ADVANCED MATERIALS

MaterialsViews

Nanostructured Organic and Hybrid Solar Cells

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Outline

- Introduction
- Operating principle
- OPV and HSC
- Device Morphologies
- Outlook

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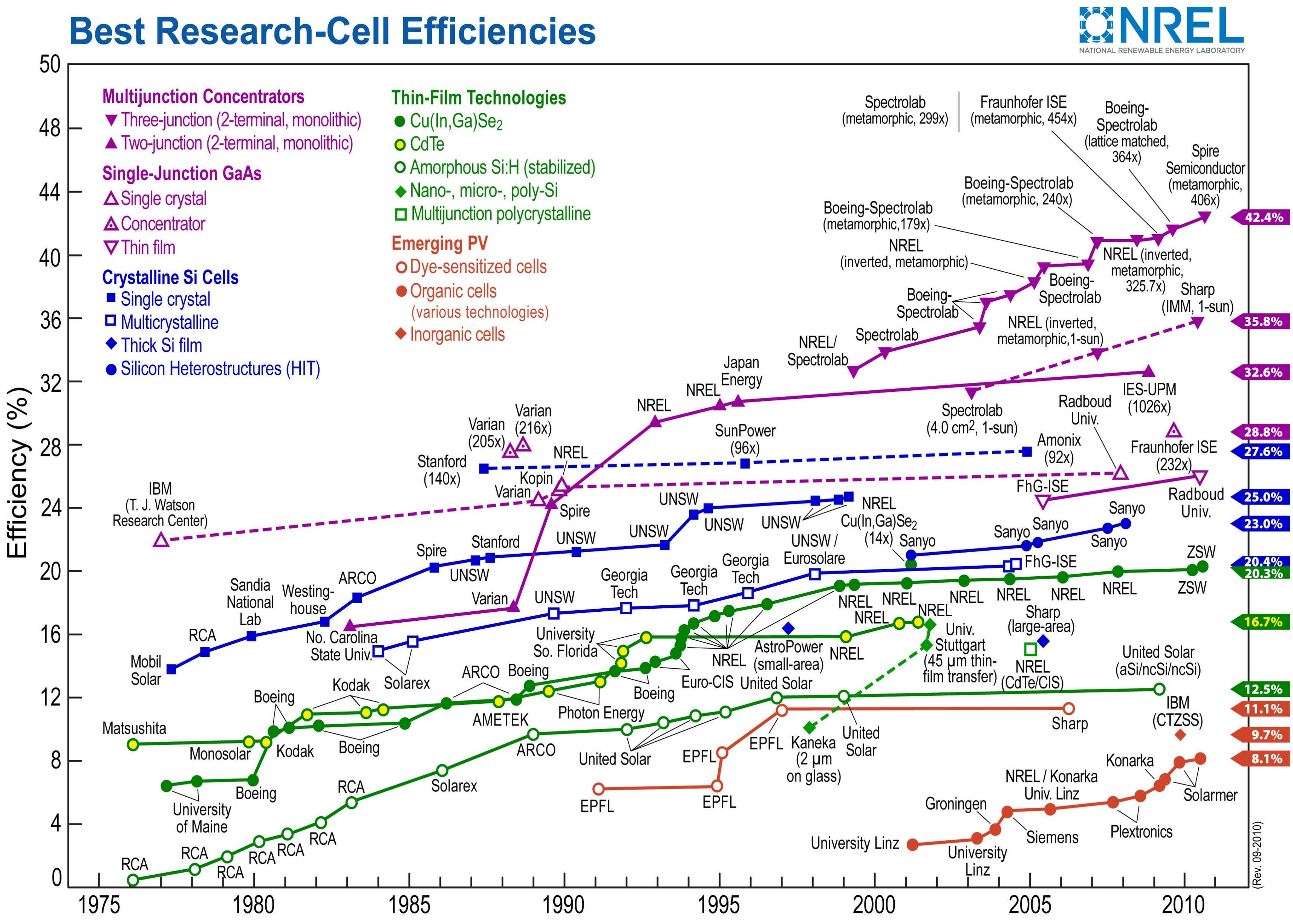
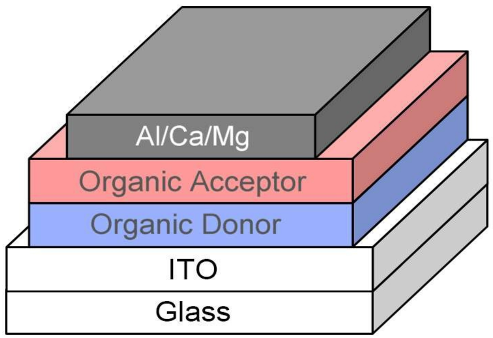
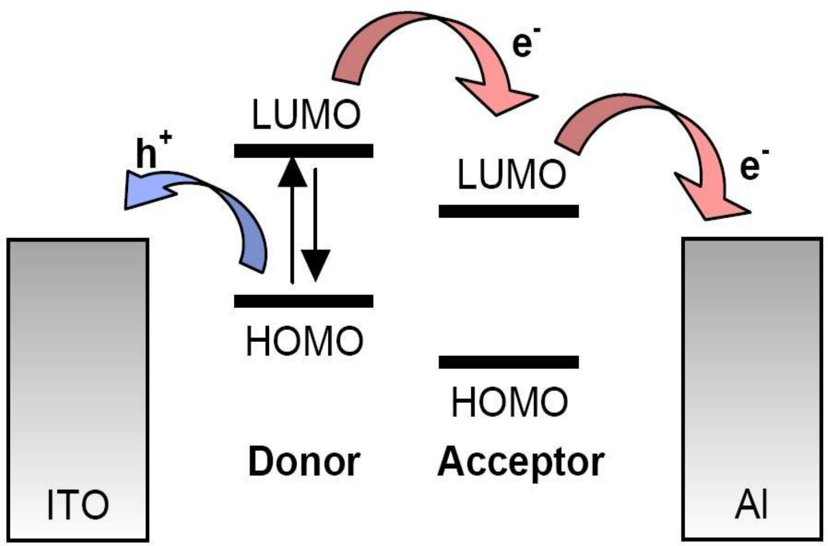
Solar Cell Efficiencies



