The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
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1938-8

Workshop on Nanoscience for Solar Energy Conversion

27 - 29 October 2008

Charge Recombination Studies in Hybrid Molecular Photovoltaic Devices

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Charge Recombination Dynamics in Molecular Photovoltaic Devices.

Dr. Emilio Palomares. ICREA Research Professor
Institute of Chemical Research of Catalonia (ICIQ).
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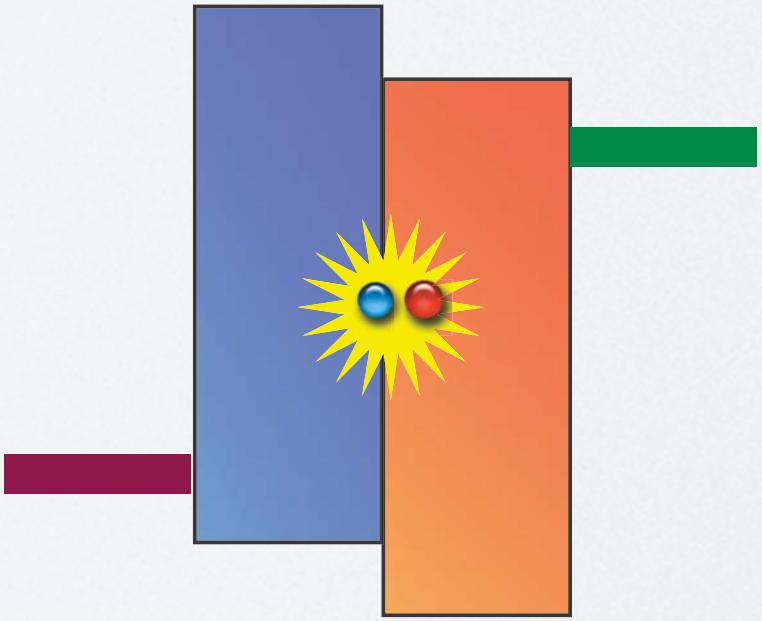
Photons in....Electrons Out

- Always Different Interfaces



Molecular Solar Cells

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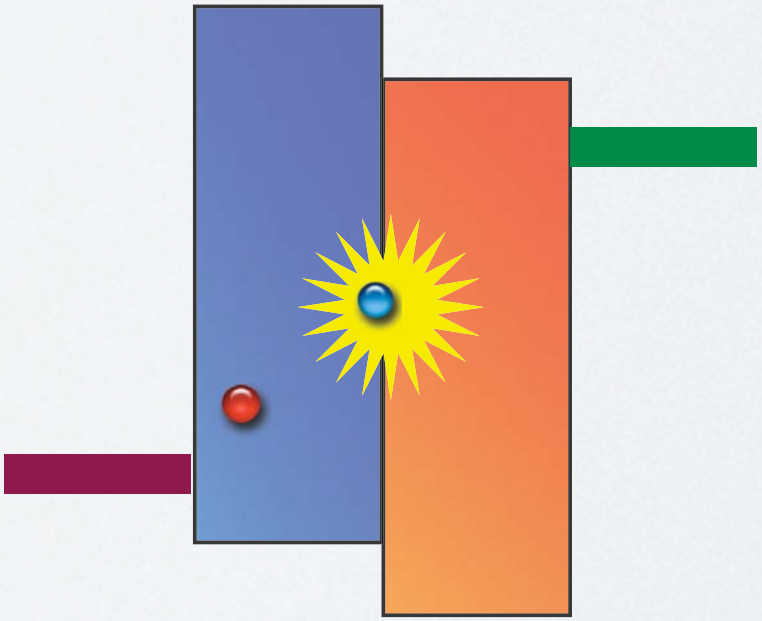

Molecular Solar Cells

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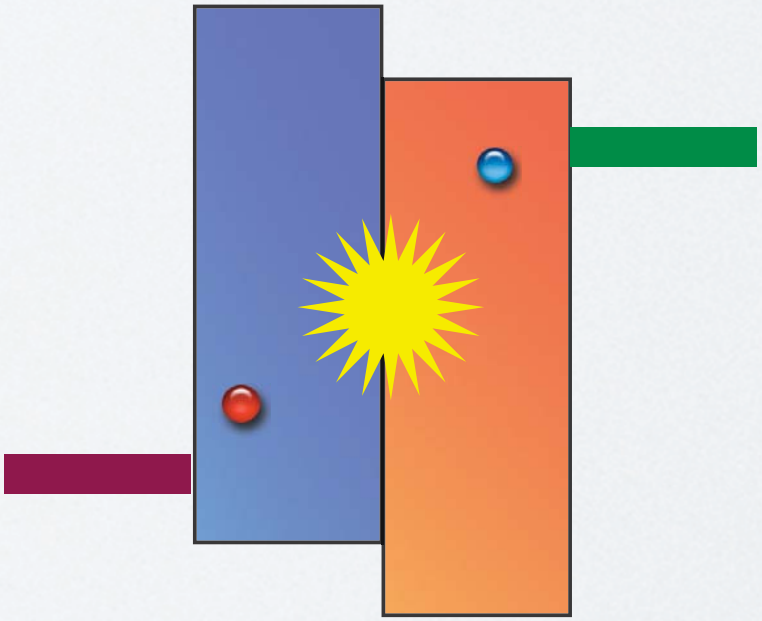

Molecular Solar Cells

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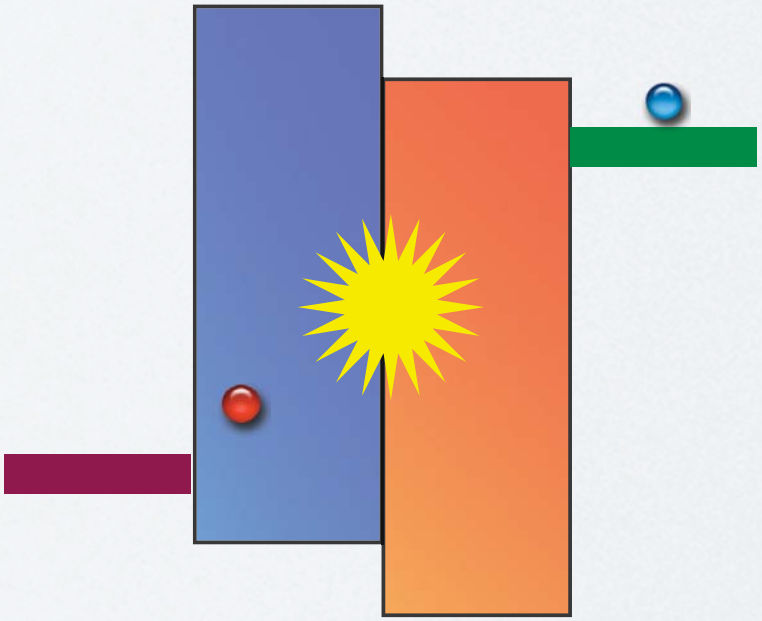

Molecular Solar Cells

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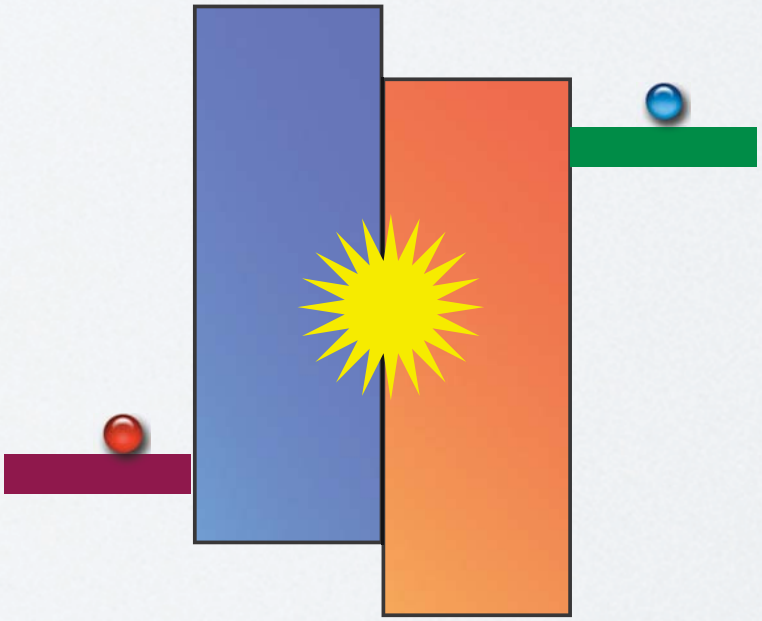
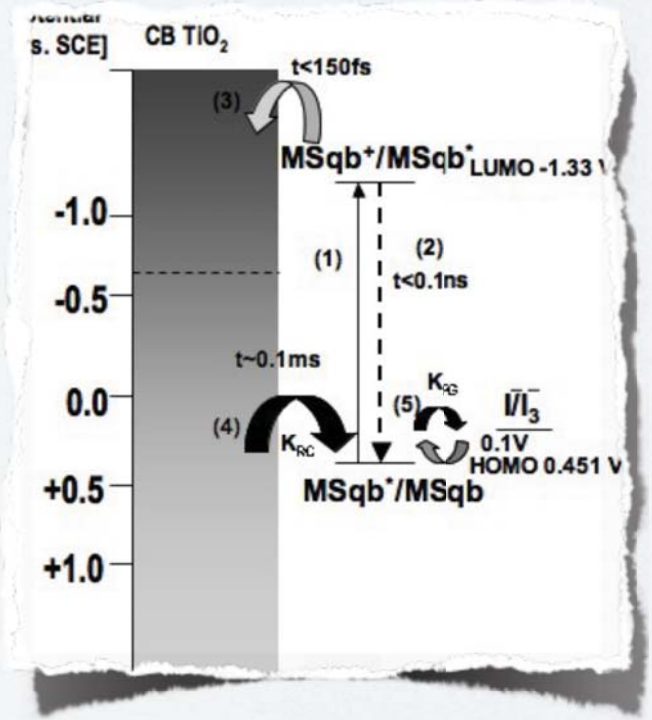


