

## Watching a Solar Cell Die morphological degradation in organic photovoltaics

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## some challenges of an ideal energy supply

versatility &  
applicability

neubers.eu

no environmental  
impact

inma.org



safety

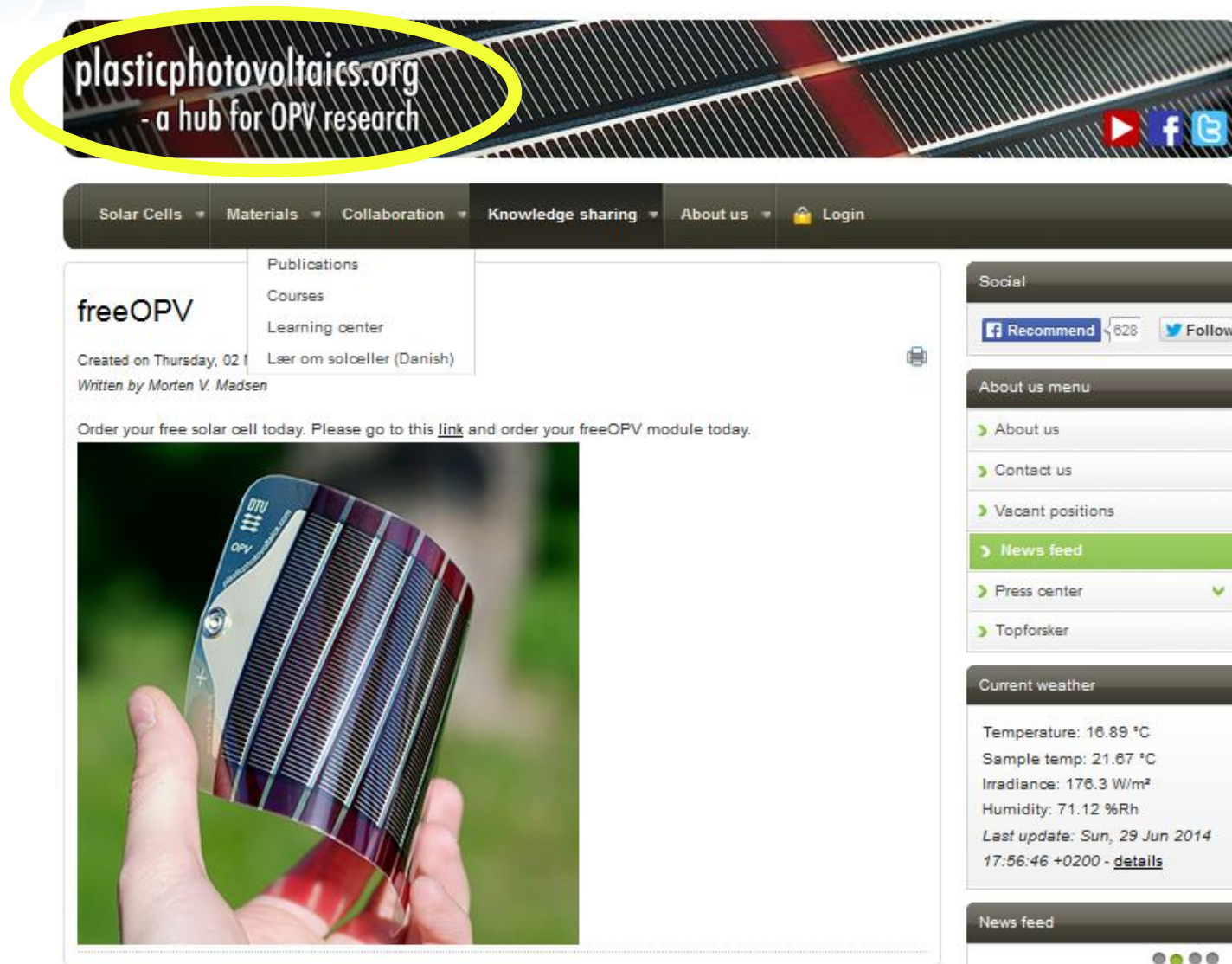
accessible  
for everybody

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
- accessibility:
  - microgrids
  - autonomous units
  - mobile power generation
- price
  - conserve energy



The screenshot shows the website plasticphotovoltaics.org, which is a hub for OPV research. The site features a navigation menu with categories like Solar Cells, Materials, Collaboration, Knowledge sharing, and About us. A prominent yellow circle highlights the website's name in the header. The main content area displays a 'freeOPV' offer, created on Thursday, 02 June 2014, and written by Morten V. Madsen. The offer includes a link to order a free solar cell module. A large image shows a hand holding a flexible, curved solar cell module. The right sidebar contains social media links, an 'About us menu' with options like About us, Contact us, and News feed, and a 'Current weather' section showing temperature, sample temperature, irradiance, and humidity.

plasticphotovoltaics.org  
- a hub for OPV research

Solar Cells ▾ Materials ▾ Collaboration ▾ Knowledge sharing ▾ About us ▾ Login

freeOPV

Created on Thursday, 02 June 2014 12:00  
Written by Morten V. Madsen

Publications  
Courses  
Learning center  
Lær om solceller (Danish)

Order your free solar cell today. Please go to this [link](#) and order your freeOPV module today.

