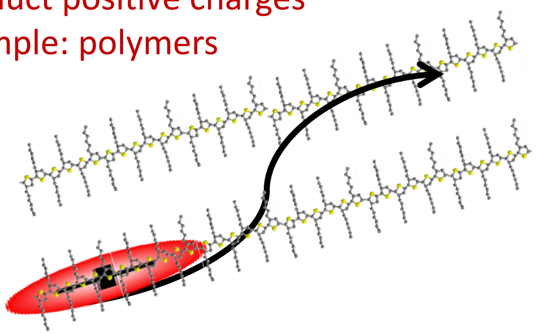

rieke


Wikipedia / meharris


Nobel prize 2000

organic p-type semiconductors:

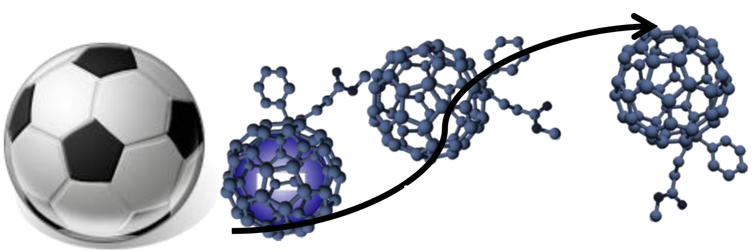
- conduct positive charges
- example: polymers



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

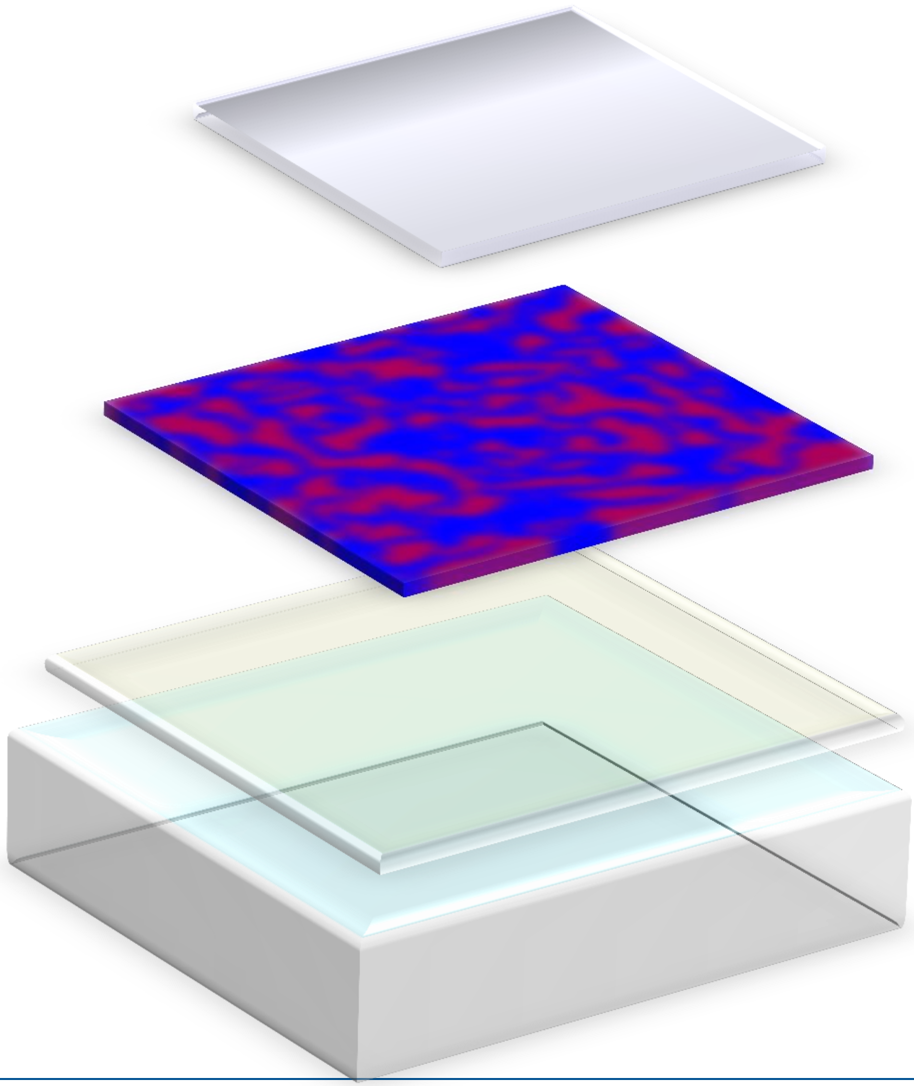
organic n-type semiconductors

- conduct negative charges
- example: polymers, mostly fullerenes



- phenyl C_{61} butyric acid methyl ester (**PCBM**)