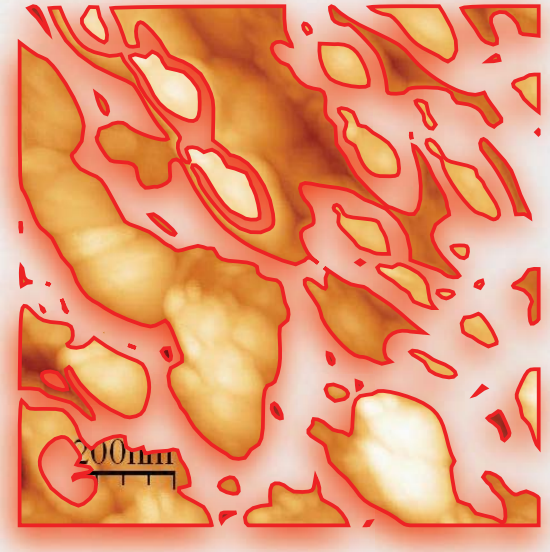
Molecular Solar Cells

Different Photovoltaic Devices

- Two different approaches



Dye Sensitised Solar Cells



"Blend" Solar Cells

Charge Transfer Processes

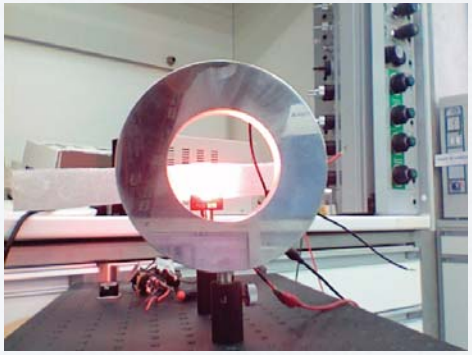
L-TAS

- E_{TIO_2}/ DYE Injection
- E_{TIO_2}/ DYE^+ RECOMBINATION

TCSPC

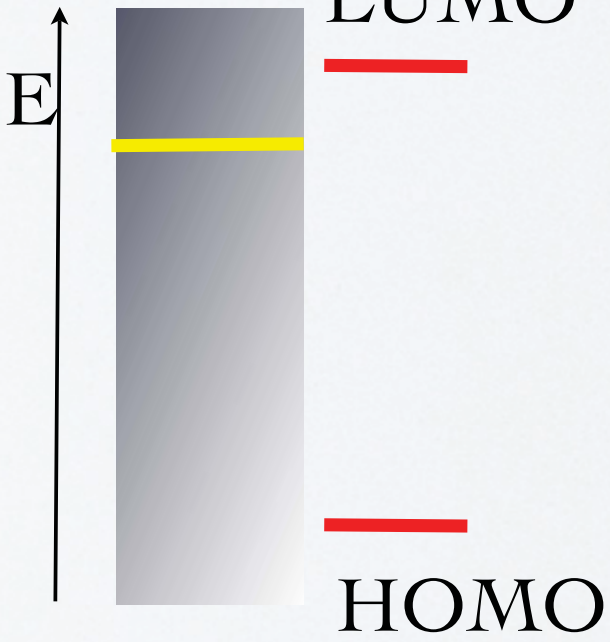
- E_{TIO_2}/ HTM RECOMBINATION

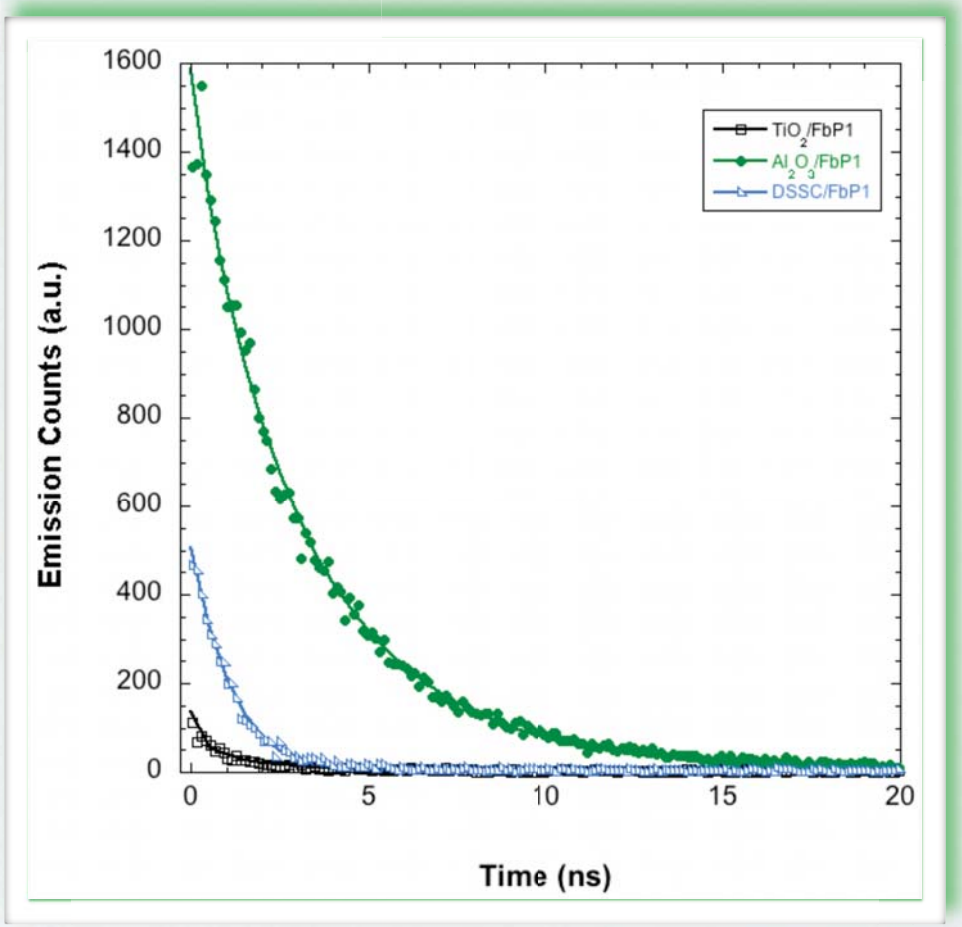
TPV



- HTM/ DYE^+ Regeneration

Charge Transfer Processes





E_{TIO_2}/ DYE^+ injection

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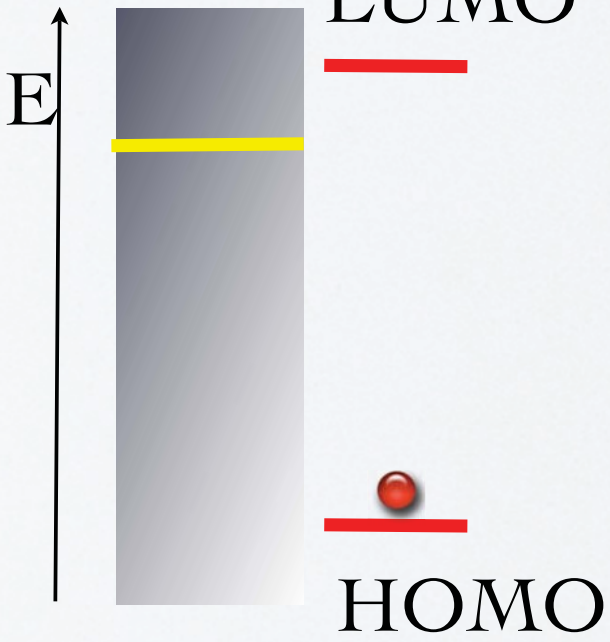

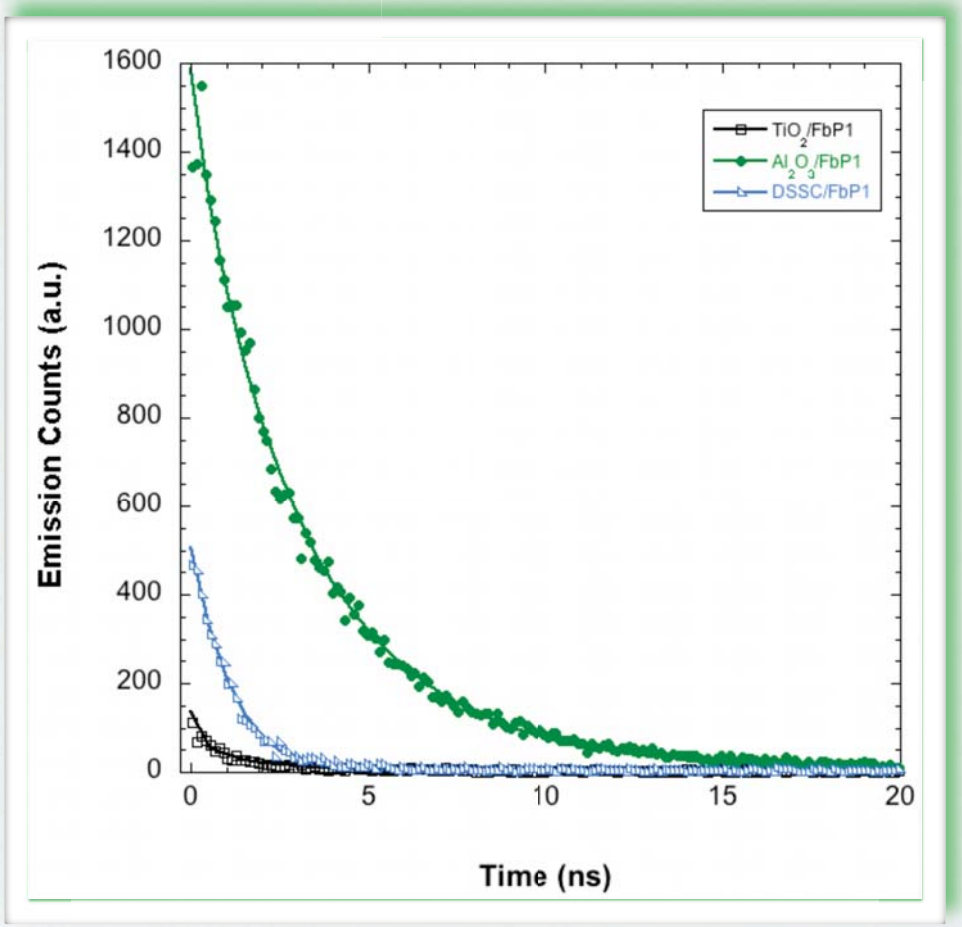

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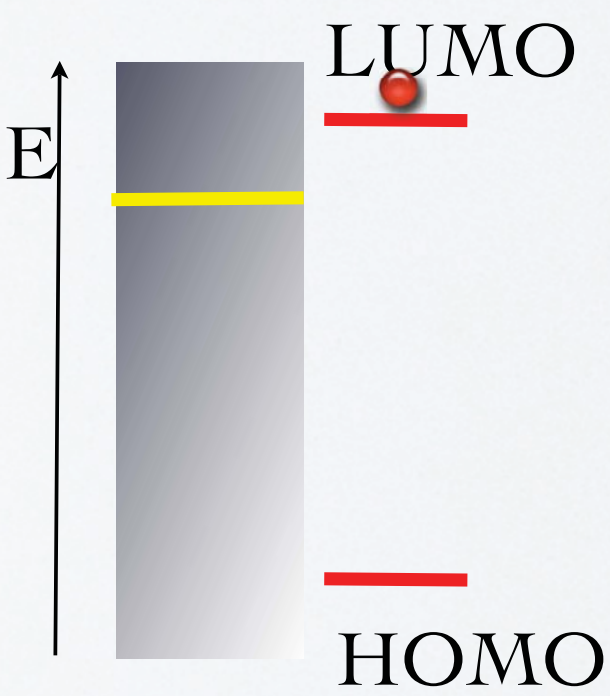

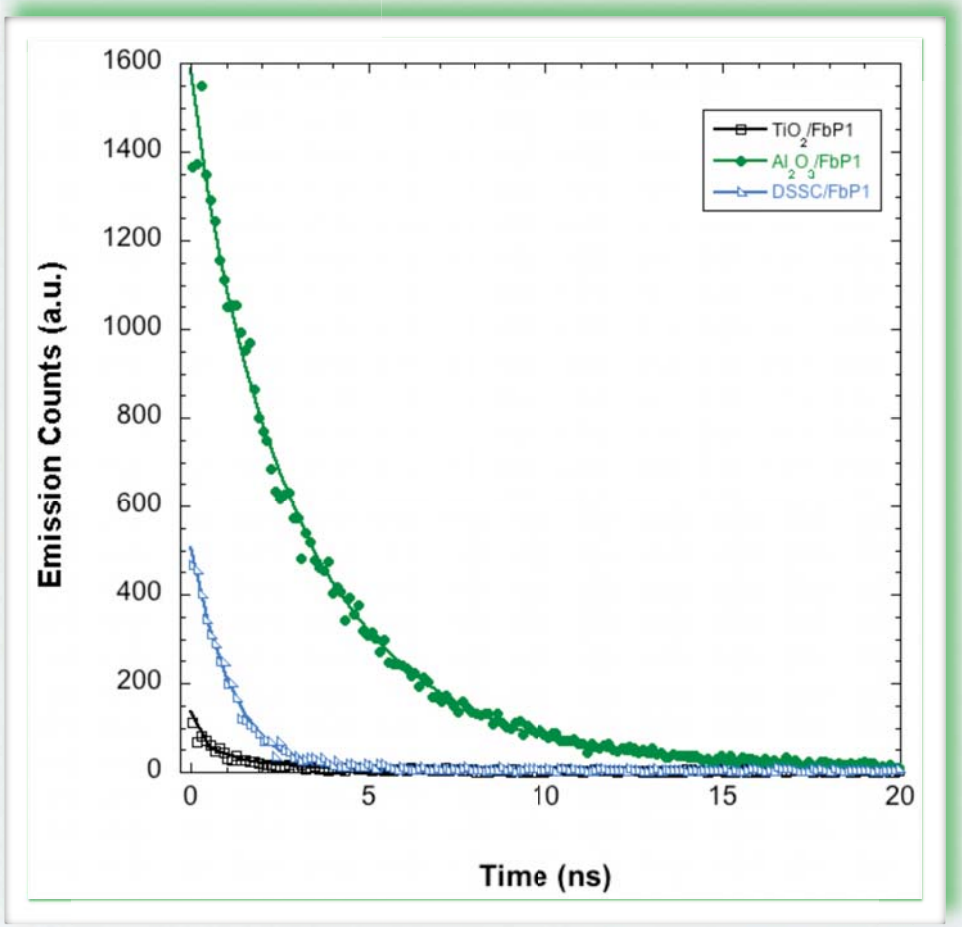

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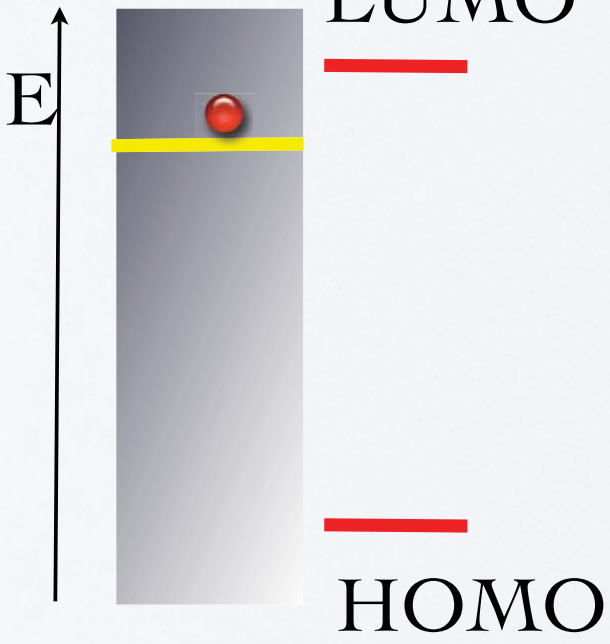