Temperature: 16.89 °C  
Sample temp: 21.87 °C  
Irradiance: 176.3 W/m<sup>2</sup>  
Humidity: 71.12 %Rh  
Last update: Sun, 29 Jun 2014 17:56:46 +0200 - [details](#)



## „Energy in Motion“

4th Colloquium of the Munich School of Engineering

03.07.2014  
8.30 am to 9.00 pm

## BMW i3



- consumption: 13 kWh/ 100 km
- **a very rough estimation:**
  - 4.5 m<sup>2</sup> 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<sub>2</sub>)
- for Munich: ~ 10000 t CO<sub>2</sub> / week

Wikipedia / Joe Mabel



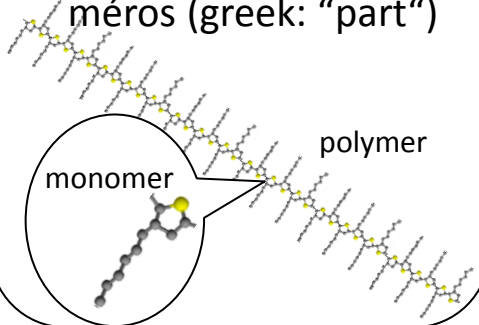
## BMW i3



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

**chemical definition:**  
poly (greek: "many")  
méros (greek: "part")



**daily "definition":**  
plastics



**organic electronics**  
conducting polymers



rieke



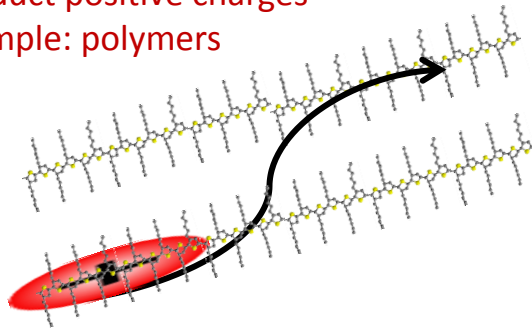
Wikipedia / meharris



Nobel prize 2000

**organic p-type semiconductors:**

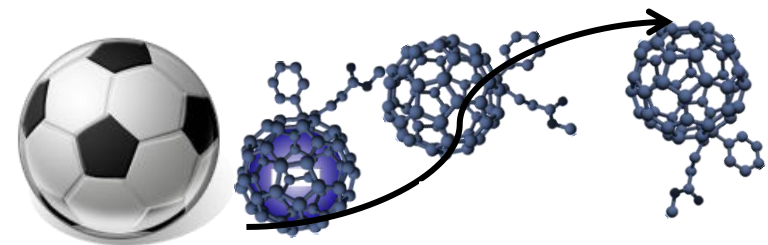
- conduct positive charges
- example: polymers



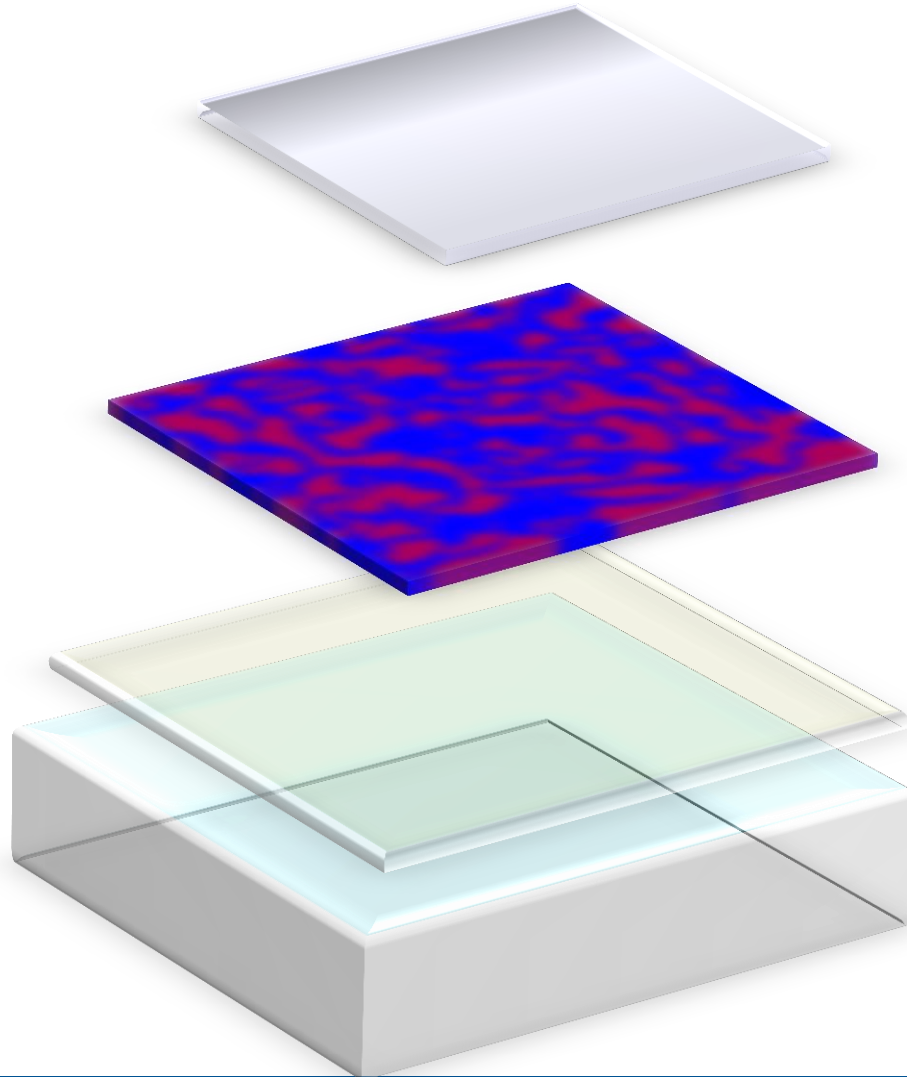
- poly(3-hexylthiophene-2,5-diyl) (**P3HT**)