OPV Architecture



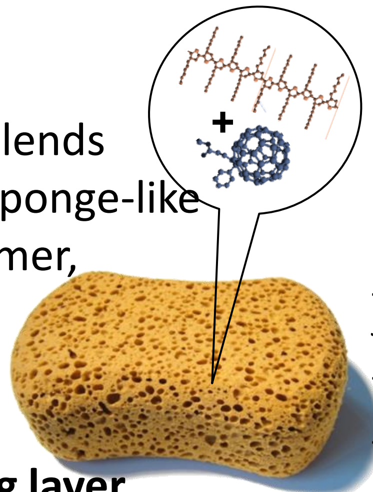
multilayer architecture

back contact

- aluminum, gold, silver, graphite, conducting polymers

active layer

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



Wikipedia / Johan

transparent conducting layer

- transparent conductors (ITO, FTO), conducting polymers

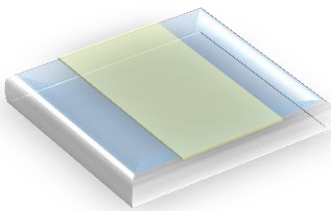
substrate

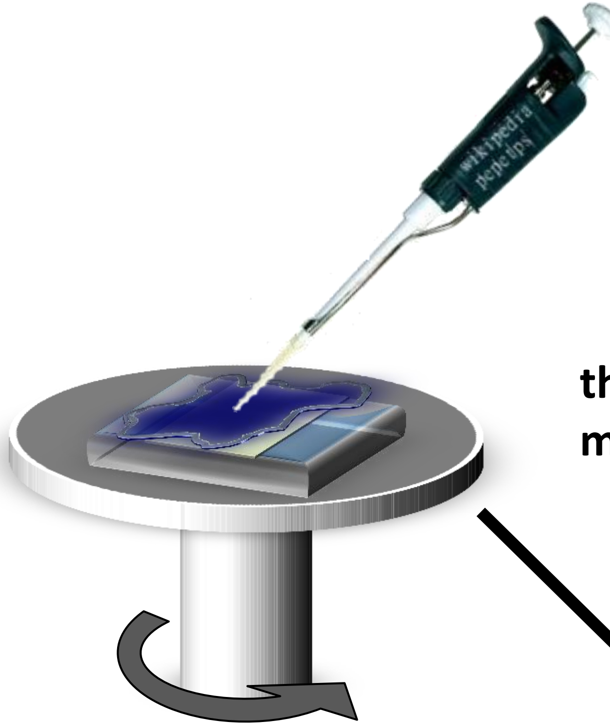
- glass, PET foils, …

Fabrication of Polymer Based Solar Cells

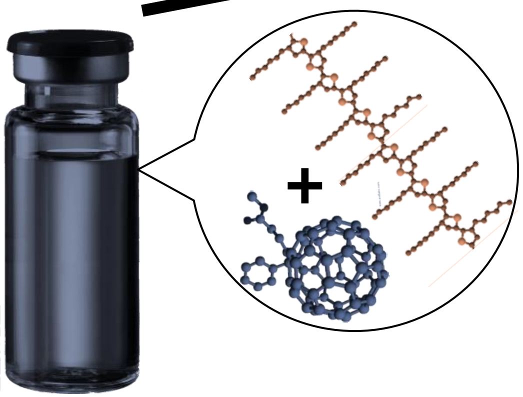
fabrication on lab scale

substrate with transparent (ITO) electrode



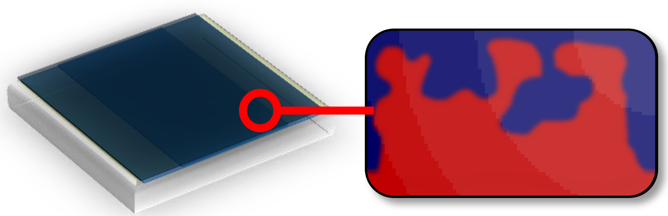


thermal evaporation of metal cathodes (Al)