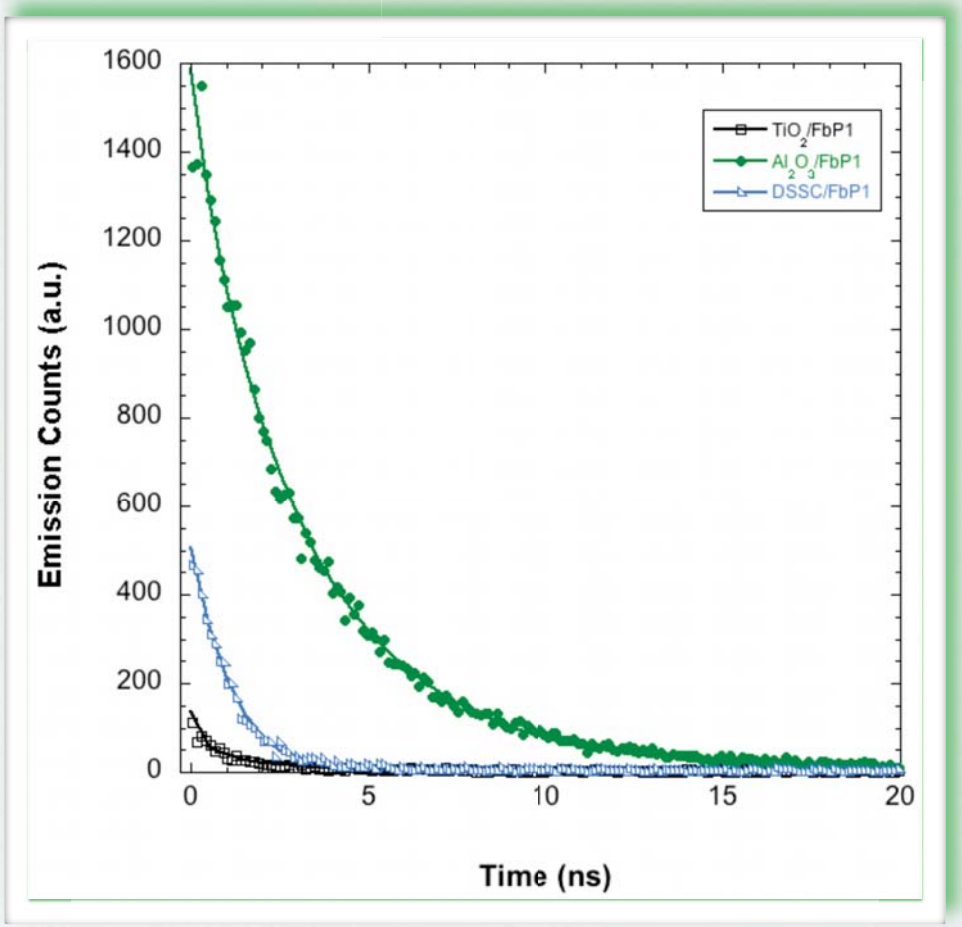

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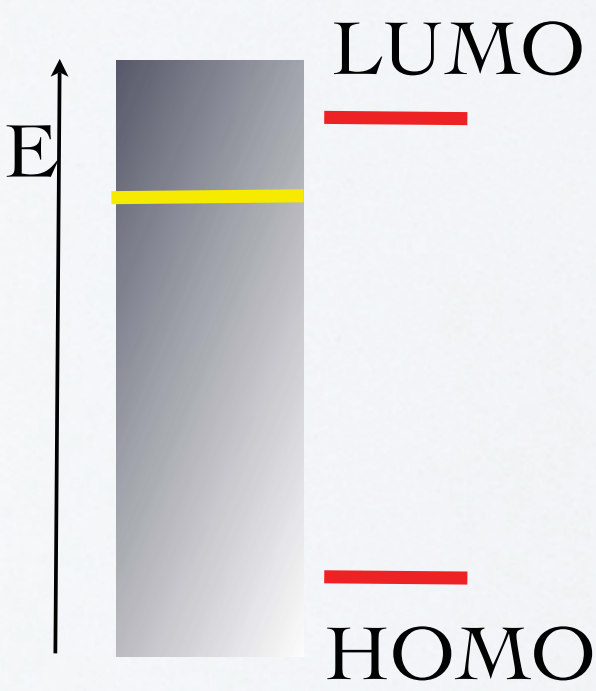
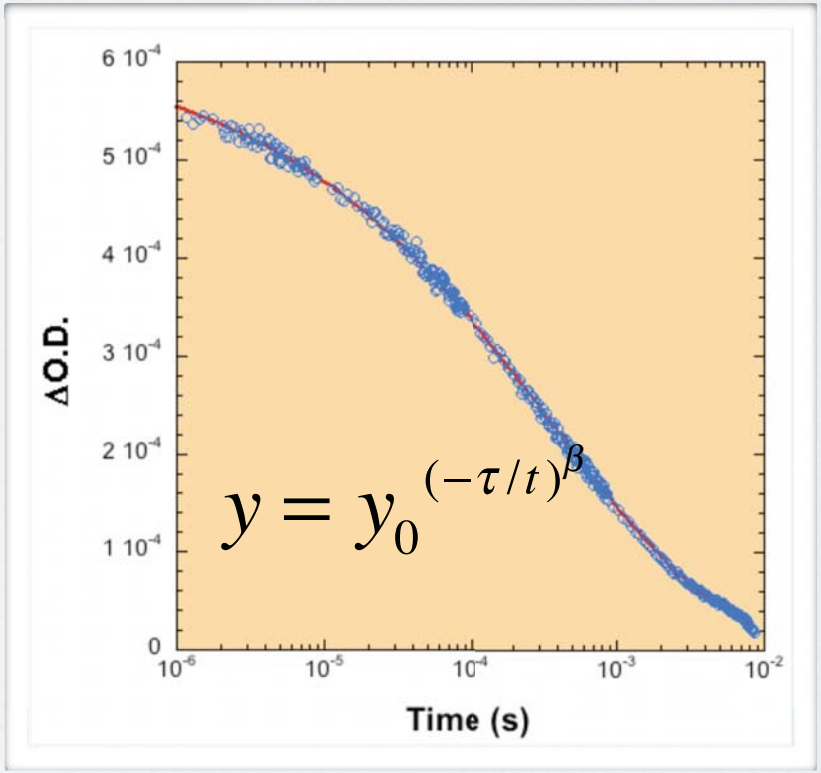
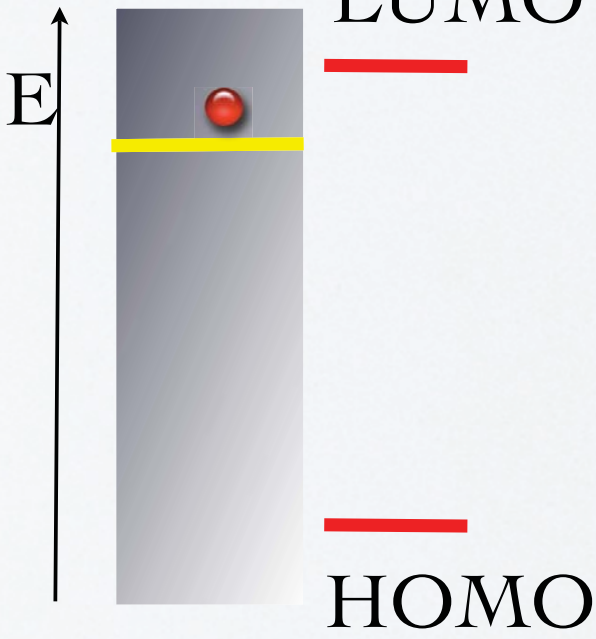


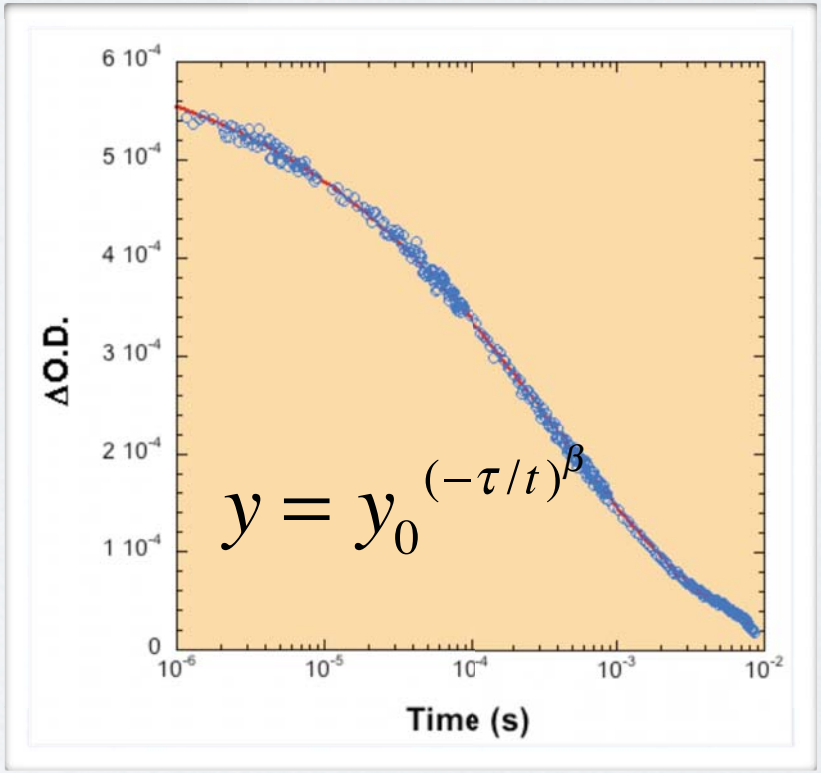


Fitting to KWW function

E_{TIO_2}/ DYE^+ recombination

Charge Transfer Processes





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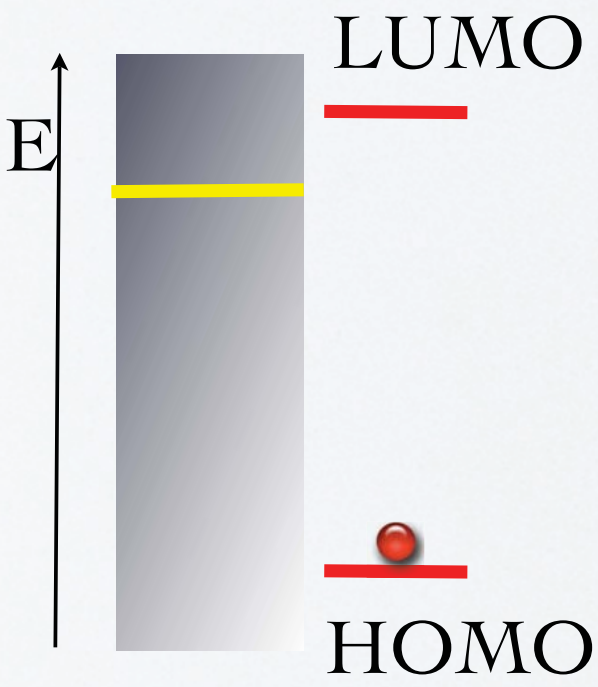

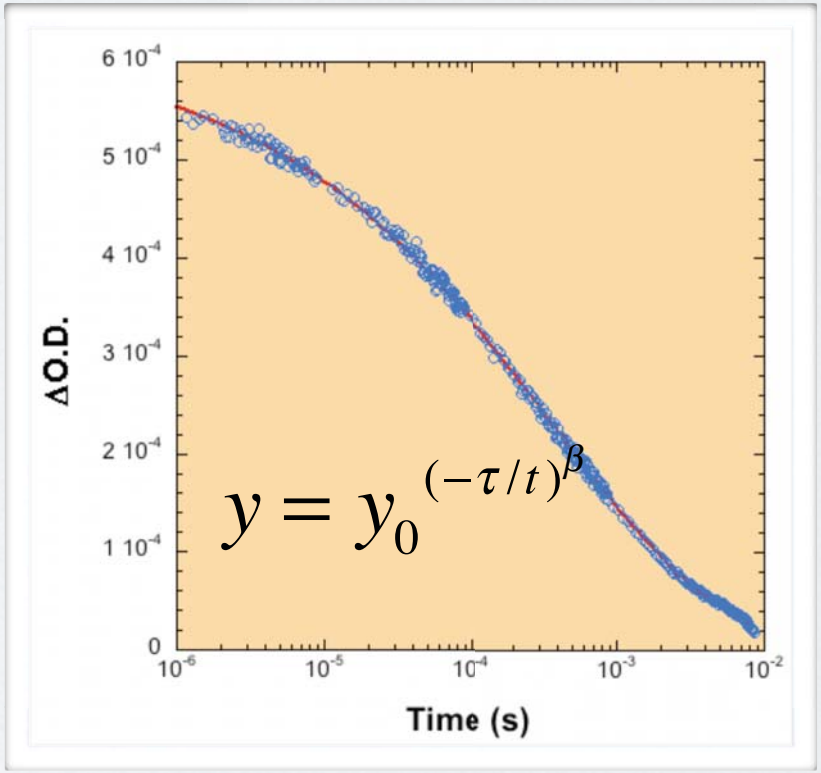

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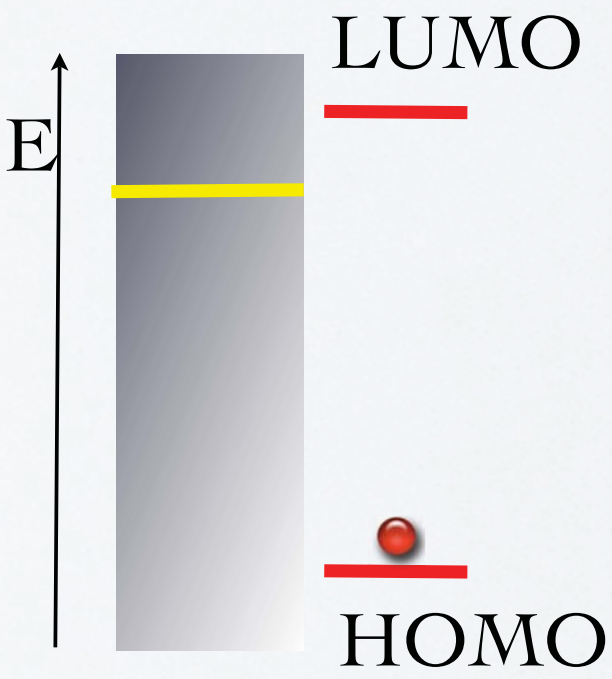