**organic n-type semiconductors**

- conduct negative charges
- example: polymers, mostly fullerenes



- phenyl C<sub>61</sub> butyric acid methyl ester (**PCBM**)



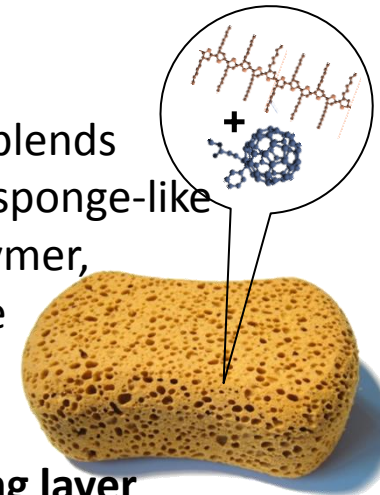
## multilayer architecture

### back contact

- aluminum, gold, silver, graphite, conducting polymers

### active layer

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



Wikipedia / Johan

### transparent conducting layer

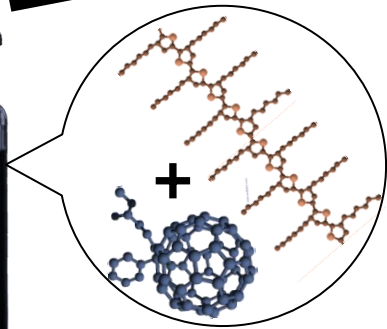
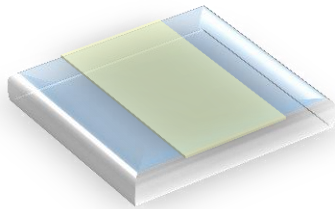
- transparent conductors (ITO, FTO), conducting polymers

### substrate

- glass, PET foils, ...

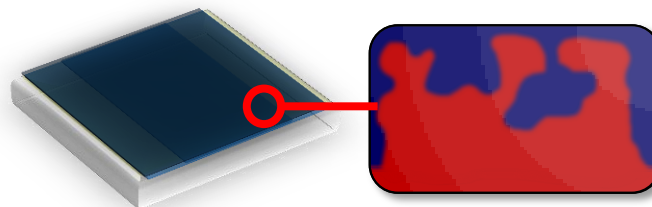
## fabrication on lab scale

substrate with transparent (ITO) electrode



polymer:fullerene blend

spin coating:  
thin film formation,  
micro phase separation

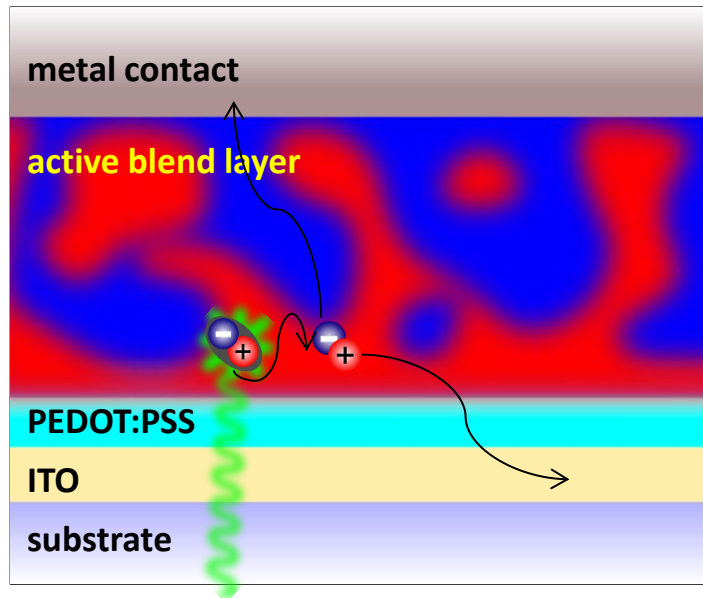



thermal evaporation of  
metal cathodes (Al)





electron donor (polymer)  
electron acceptor (fullerene)