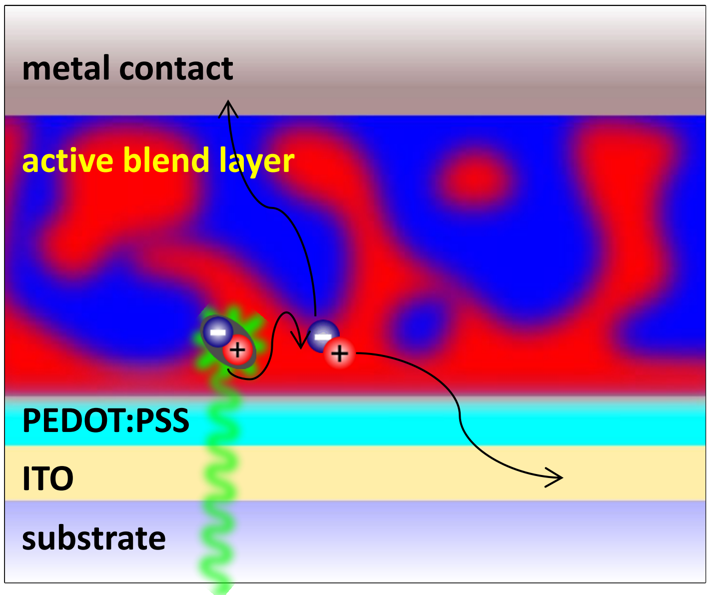
polymer:fullerene blend

spin coating:
thin film formation,
micro phase separation



Working Principle

electron donor (polymer)
electron acceptor (fullerene)

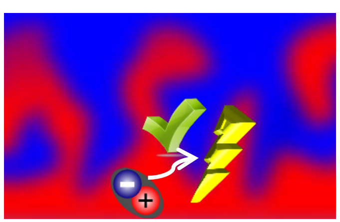


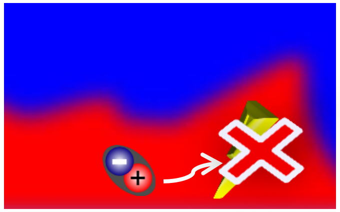
light absorption

exciton generation

exciton diffusion (l_d ~ 10 nm) and splitting

charge carrier transport and extraction





structure length scales crucial for functioning
coarsening ➔ **“structural degradation“**

