Degradation and Stability of Organic Solar Cells

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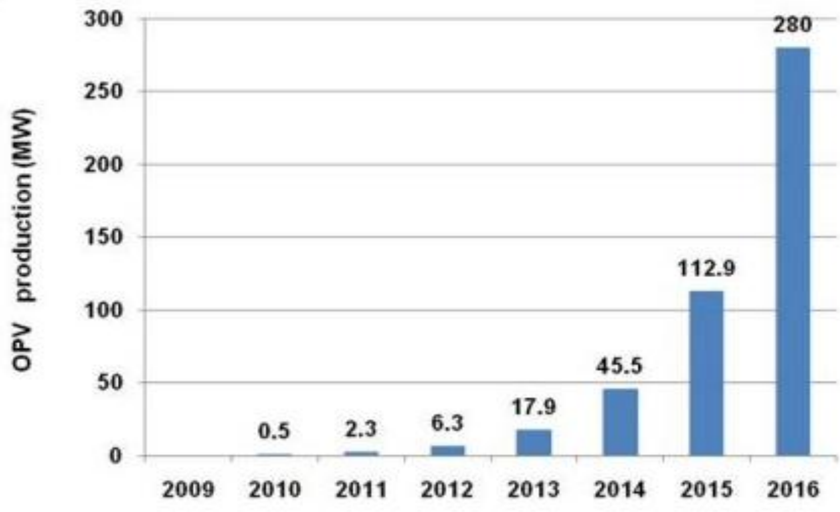
Characteristics of OPV

Advantages

- Low weight
- Flexibility and tensile resistance
- Production in large areas
- Numerous usable polymers
- Ease of production
- Recyclable
- Use of ITO-free substrates



i)

Disadvantages

- Lower efficiency: ~10% by Mitsubishi Chemical
- Affected by weathering – **UV-light**, O_2, H_2O
- Need of lamination and protection
- Low estimated life-time: ~1000-2500 h

i) www.world-of-photonics.net

Applications of OPV

Shading canopies

i)

Agricultural plastic covers

iii)

Parking shading

ii)

On fabrics

iv)

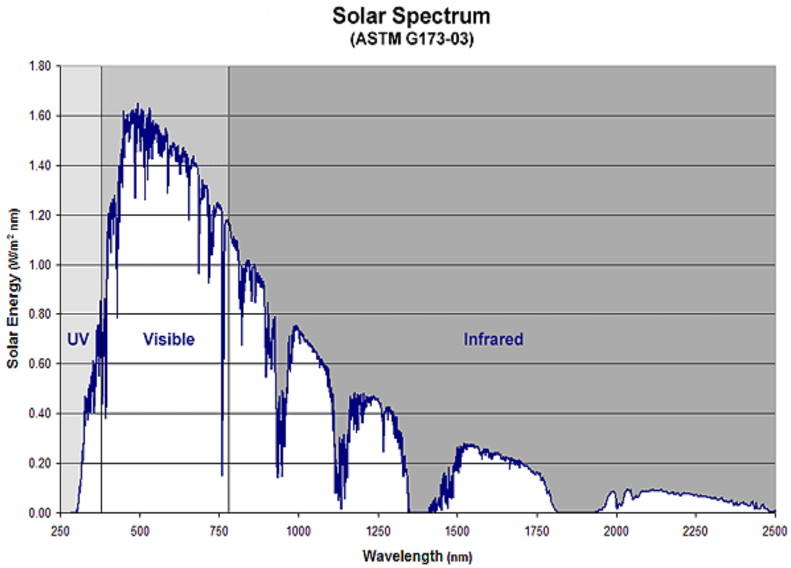
i) www.inside2outside.co.uk
ii) www.shadecomforts.com
iii) www.world-of-photonics.net
iv) www.caconcepts.co.za

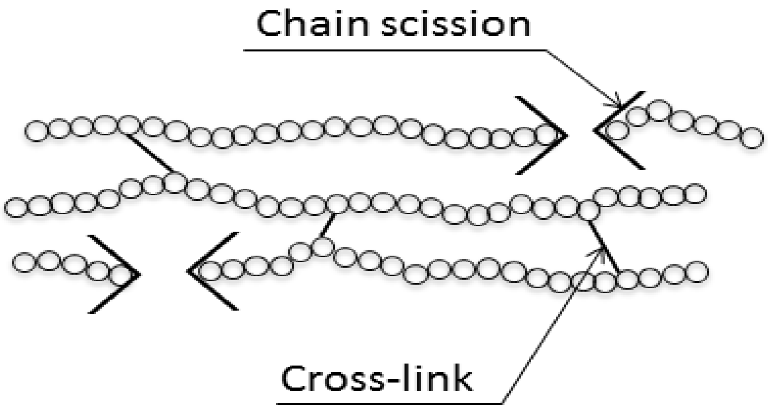
Aims

- Real life application of OPV elements
- High module efficiency: >7%
- Large-area PV elements
- Low production cost
- OPV with long-life: >20 years
- High stability against weathering
- UV degradation tests