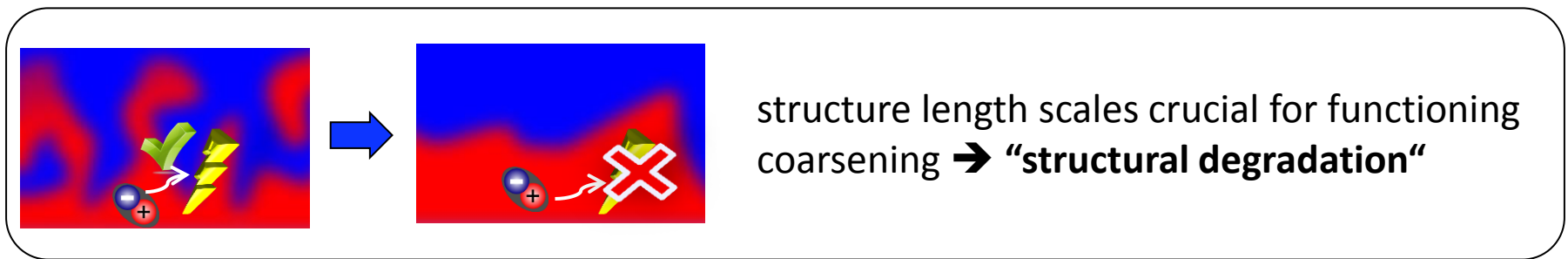
light absorption  
exciton generation 



exciton diffusion ( $l_d \sim 10$  nm)  
and splitting



charge carrier transport  
and extraction



structure length scales crucial for functioning  
coarsening → “structural degradation”