Evidencing Structural Degradation

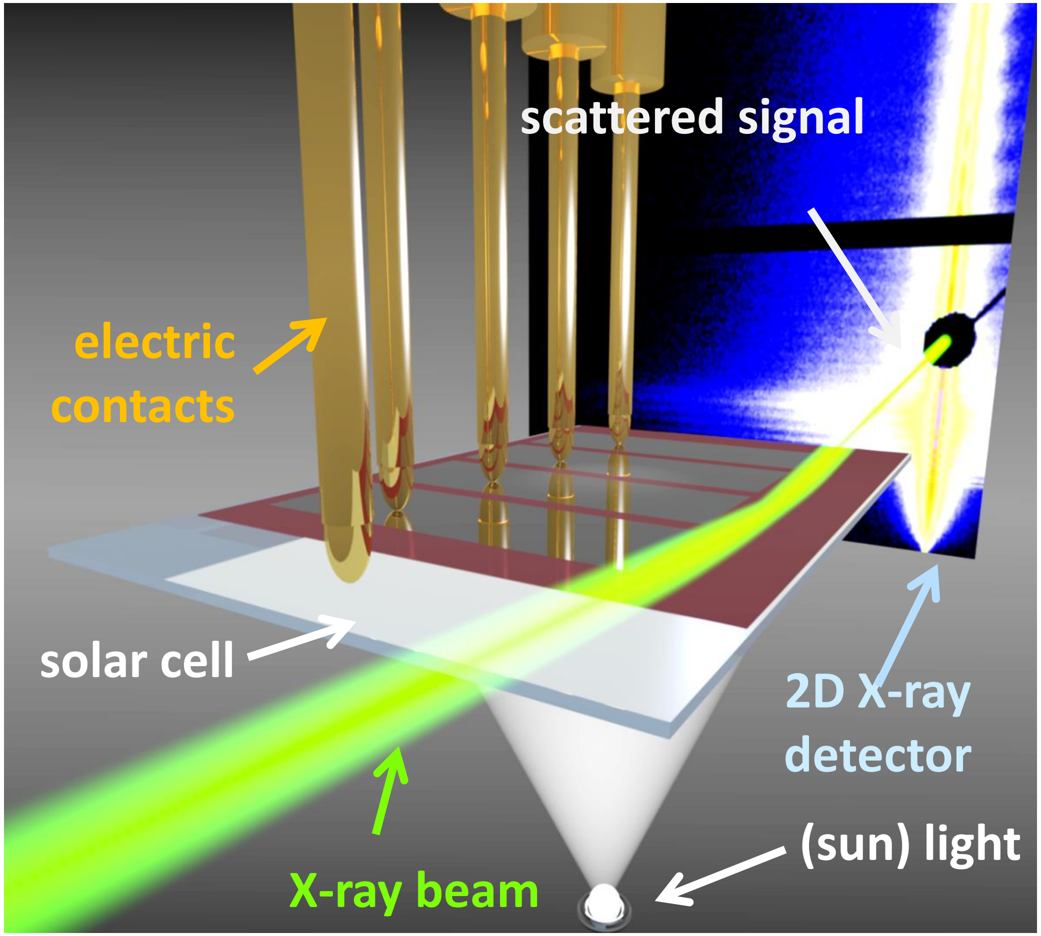
time resolved I-V measurements

+

time resolved morphology probe

⇩

in-situ X-ray scattering experiment (GISAXS)



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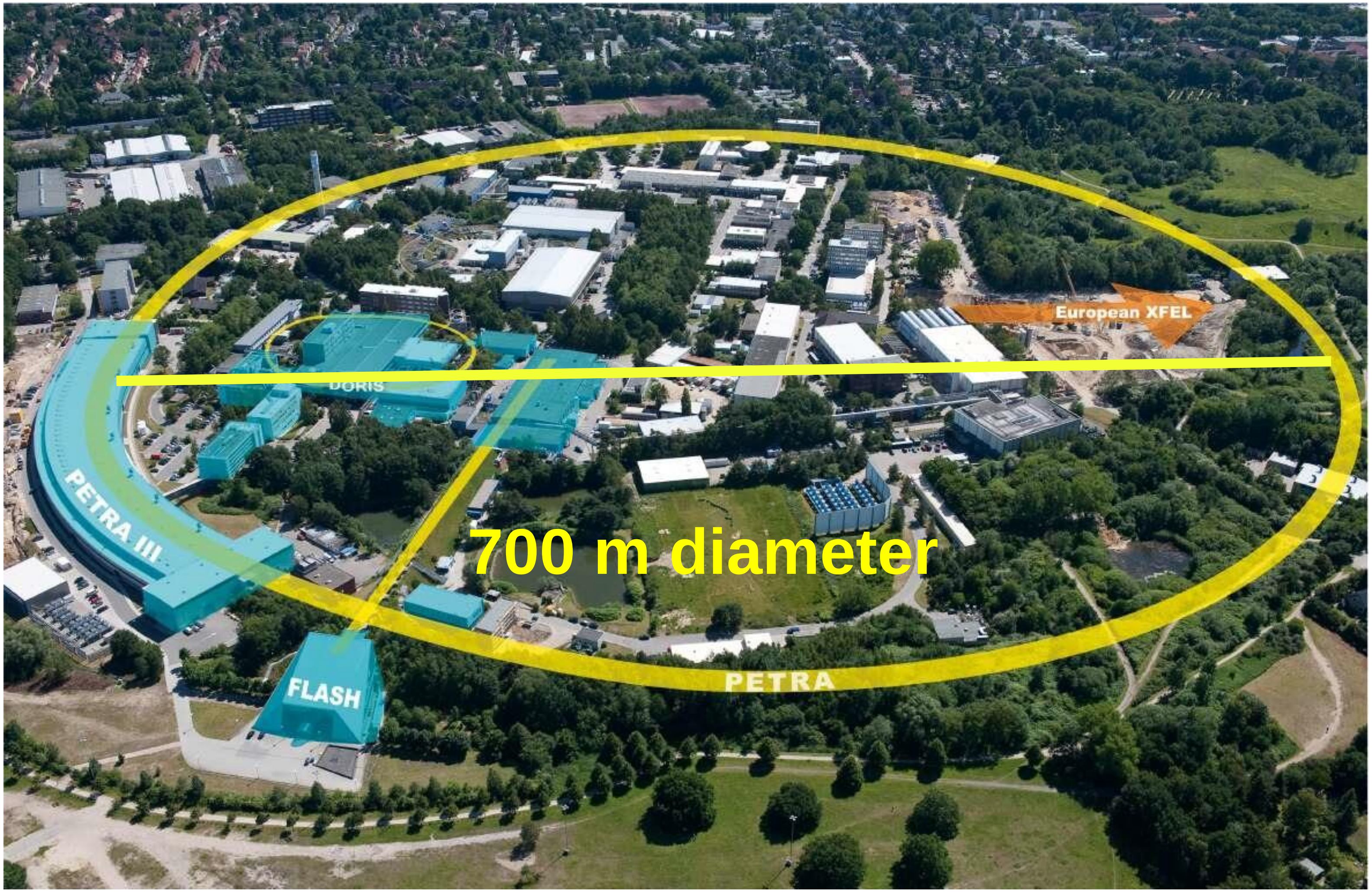
MiNaXS - Micro- and Nanofocused X-ray scattering beamline P03, DESY, Hamburg