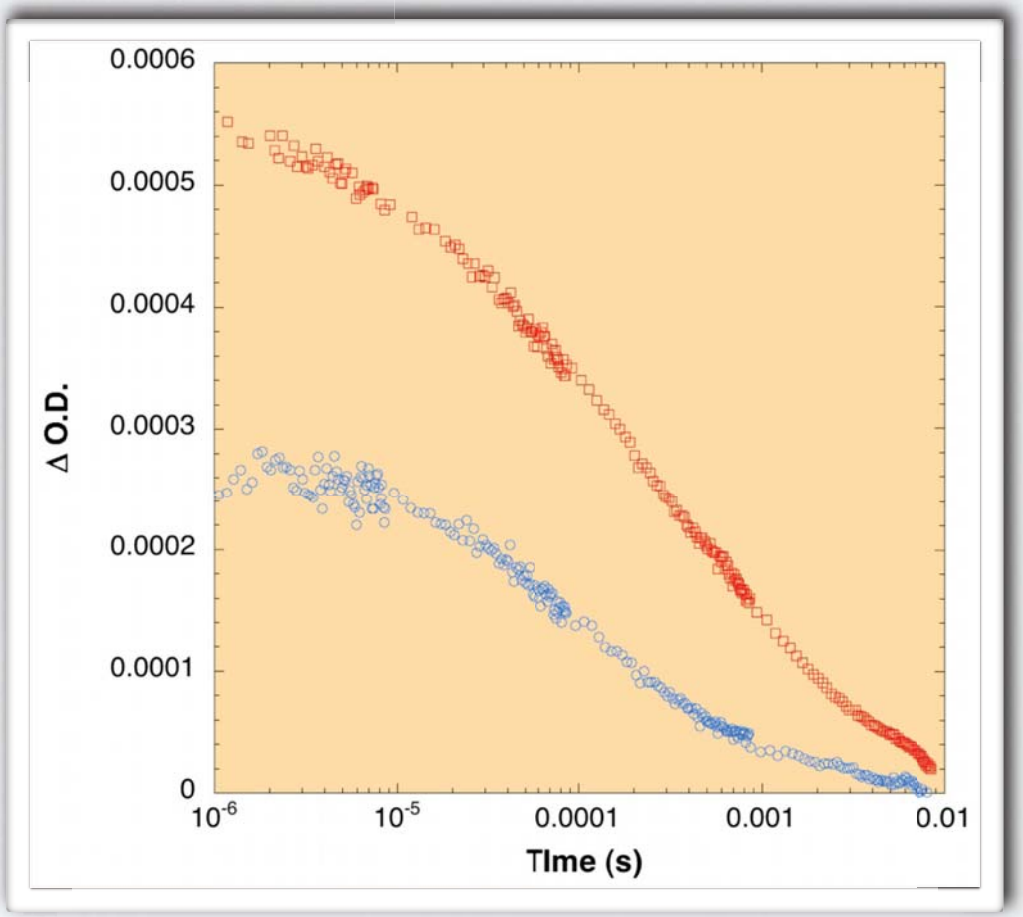

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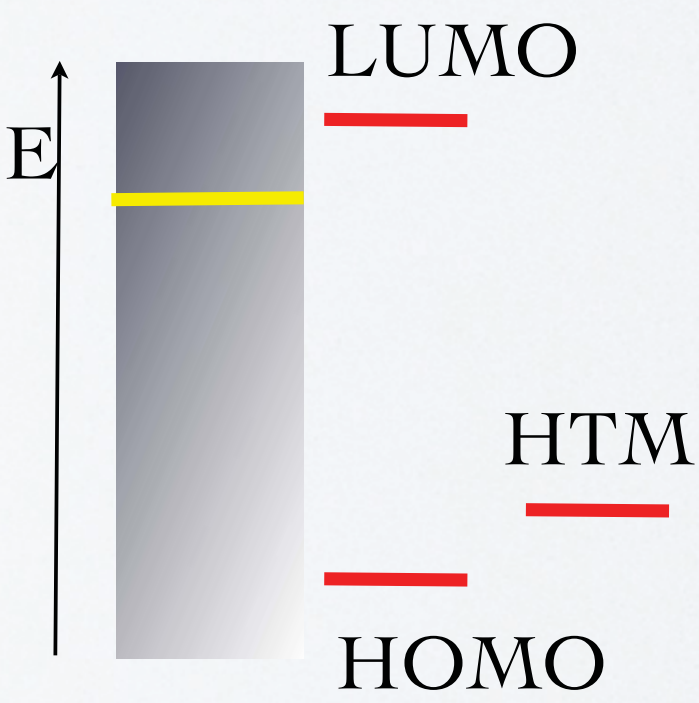

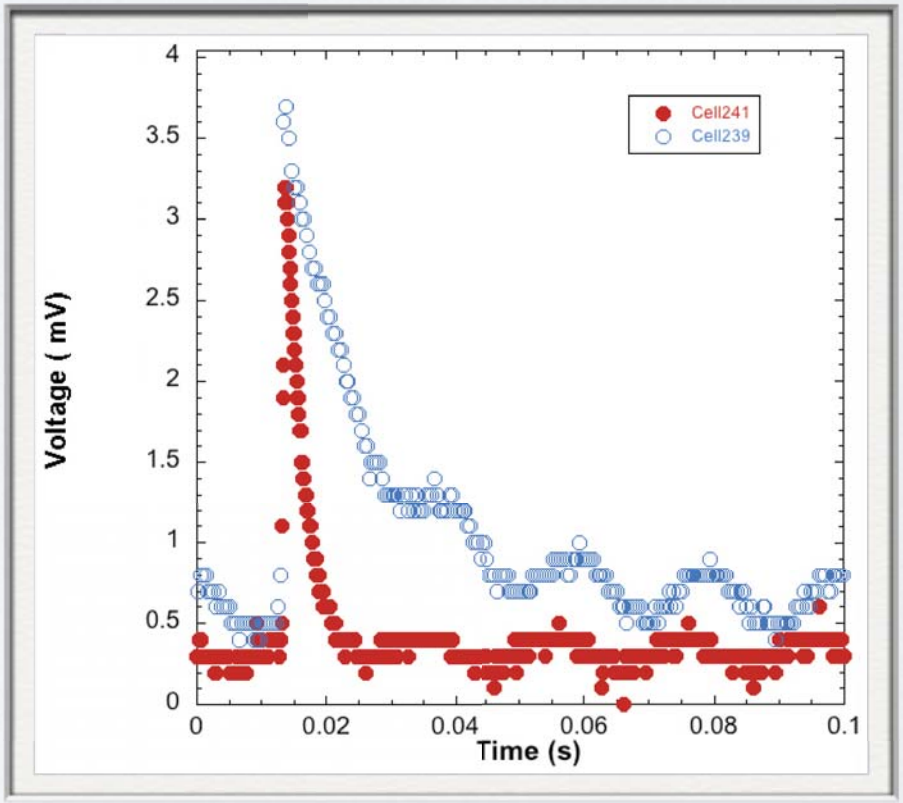

E_{TiO_2}/ HTM RECOMBINATION

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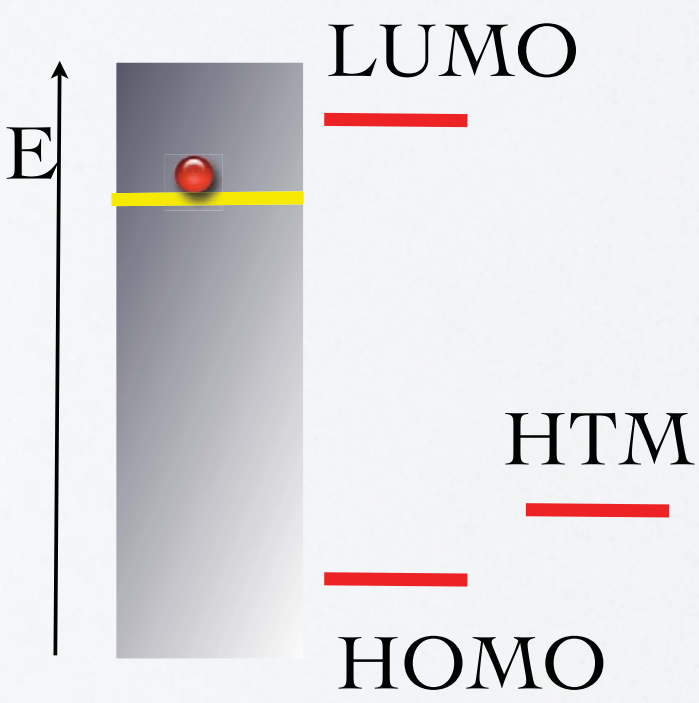

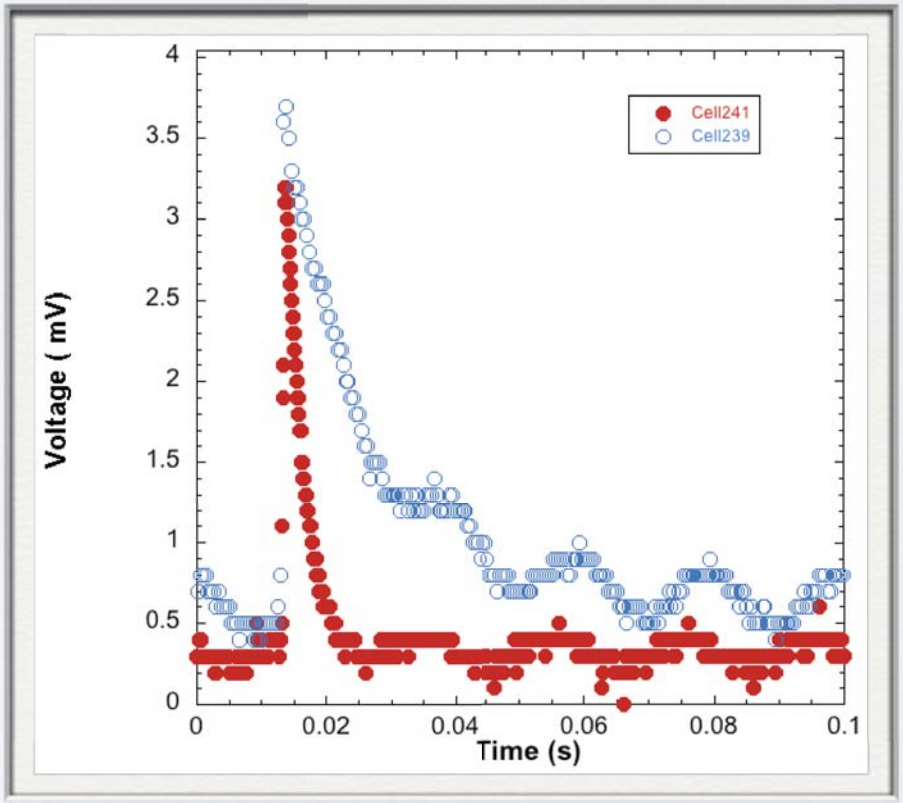

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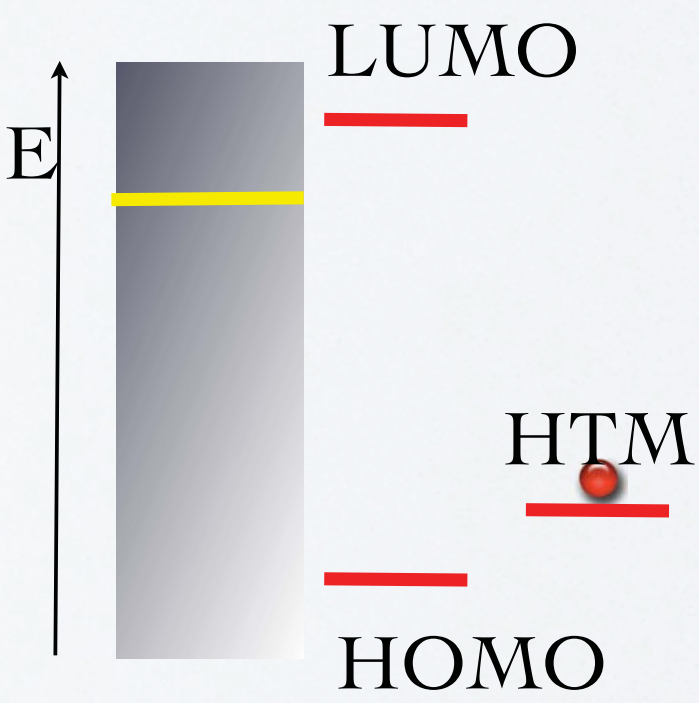