time resolved I-V  
measurements

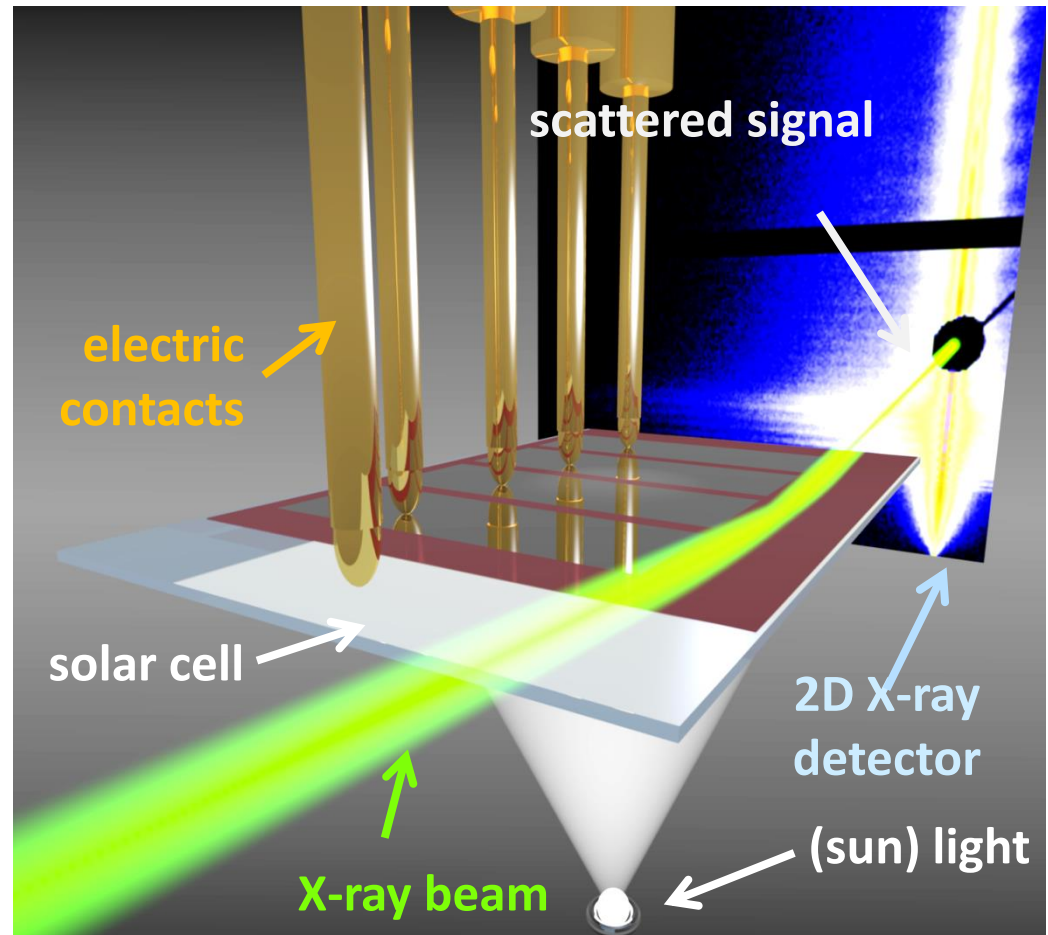
+



time resolved  
morphology probe

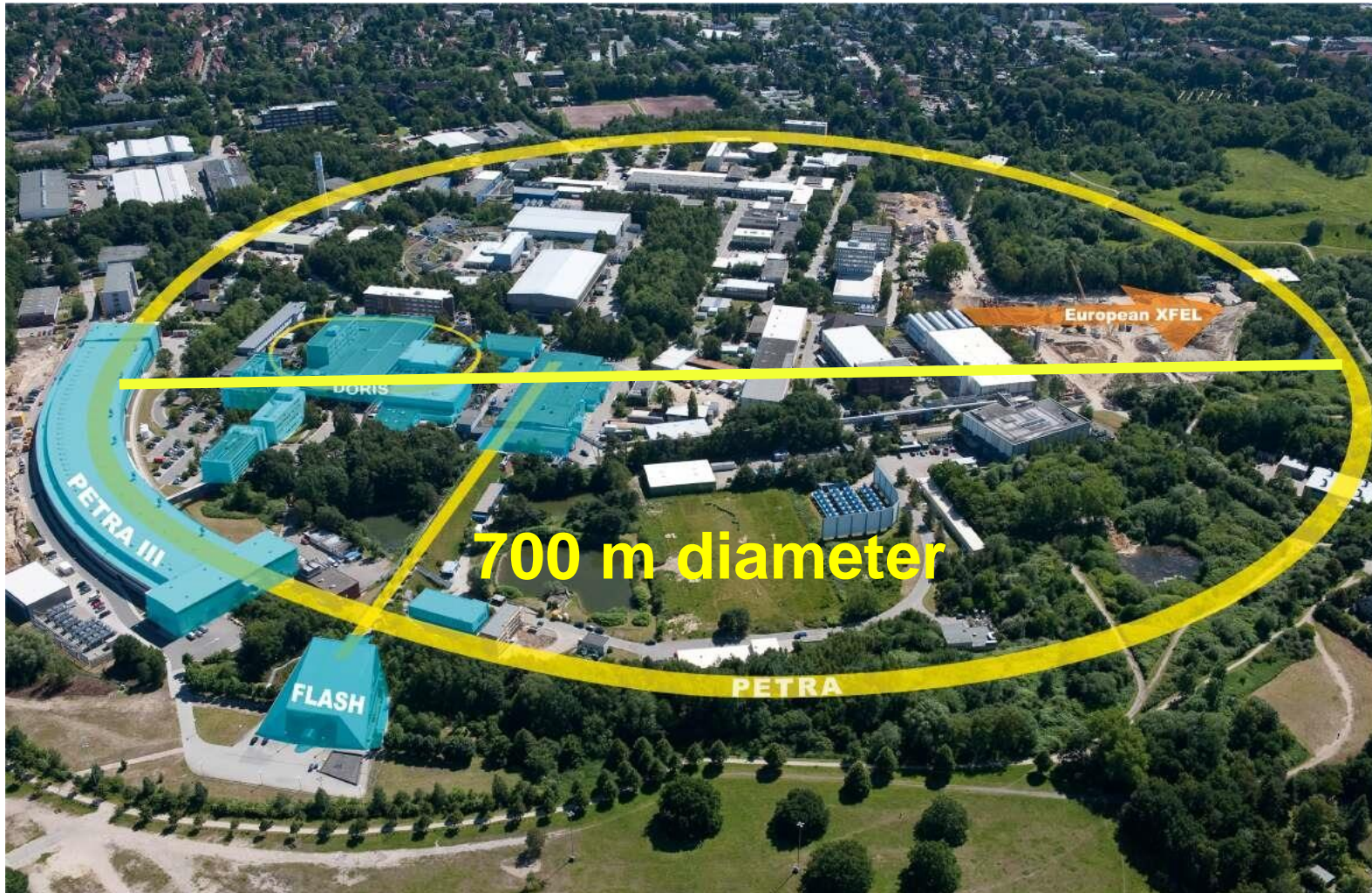