MiNaXS - Micro- and Nanofocused X-ray scattering
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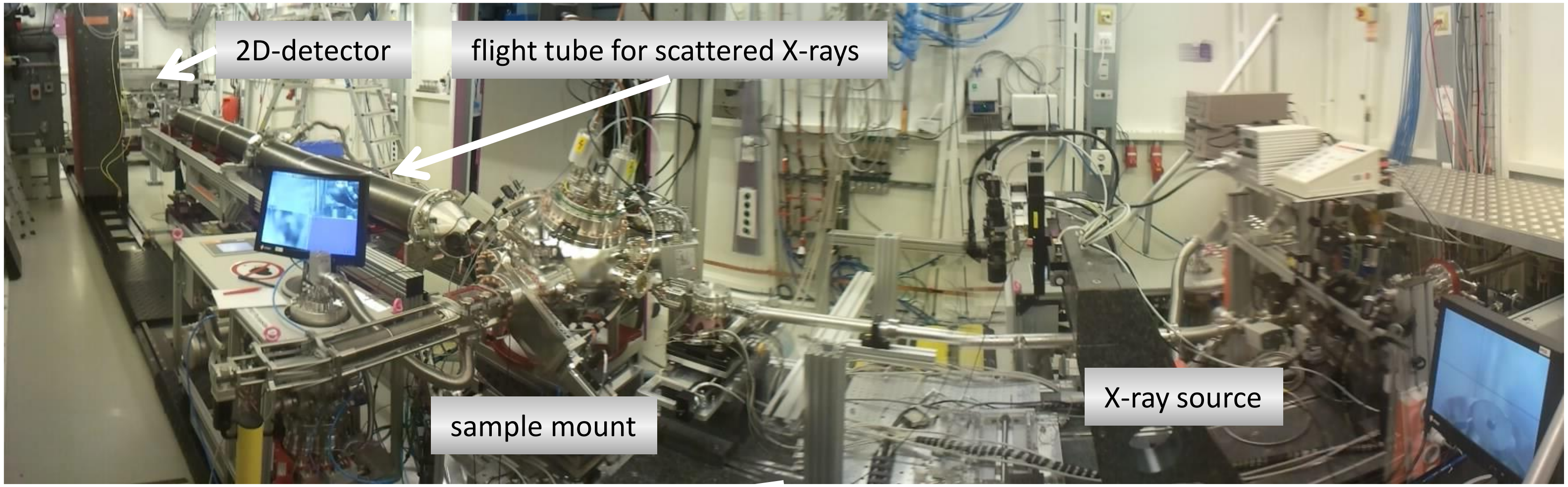