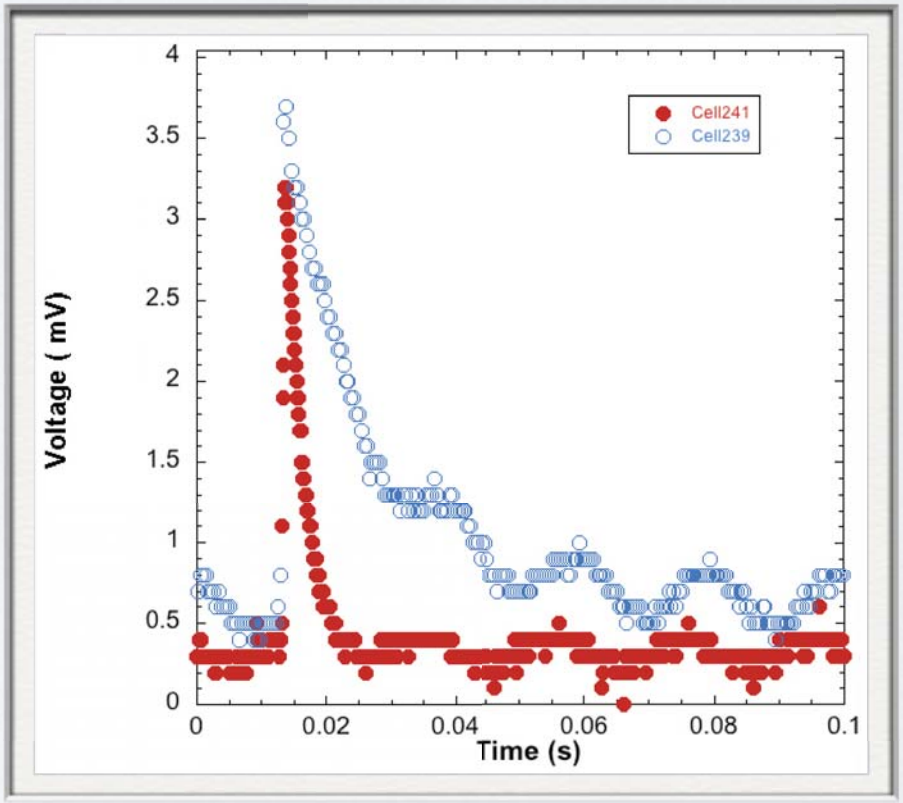

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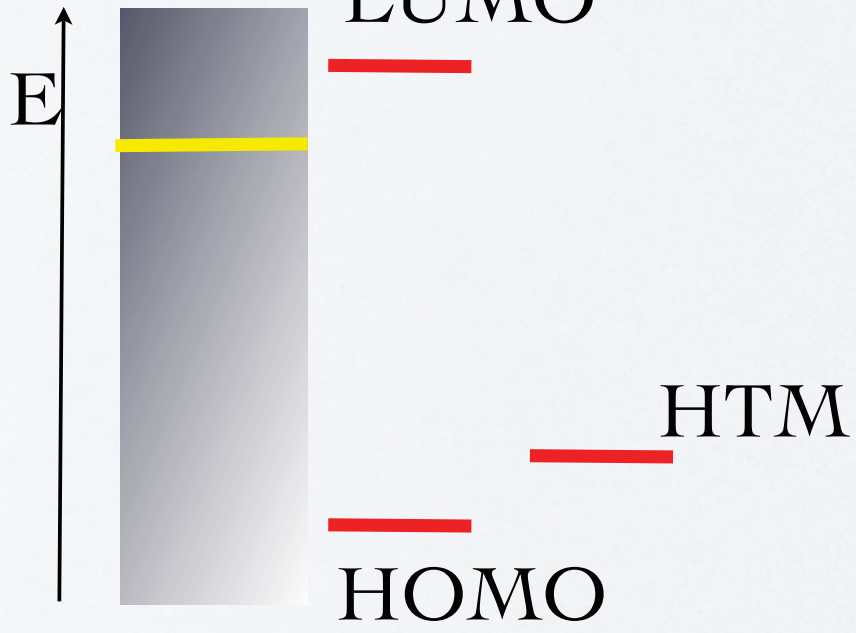

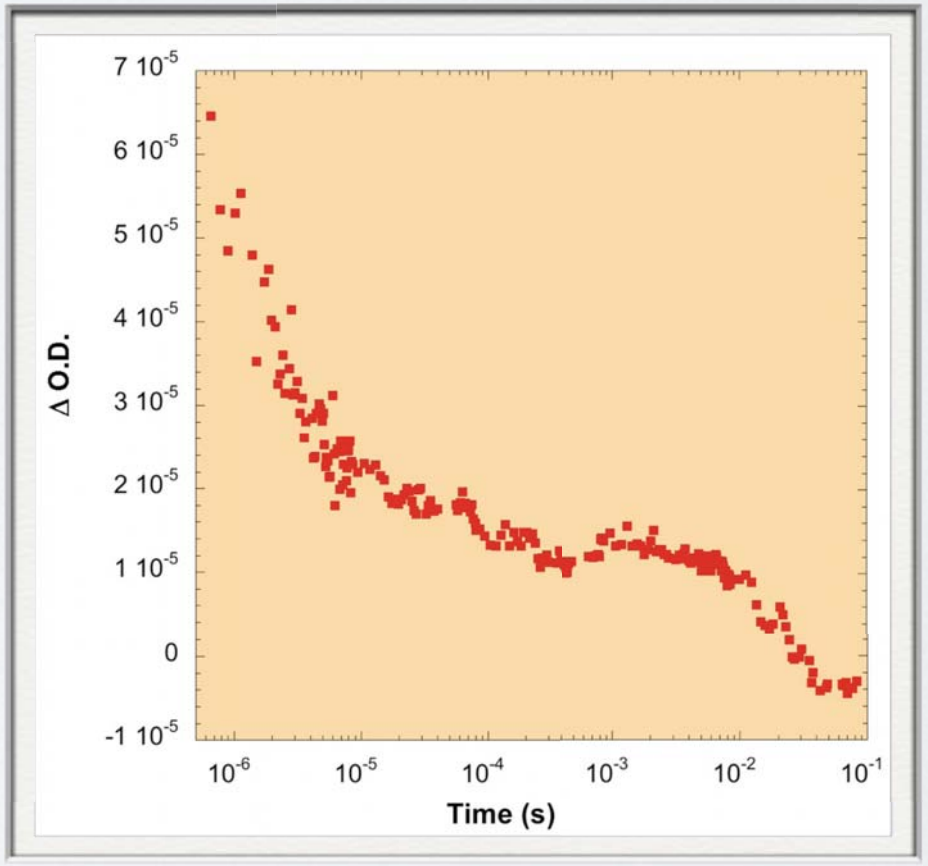

HTM/ DYE^+ Regeneration

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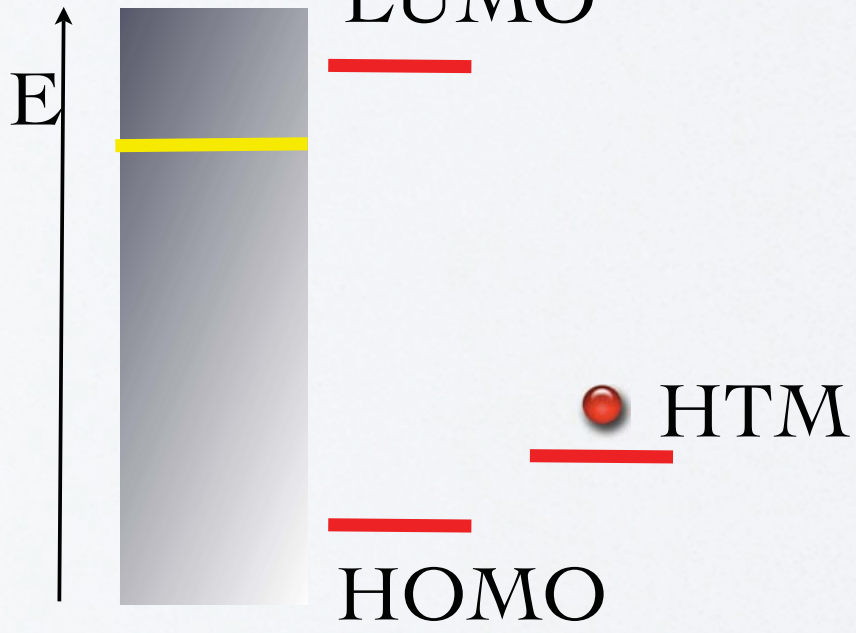

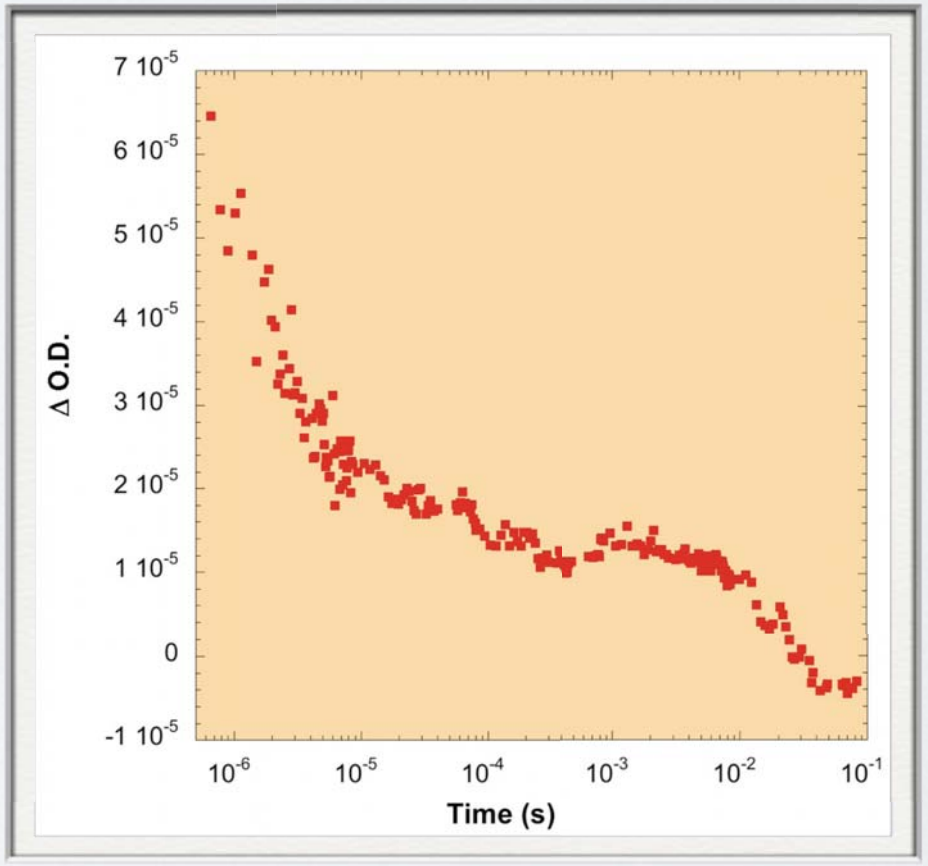

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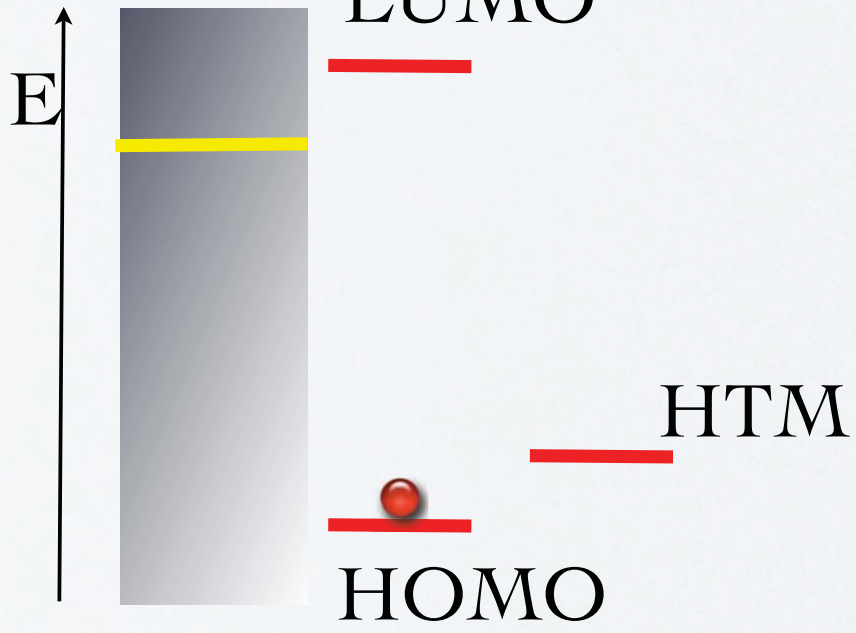