**in-situ X-ray scattering  
experiment (GISAXS)**

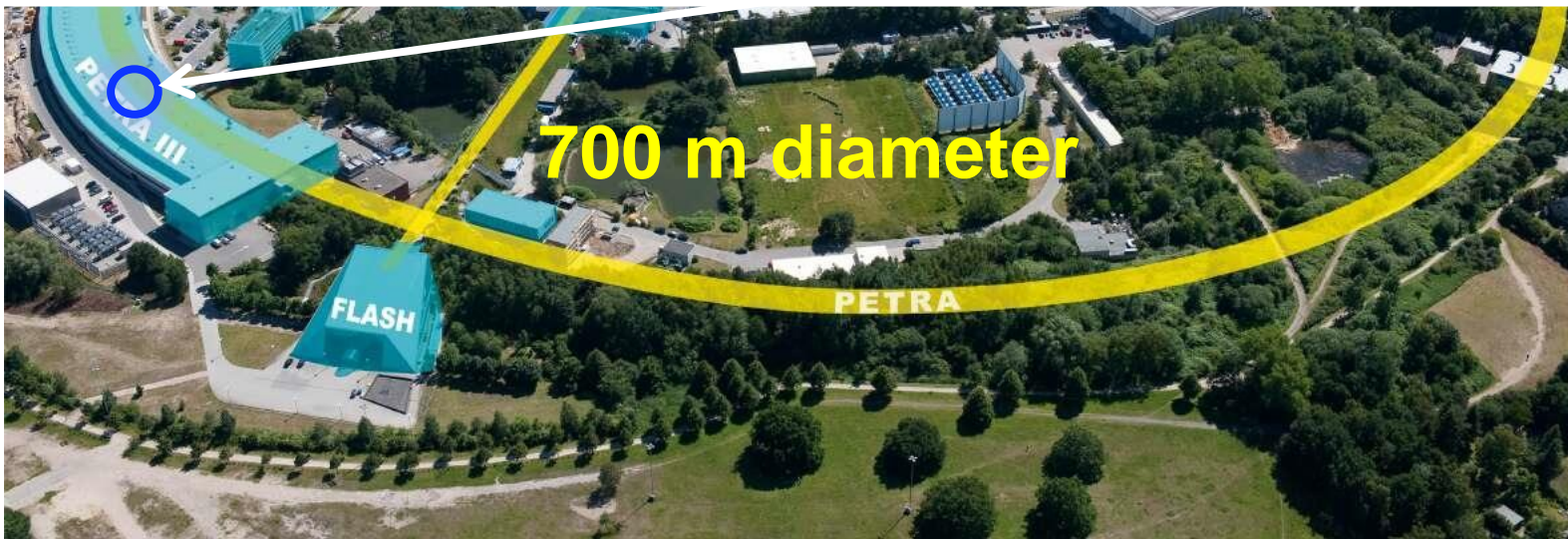
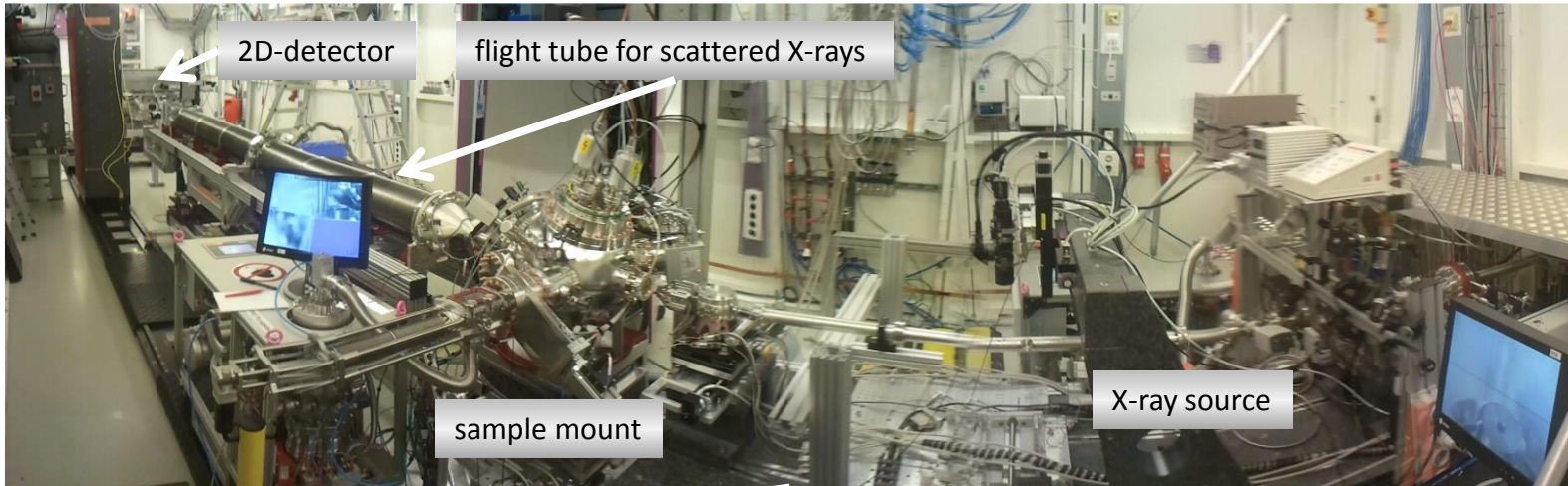