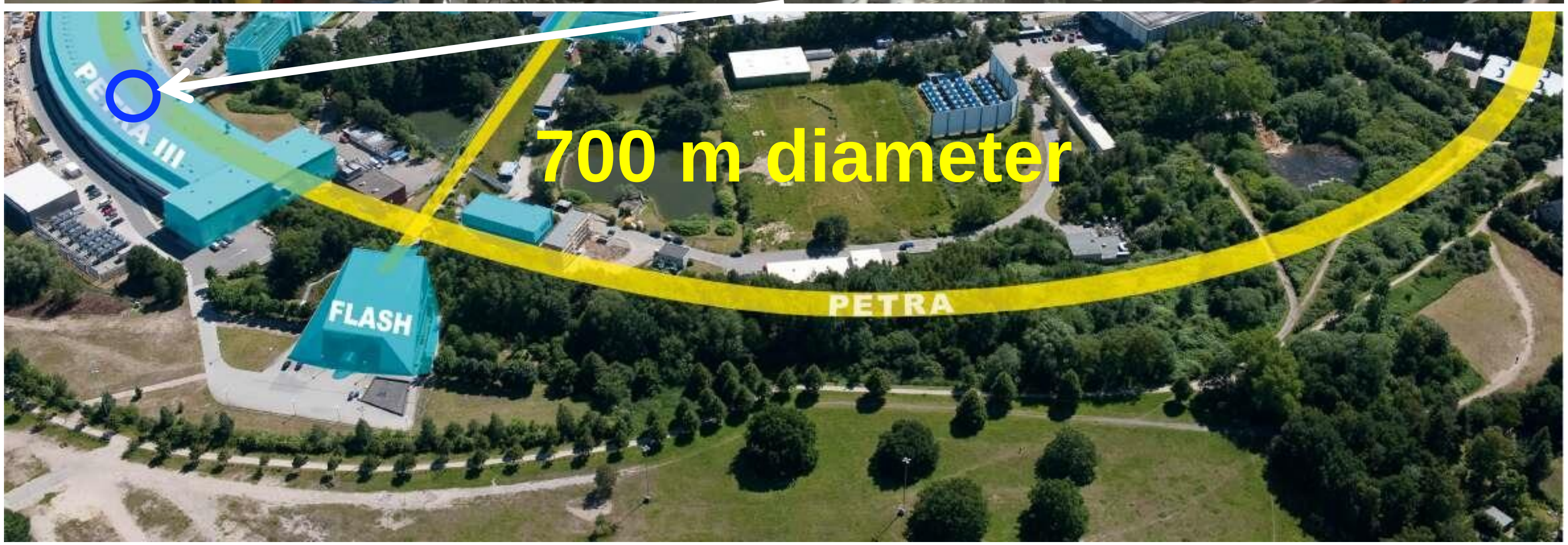

Experimental Setup: P03

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