Operating principle





- Cell absorbs light
- Electron-hole pair (exciton)
- Binding energy of exciton:

  ~ 0.5 eV
- Heterojunction with offset between HOMO und LUMO
- Charge separation
- Charge extraction by electrodes

[1] D. Lehmann. *TU Chemnitz.* Presentation **2005**,

OPVC versus HSC

- **O**rganic **P**hoto**V**oltaic **C**ell
- Organic polymers:

  - light absorption

  - charge transport
- Change absorption spectra:

  - polymer length

  - functional groups
- Flexible and low cost
- Low efficiency and stability

- **H**ybrid **S**olar **C**ell
- Organic polymers:

  - light absorption (donor)

  - hole transport
- Semiconductors:

  - acceptor

  - electron transport
- Example: DSSC

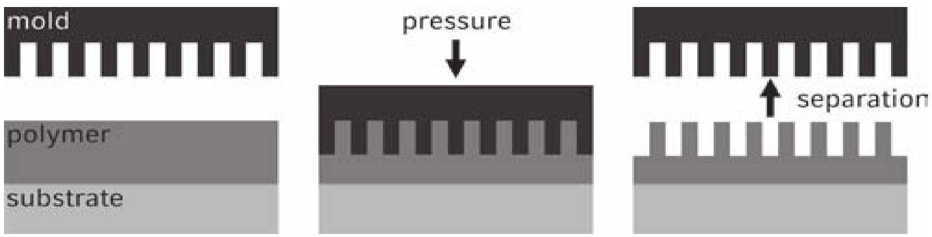
Optimal device morphology

- Domain size of donor and acceptor material should be small compared to the exciton diffusion length (~10 nm for polymers)
- Electrochemical potential drop at donor-acceptor interface must be large enough to overcome exciton binding energy (~0.5 eV)
- Exciton must split into free charges before recombination
- Electron and hole mobility must be high enough to extract charges (and they should be equal)