Schaffer et al., *Adv. Mater.* **2013**, 25 (46), 6760

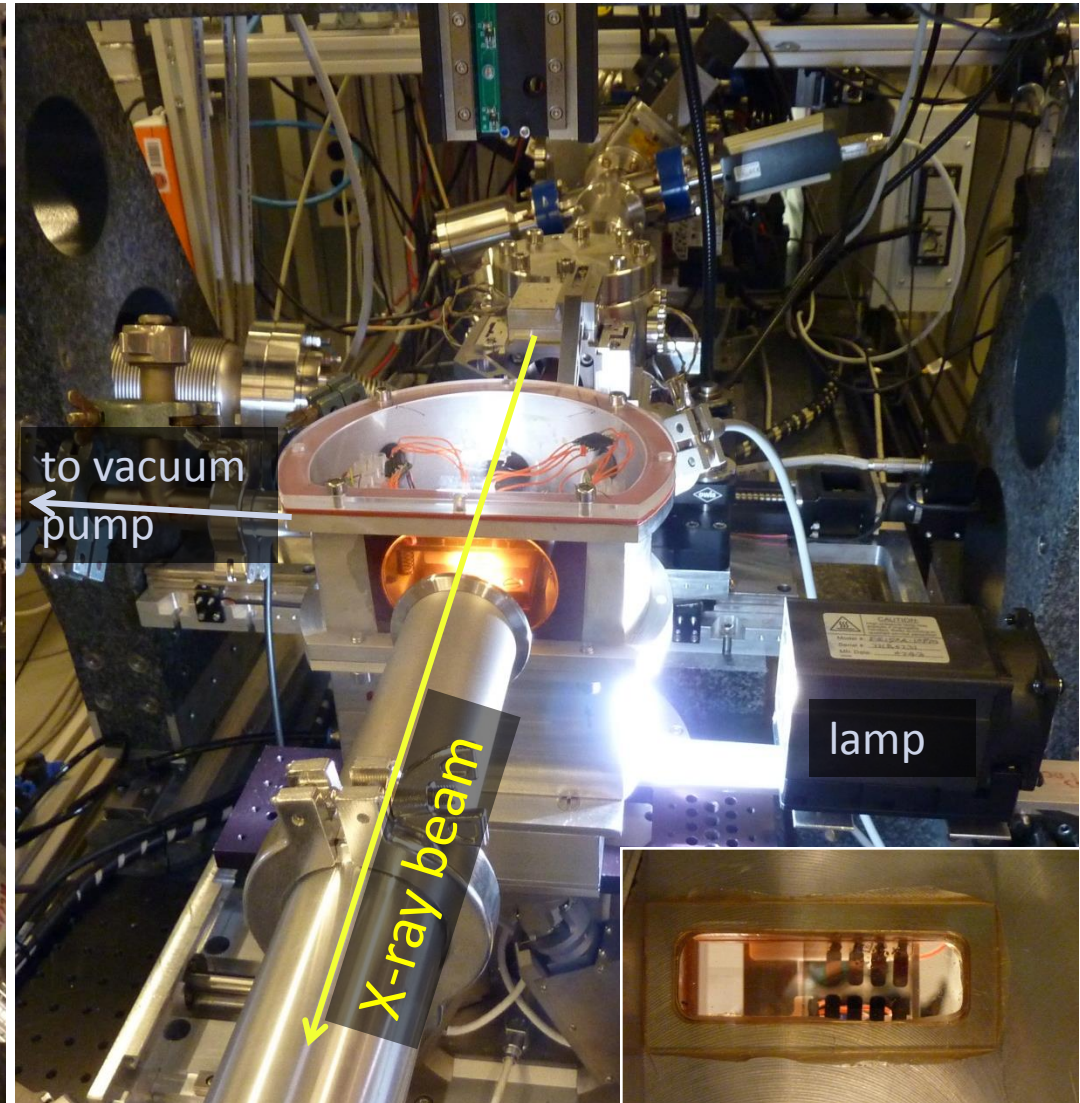
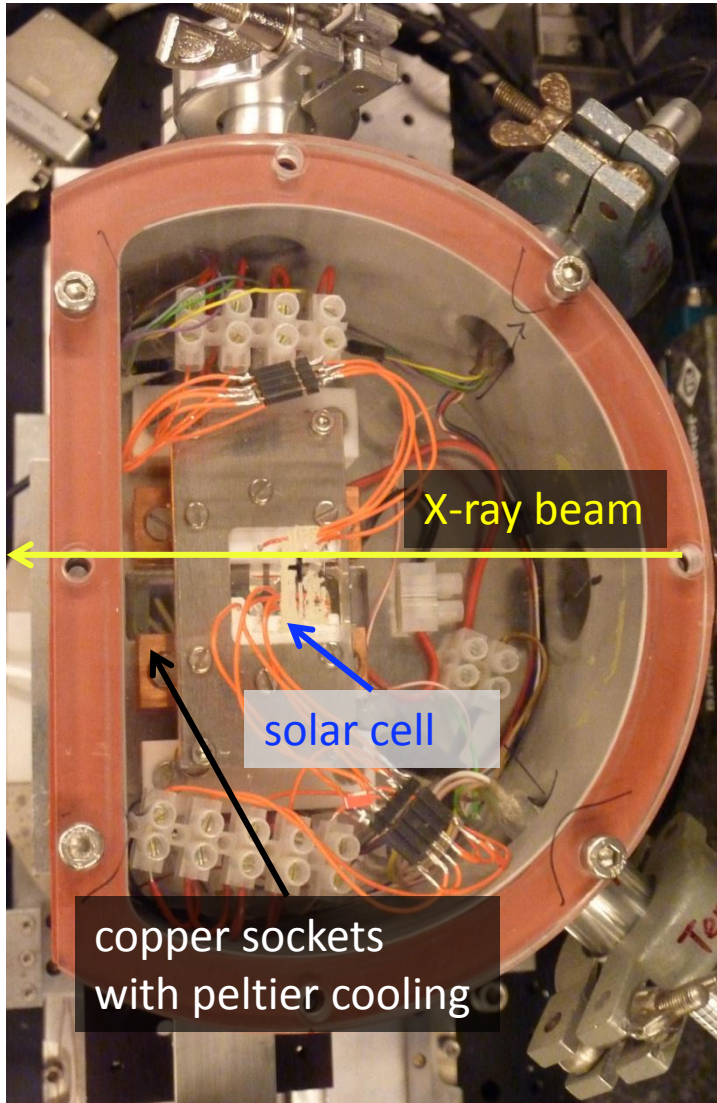
MiNaXS - Micro- and Nanofocused X-ray scattering  
beamline P03, DESY, Hamburg