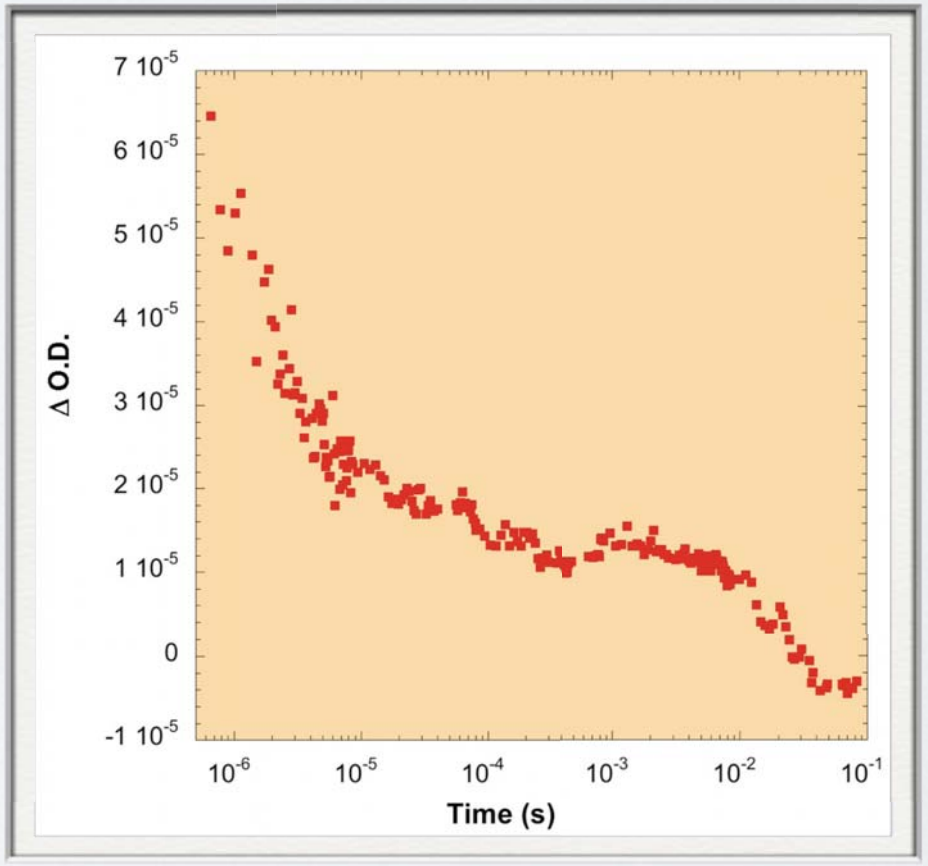

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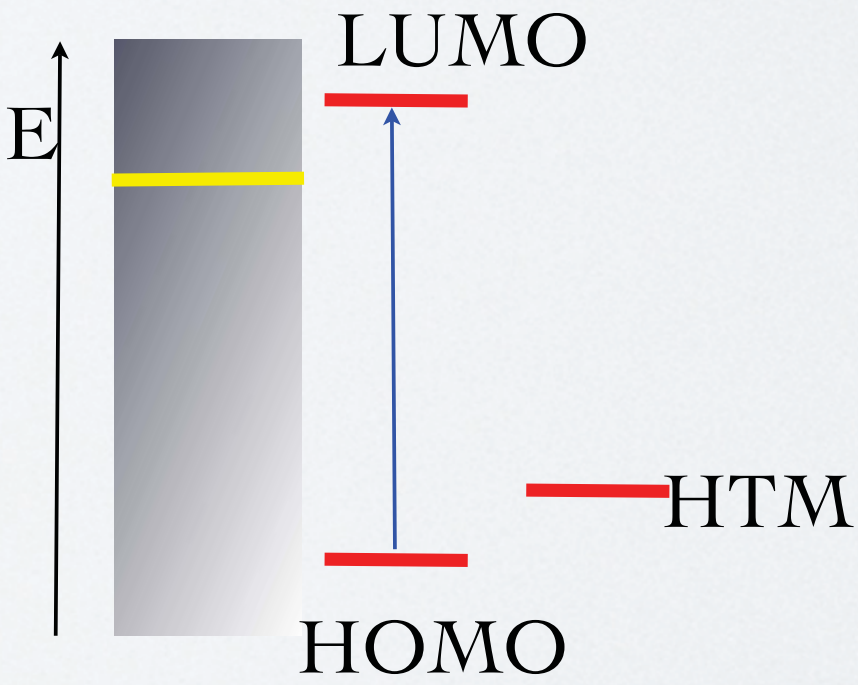
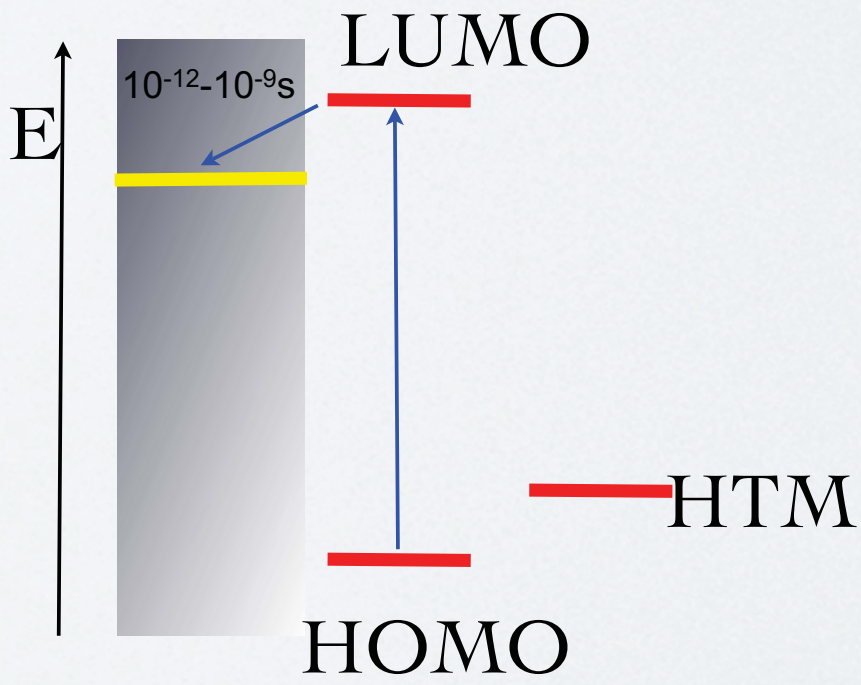


Overall charge transfer processes

Charge Transfer Processes



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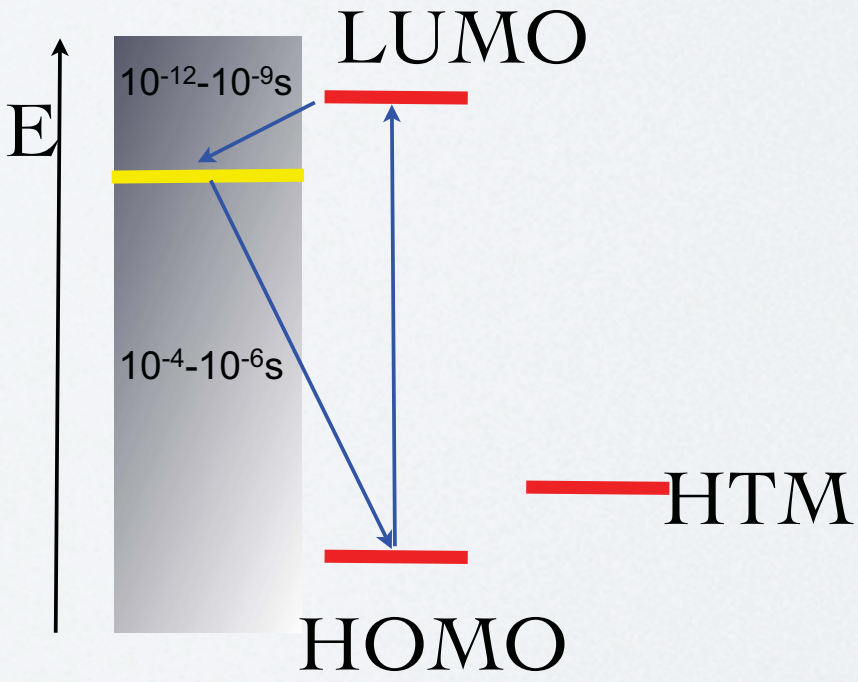

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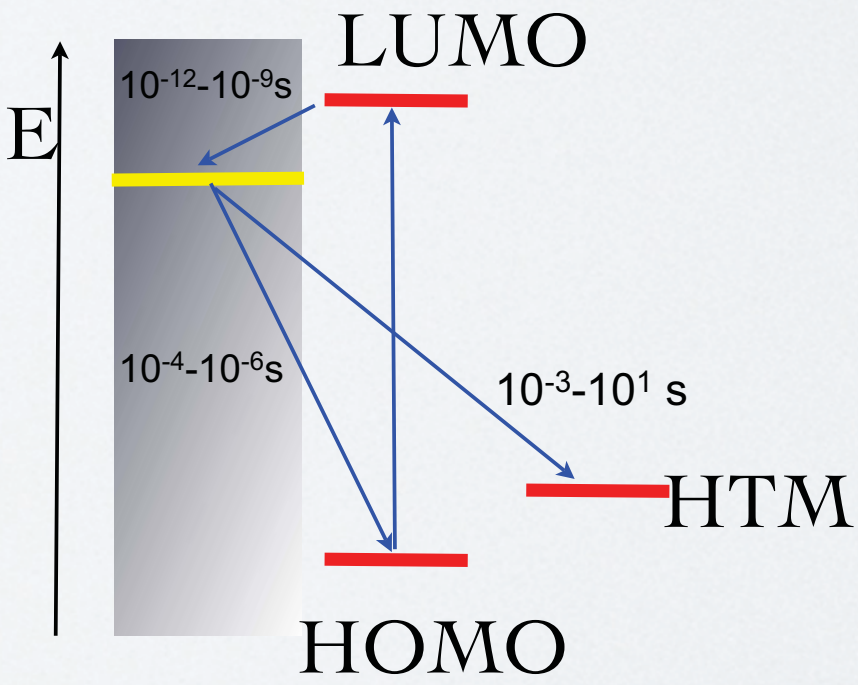

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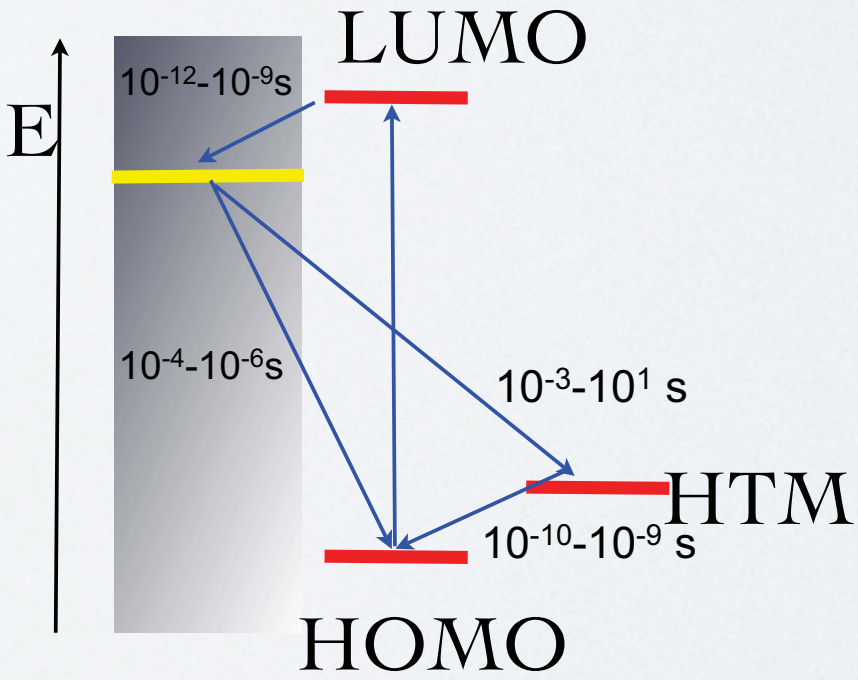