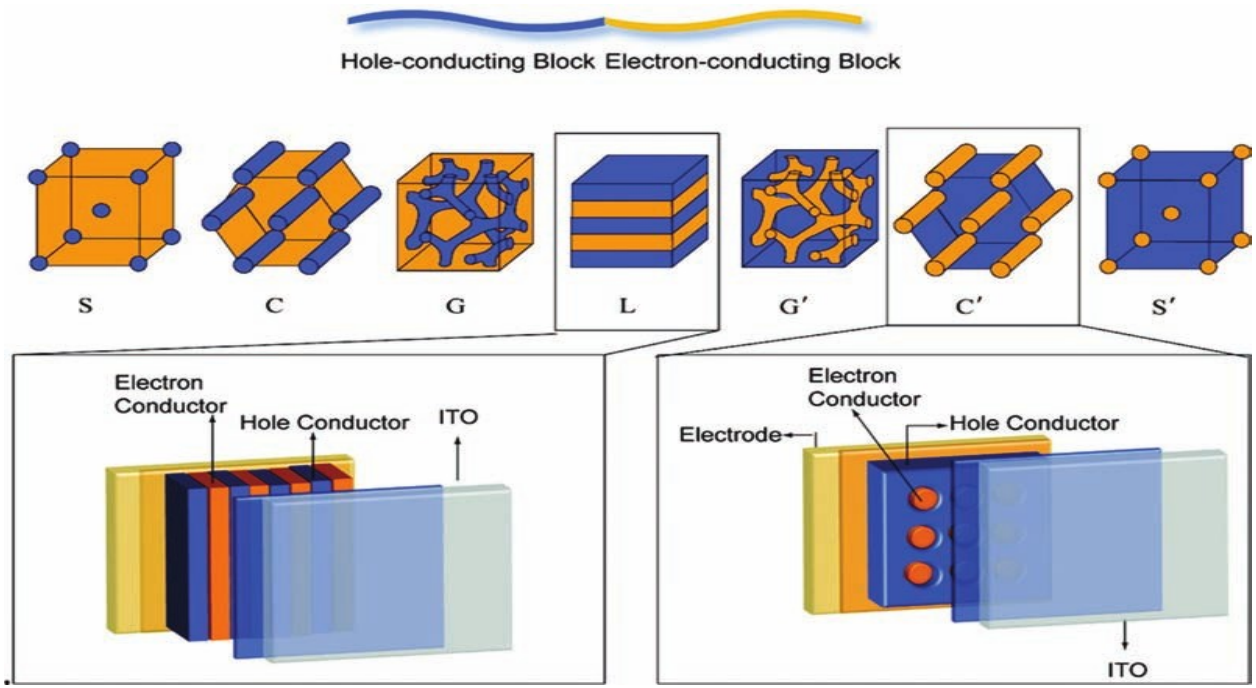
=> Minimize charge carrier recombination

=> Optimal morphology still unknown

Approaches for OPVC



- Small molecules
- Di-Block Co-Polymers
- Nanoimprint Lithography



[4] J. Björk et. al. *Physical Chemistry Chemical Physics.* **2010**, 12, 8815–8821