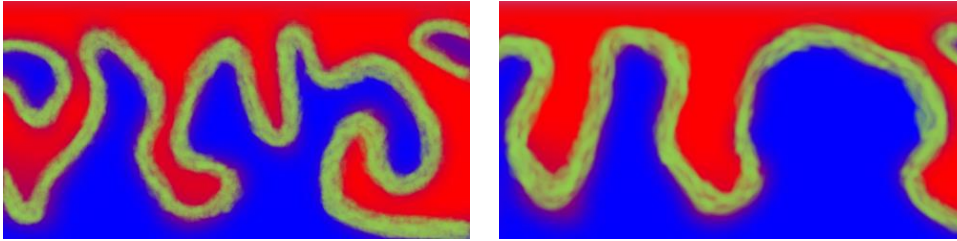
## MiNaXS - Micro- and Nanofocused X-ray scattering beamline P03, DESY, Hamburg



Special thanks to Christian Jendrzewski for taking pictures.

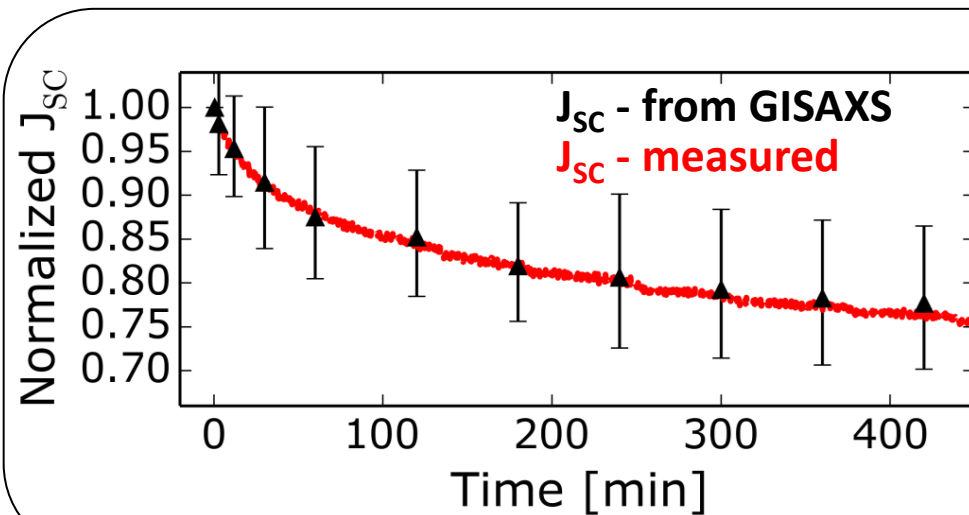


electron donor (polymer)  
electron acceptor (fullerene)



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
- 1<sup>st</sup> direct evidence for morphological degradation
- main mechanism of degradation

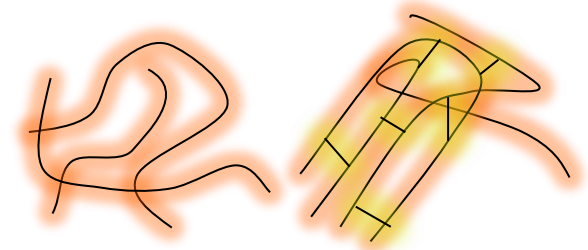
Schaffer et al., *Adv. Mater.* **2013**, 25 (46), 6760

**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



## Acknowledgements

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