Effects of UV-light

- High degradation by UVB-light (315-280nm)
- Accelerated degradation when combined with O_2 and H_2O ingress
- Radical formation
- Changes in polymer structure
- Degradation of active layer
- Efficiency loss
- Coloring effects of laminate
- Delamination and cracking
- Lower mechanical parameters





Degradation of active layer

- Radical formation in presence of O2 and high intensity illumination - photobleaching

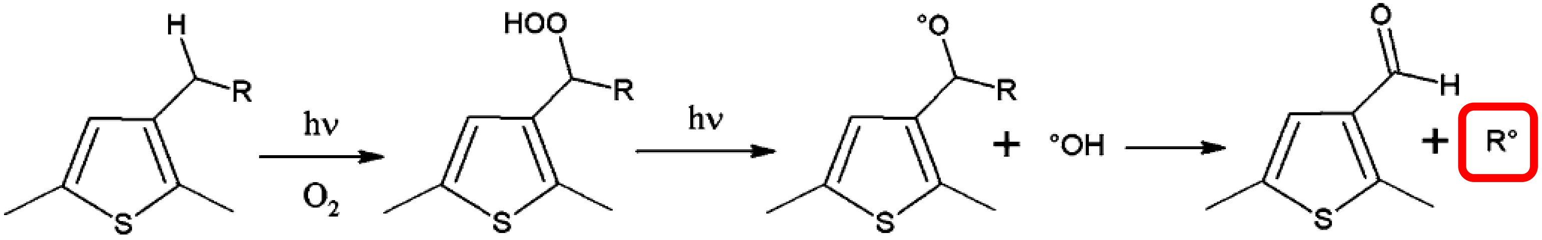


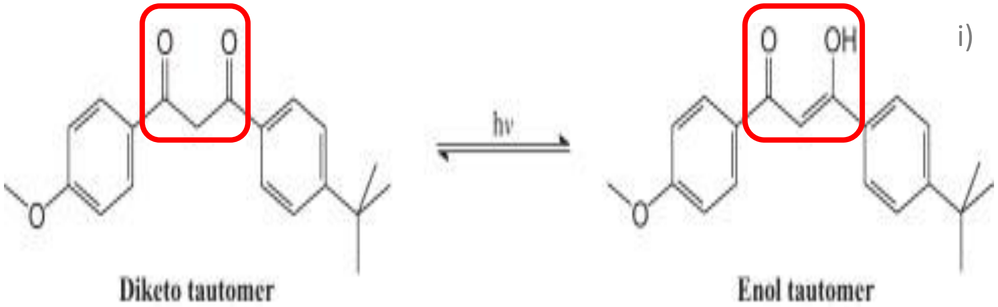
Photo-oxidation of poly-3-hexylthiophene (P3HT)

- Changes in degree of crystallinity $X = \Delta H / \Delta H^0$
- Shifts in the absorption UV-Vis spectra – lower absorption efficiency
- Changes in the FT-IR spectra due to bond and structure changes - generation of **carboxylic acid** species, formation of esters, etc.
- Arrhenius-type degradation kinetic $k = Ae^{-E_a/RT}$

UV protection of polymers

- **UV A**bsorbers (UVAs)
- **H**indered **A**mine **L**ight **S**tabilizers (HALS)
- Commercially available mixtures
- **M**ulti-**w**alled **C**arbon **N**anotubes (MWCN)

UV absorbers



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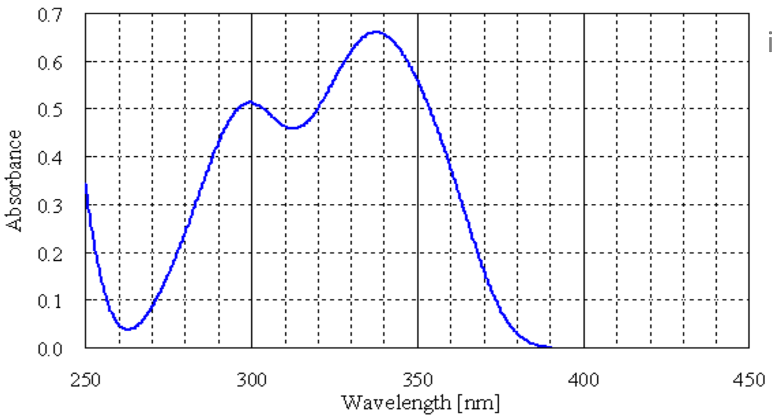
Isomeric effect of Butyl methoxy dibenzoylmethane



ii)