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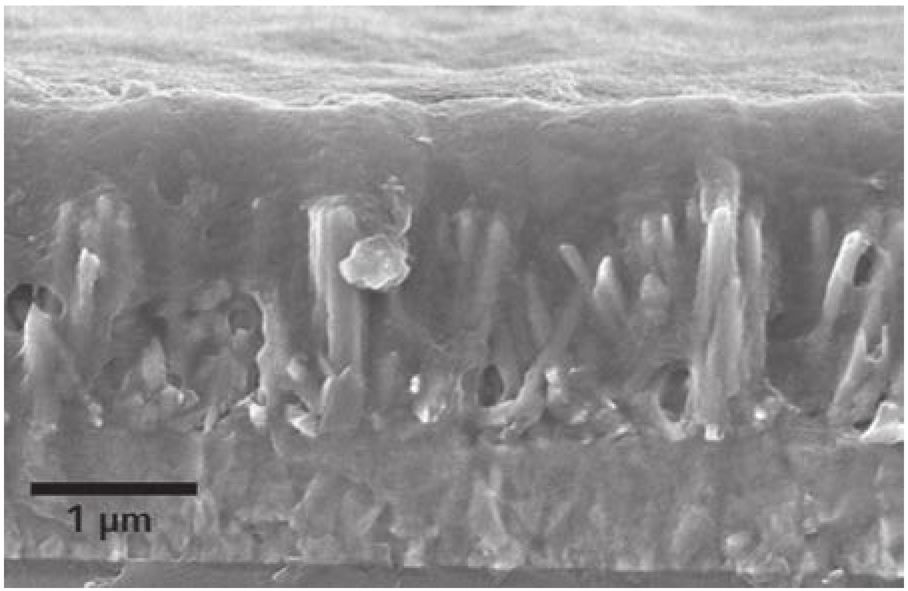
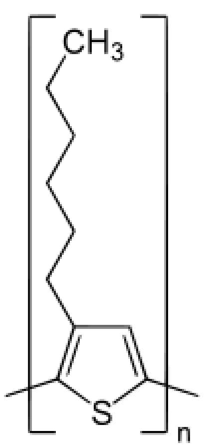
Approaches for HSC



P3HT within TiO_2 nanowires on FTO glass



Poly(3-hexylthiophen-2,5-diyl) (P3HT)

- Absorbing material: dye
- N type nanostructures:

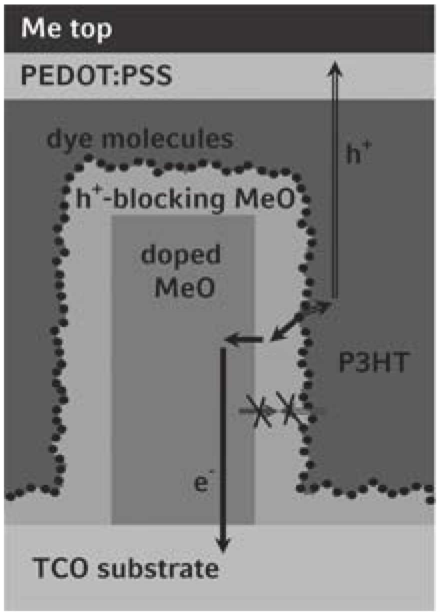
  - metal oxides: ZnO or TiO_2
- P type semiconductors:

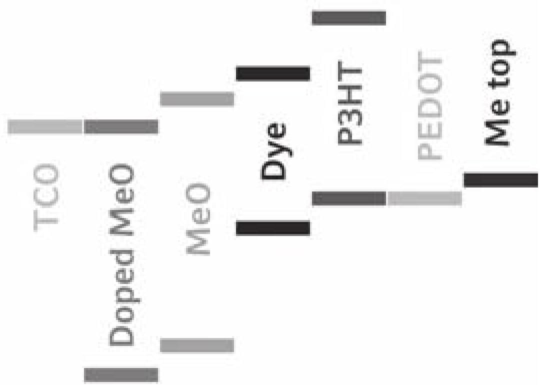
  - e.g. P3HT
- Nanowires

  - regularity and orientation
- Nanutubes

  - higher surface area

Core-shell structures





Idealized core-shell metal oxide-P3HT HSC

- High potential for HSC

  - charge transport
  - avoid recombination

- Properties

  - rutile TiO_2 nanowire
  - Transparent concuctive Oxide
  - Anastase TiO_2 for hole blocking
  - $TiCl_4$ treatment
  - Dye for absorption
  - Nanostructures ~15 nm
  - PEDOT for hole-collection
  - active layer thickness ~1 µm

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Open questions

- Exciton separation only in the direction of the external field (given by the work functions of the metal electrodes)?
- Interface design to efficiently enable charge injection but hinder charge recombination?
- Maximum size of the nanostructure to allow efficient charge transport?
- Additional effects based on the nanodimensions when getting smaller than 10 nm?
- Can efficiency be increased by light trapping approaches?

=> Defined nanostructures might give the answers!

Thank you for your attention.

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