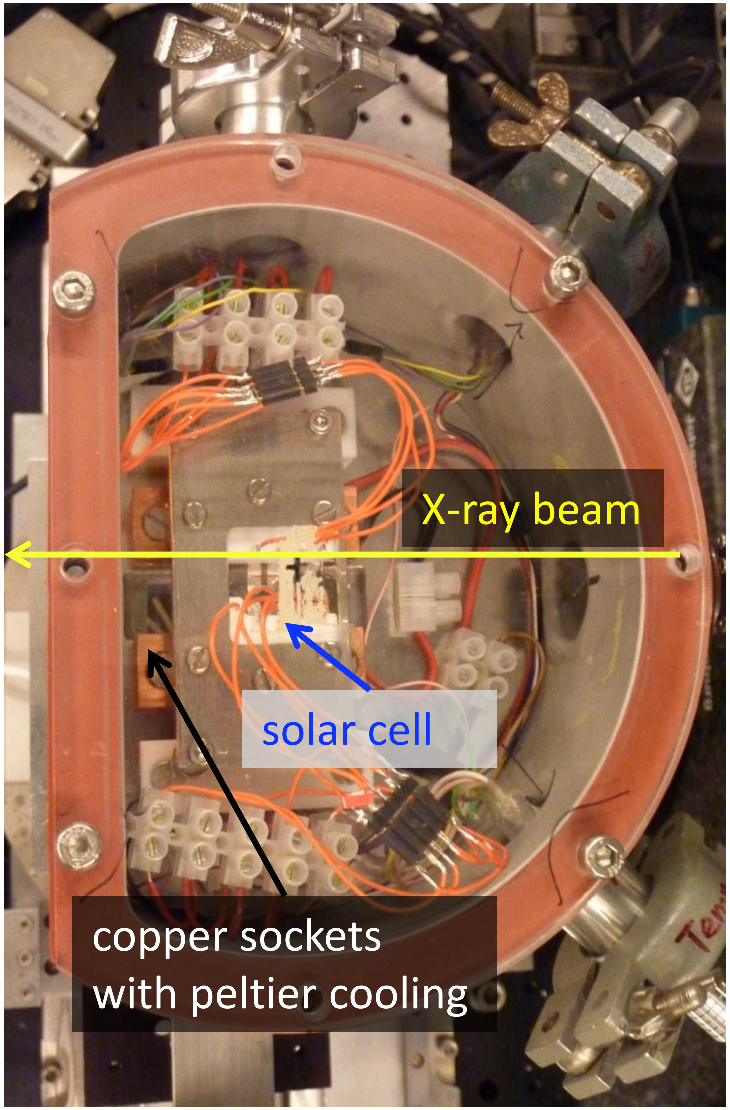
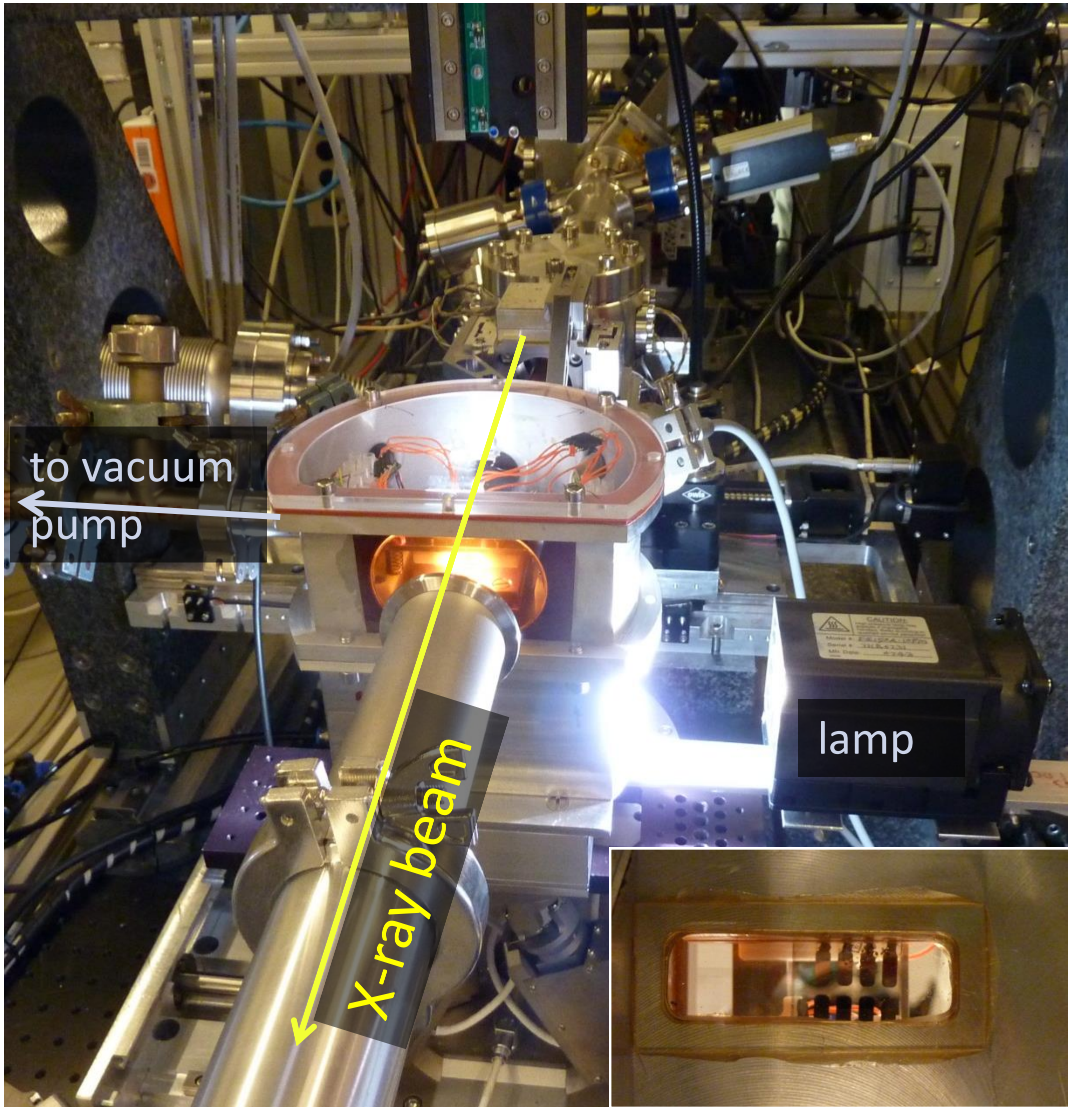
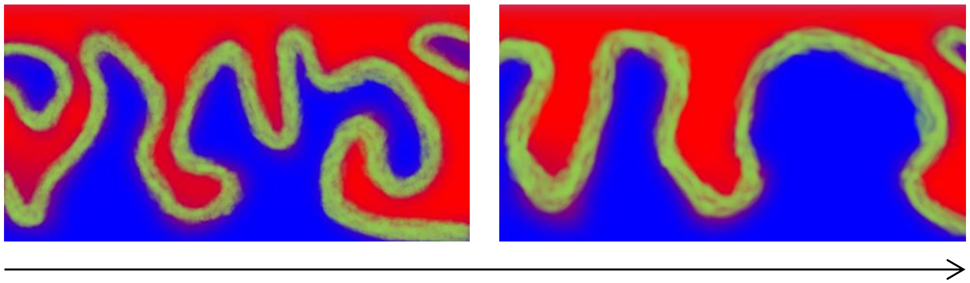