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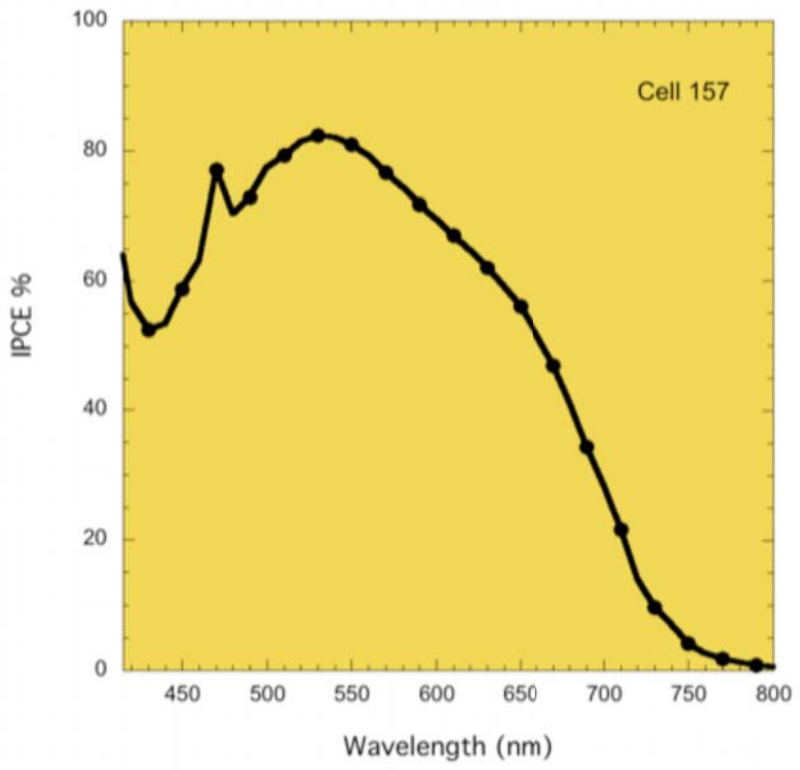
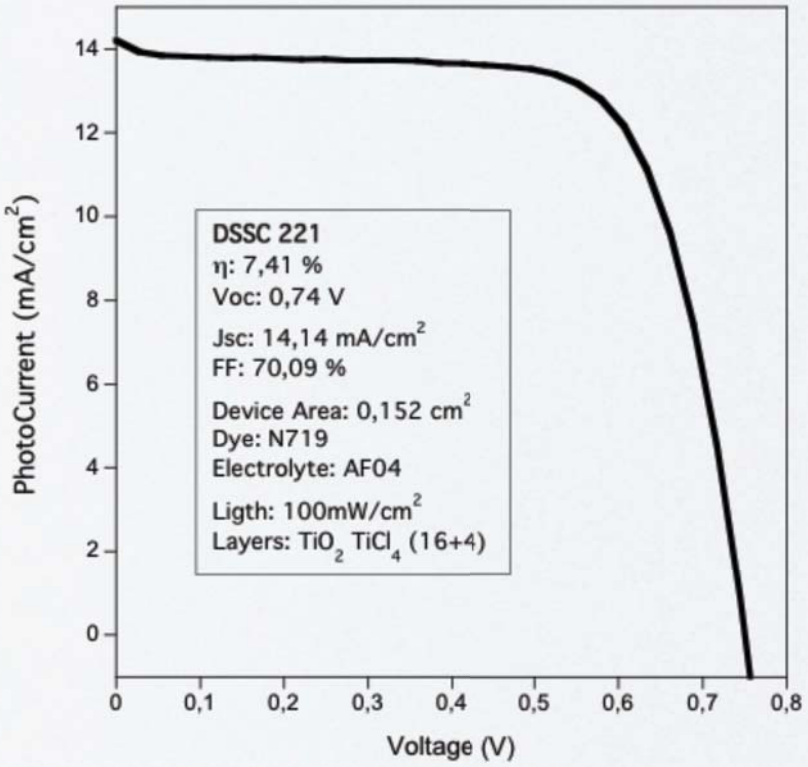


$$IPCE = \frac{Iph \times 1240}{\lambda \times P_0} \times 100$$

$$\eta_{device} = I_{sc} \times V_{oc} \times FF$$

Device Characterisation

Charge Transfer Processes



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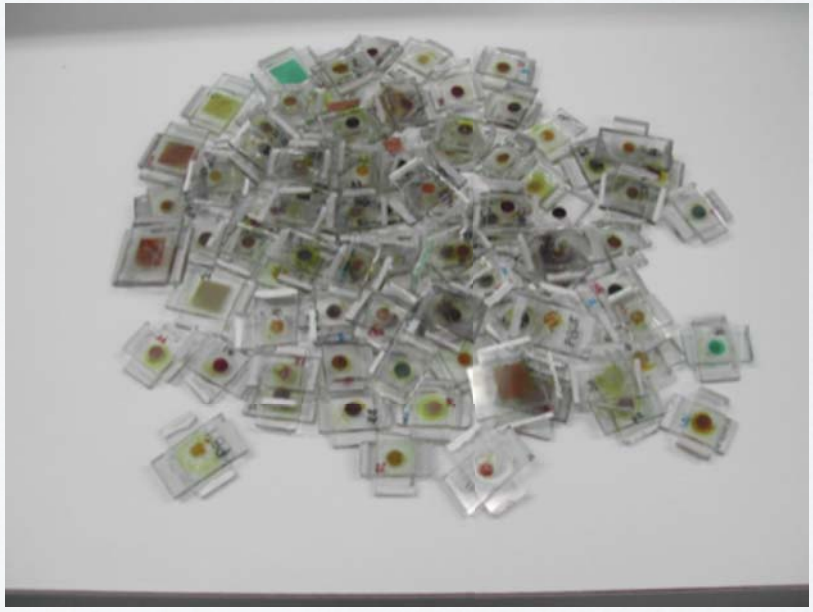

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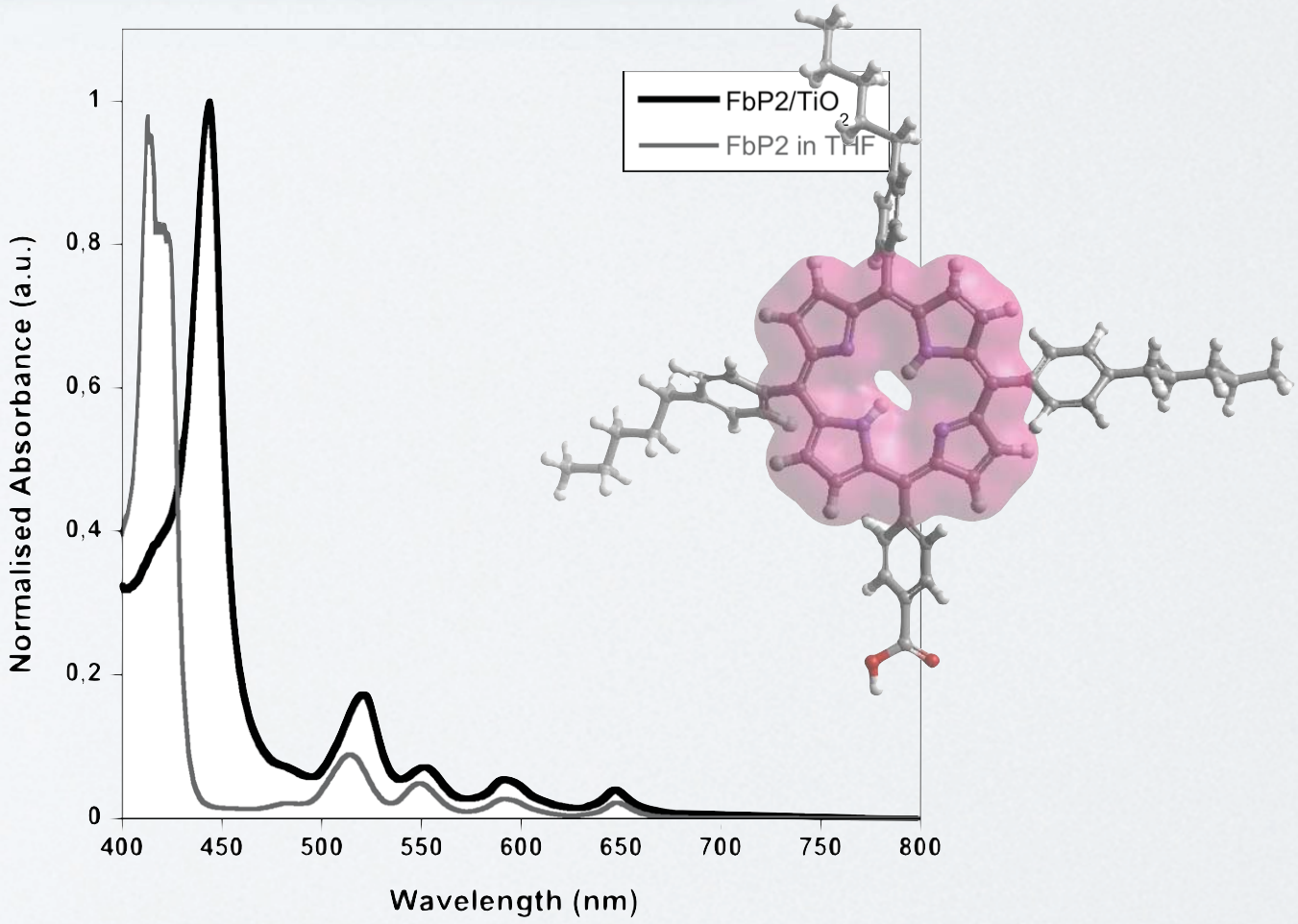
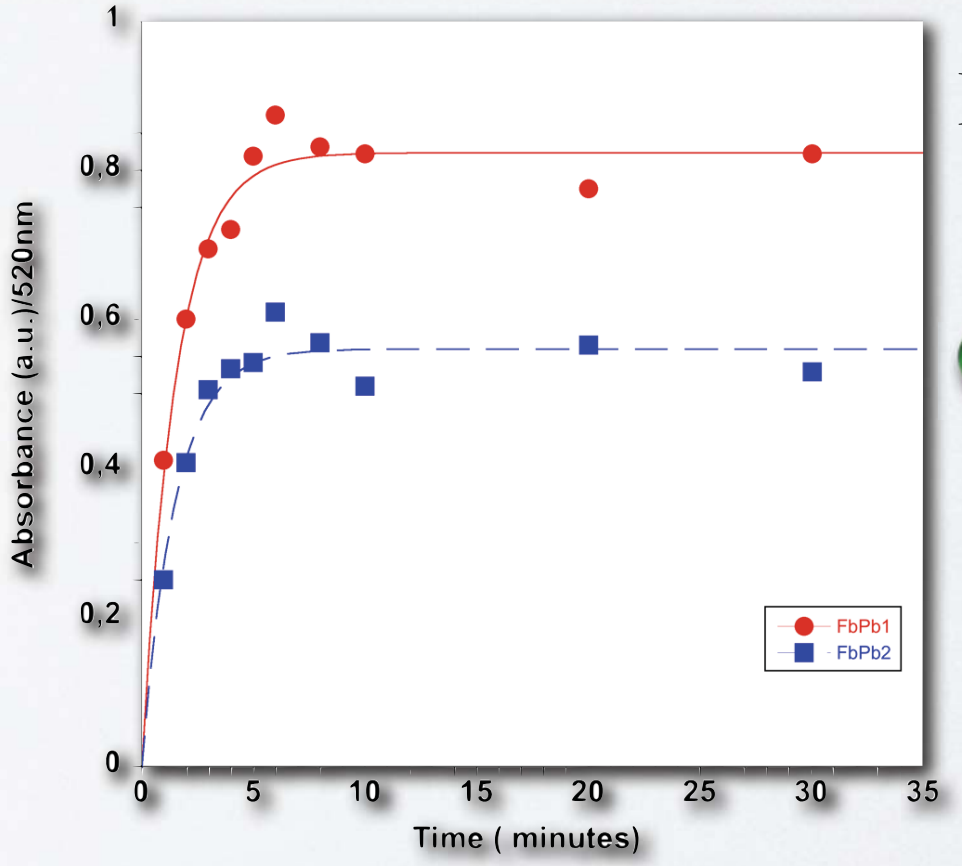
ICIQ's Research



Controlling "Dark" Electron transfer Reaction

ICIQ's Research



Dye absorption Kinetics

$$A = A_{\max}(1 - \exp(-K_{ads}t))$$

- Lagergren's Equation

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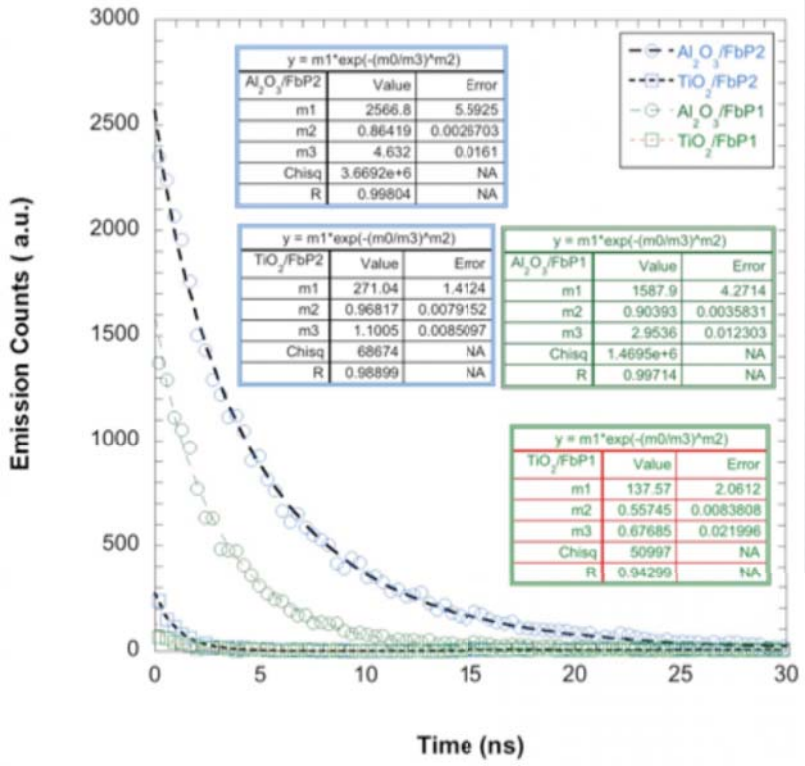