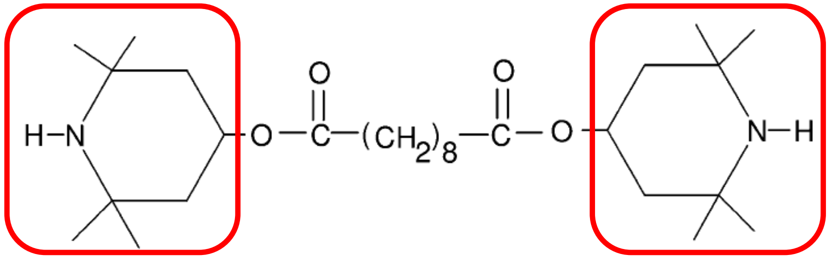
Absorption spectra of UVA

i) J. Kockler, "Photostability of sunscreens", J. Photoch. Photobiol, 13 (2012) p.91-110

ii) www.shin-nakamura.com

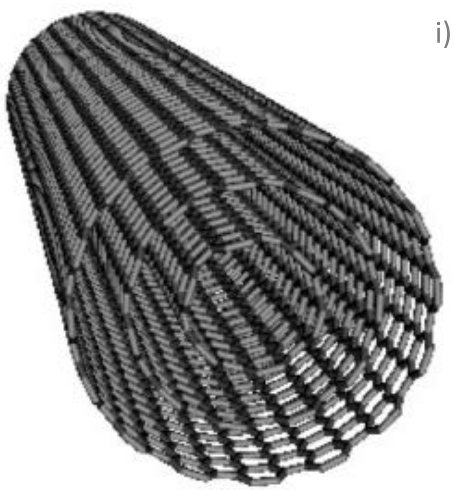
Radical scattering

Hindered amine stabilizers



2,2,6,6-tetramethylpiperidine (TMP)

Multi-walled carbon nanotubes



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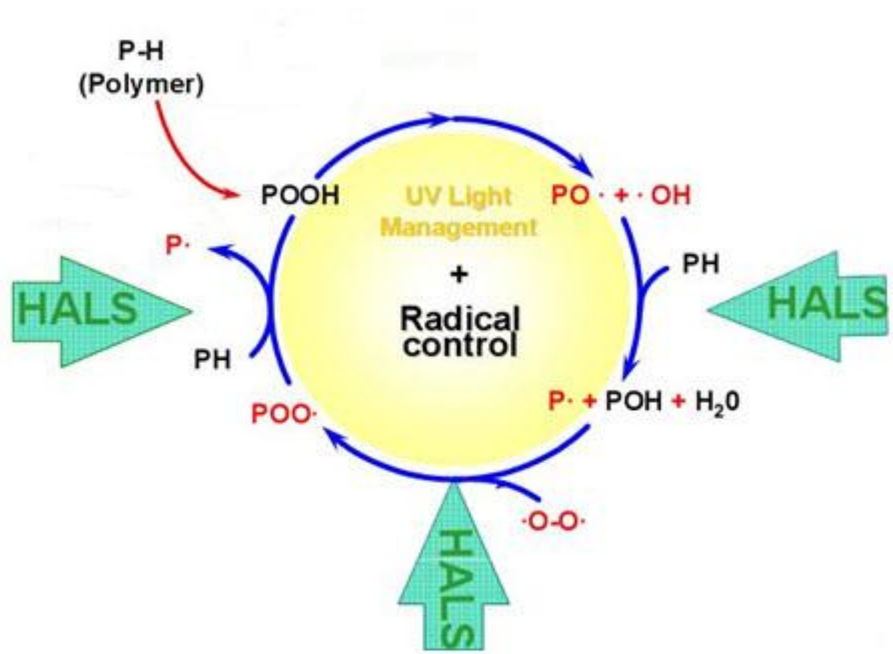
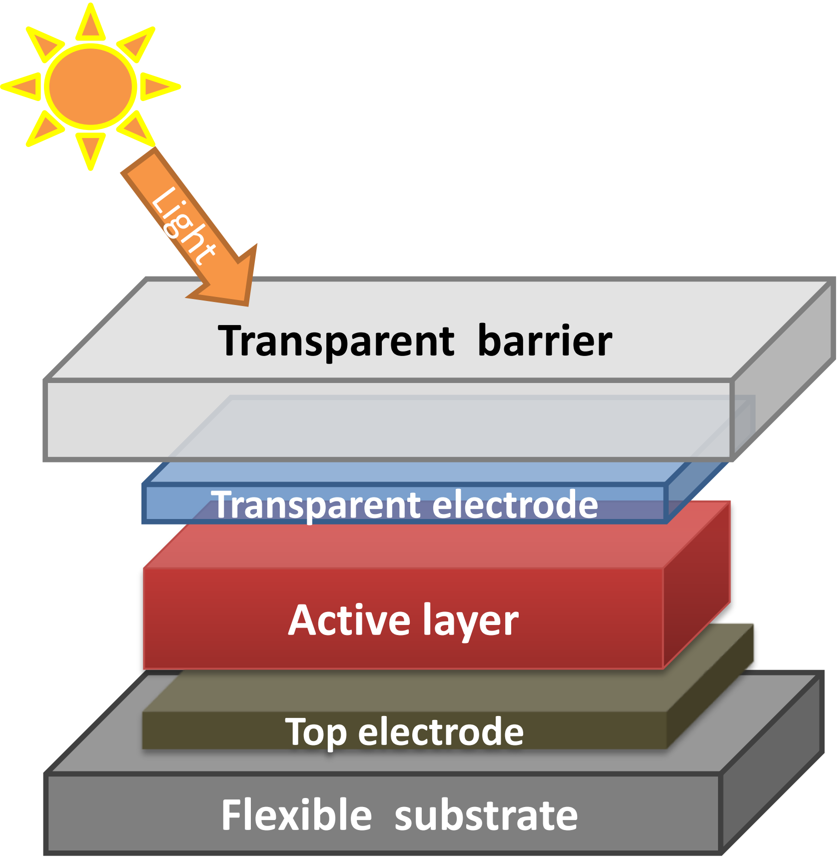
Radical deactivation