Special thanks to Christian Jendrzejewski for taking pictures.

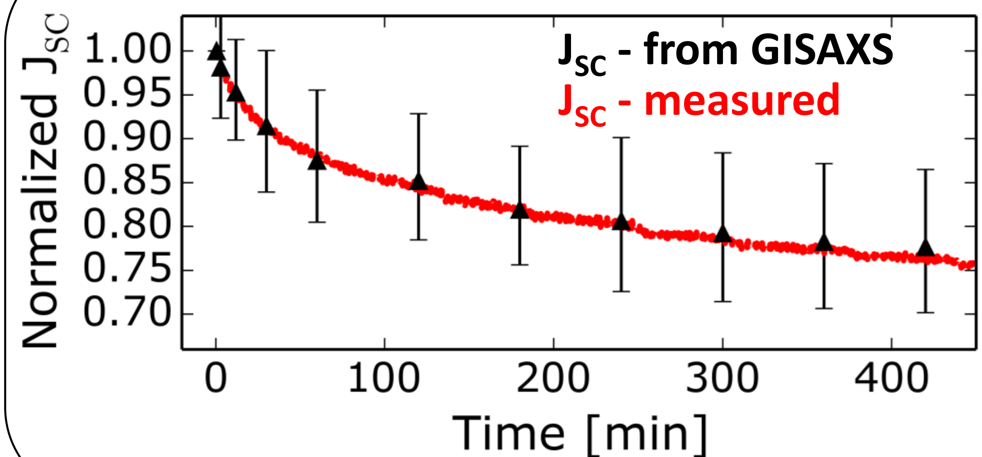
Morphological Degradation in OPV

electron donor (polymer)
electron acceptor (fullerene)



coarsening 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}

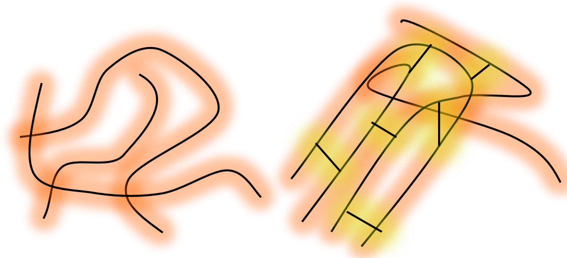


- ➢ loss of current fully explained by morphological degradation
- ➢ 1st direct evidence for morphological degradation
- ➢ main mechanism of degradation

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

Summary and Outlook

OPV lifetime shortened by morphological degradation
➔ need for morphological stabiliziation



potential routes towards elongated lifetimes

- cross linking of polymers
- processing additives
- hybrid solar cells / use of inorganic stabilizing materials

Acknowledgements

- ***Prof. Peter Müller-Buschbaum***
- ***chair of functional materials***

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