i) www-ibmc.u-strasbg.fr

Approaches for UV protection



Incorporation in barrier layers

- Suspended yellowing
- Decreased delamination of top layers
- Increase of haze
- Possible interaction with polymer

Deposition of protection layer

- Good UV protection
- No chemical reactions with polymer
- Refraction on boundary
- Need of separate production stage

Addition to active layer

- Deactivation of radicals
- No protection against yellowing
- Possible obstruction of exciton diffusion

Requirements on additives

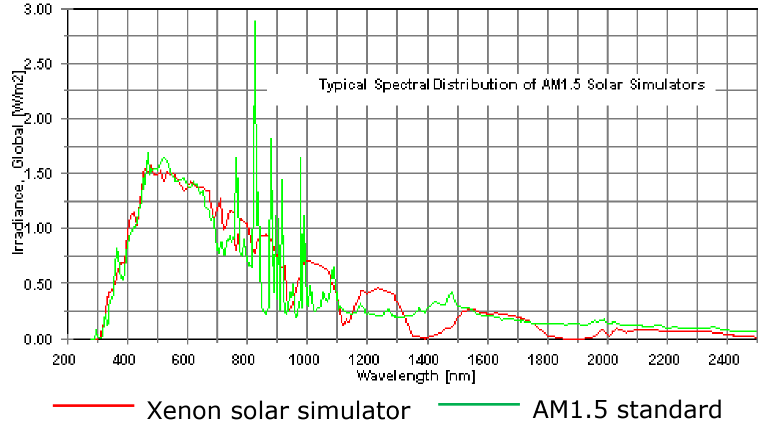
- Broad absorption spectra in UV region
- High absorption in UVB region (315-280nm)
- High efficiency in radical scattering
- Good thermal stability and miscibility
- Lack of chemical interactions with barrier polymer

  (most HALS are not applicable with fluorinated polymers)
- Long life with low efficiency loss
- Low concentration – 0,01 wt% to 2-3 wt%
- Cost consideration (~**25€/kg**- UVAs; ~**1000€/kg**- HALS and MWCN)

Weathering tests

Test requirements

- Good spectral match
- Thermal control
- Atmosphere control
- Acceleration of UV exposure
- Prolonged testing



Analytic tools

- IV-characteristics – Jsc, Voc, FF, η
- IR and UV-Vis spectroscopy
- Light transmittance
- Colorimetry – Yellowing index
- Mechanical testing
- SEM/EDX and TEM
- DTA/TGA
- Surface topology (AFM)

Summary

- Development of durable flexible OPV elements
- Low cost OPV
- Introduction of UV-light stabilizing additives in OPV
- Polymer-specific UV stabilizers
- Selection of appropriate additive concentration
- Investigation of degradation kinetics of OPV cells and modules


Thank you for the attention!
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