Dye Injection kinetics

$$y = y_0^{(-\tau/t)^{\beta}}$$

- Injection into TiO_2 CB occurs before 100 ps
- Injection on Devices is slower.
  Nonetheless still faster than 250 ps

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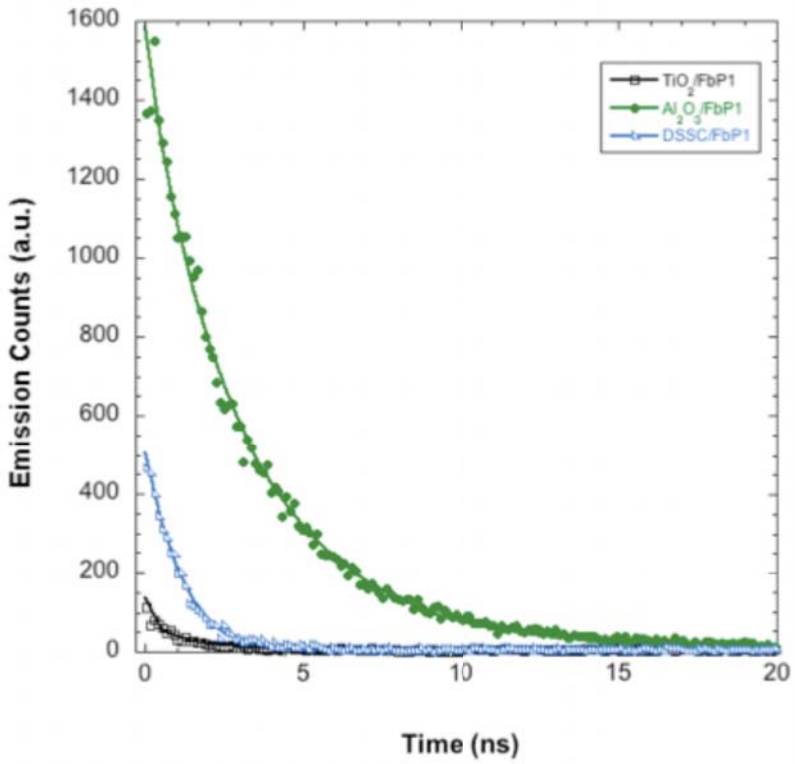

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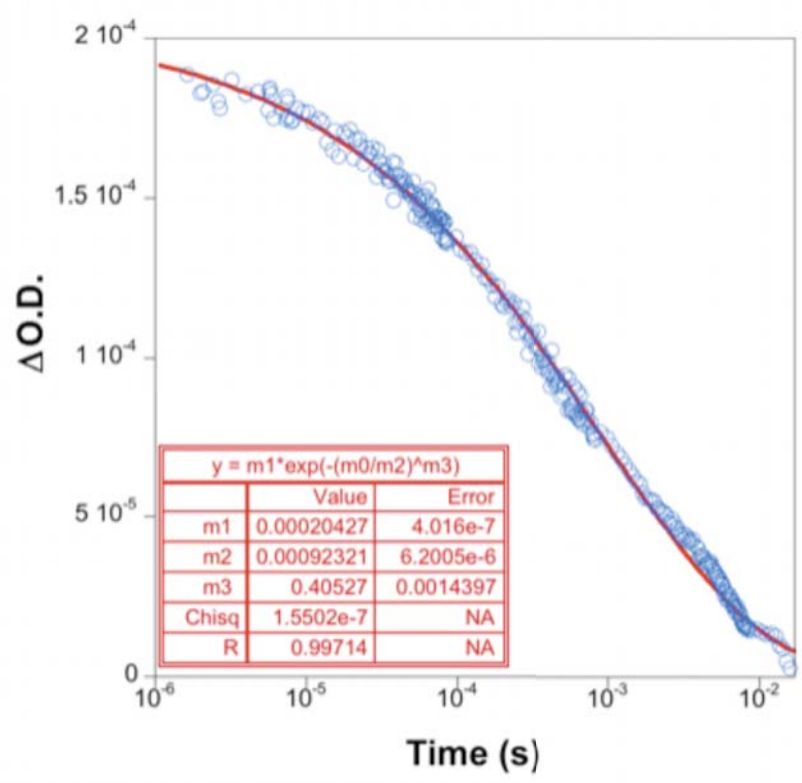

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- TiO_2/dye^+ recombination half-lifetime ~3 x 10^{-4} s.

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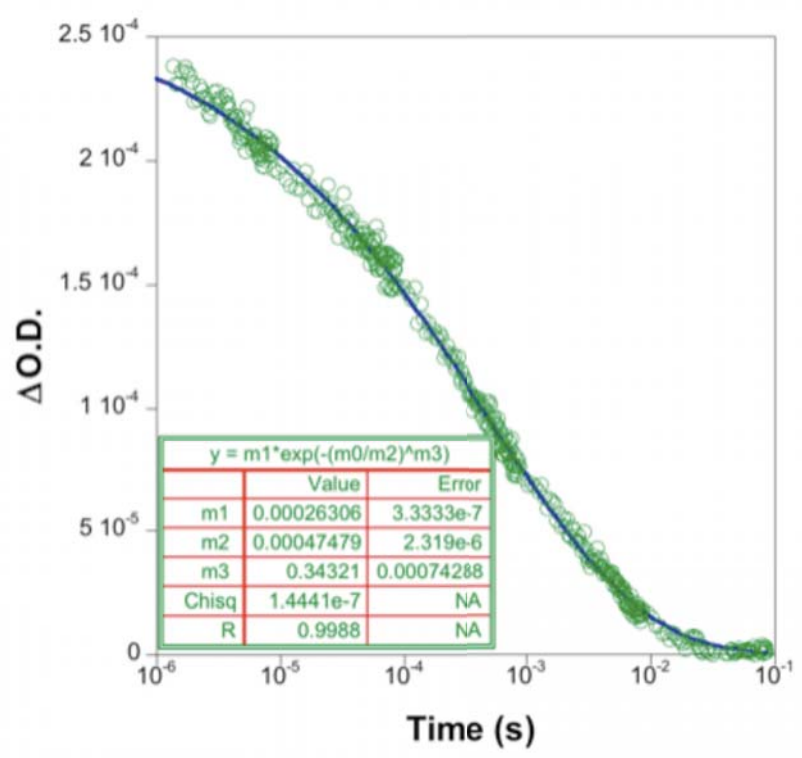

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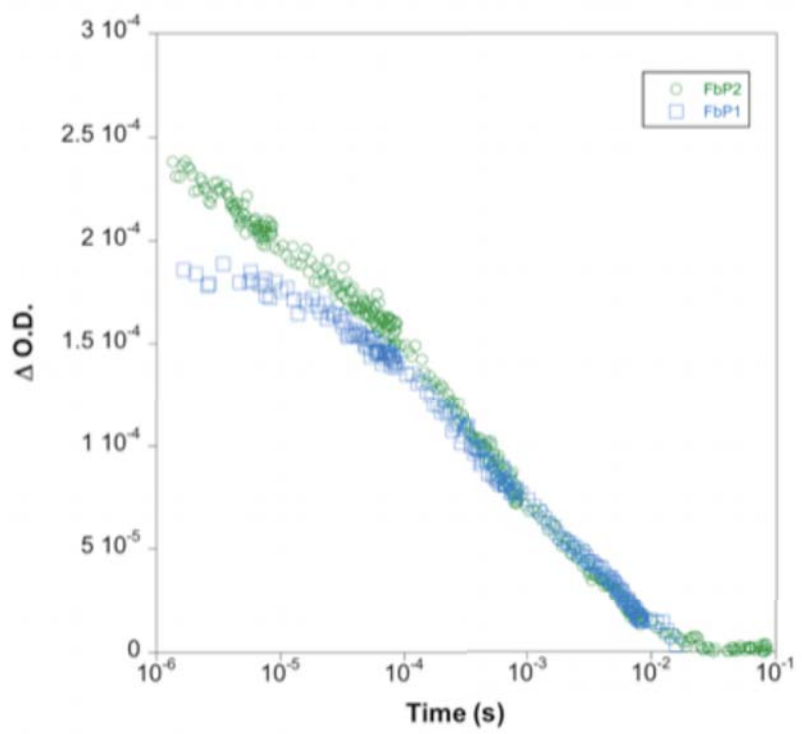

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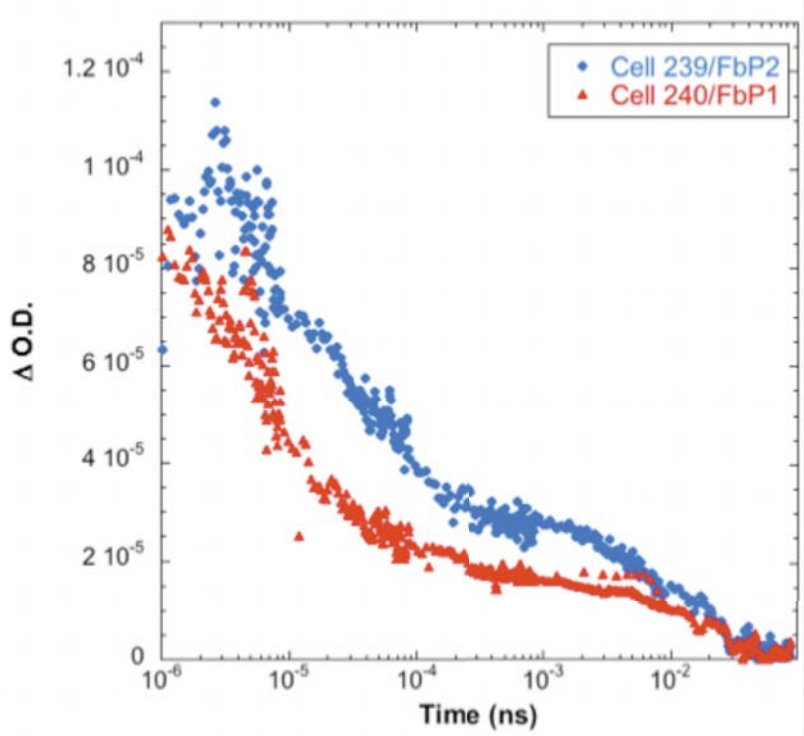

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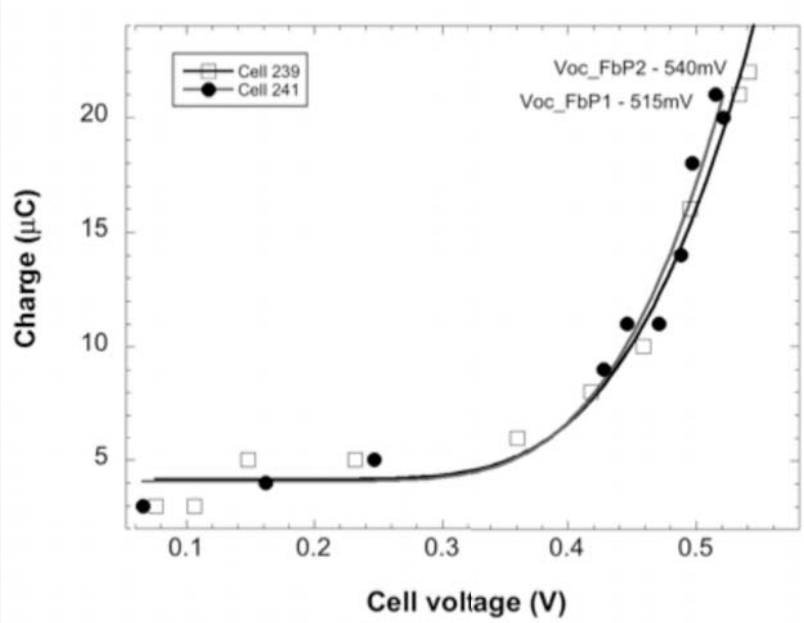
Controlling "Dark" Electron transfer Reaction

ICIQ's Research



TiO_2/electrolyte$^+$ charge transfer kinetics

- No TiO_2 CB shift. No effect on the DOS by alkyl chains
- Slow "dark" recombination dynamics

Controlling "Dark" Electron transfer Reaction

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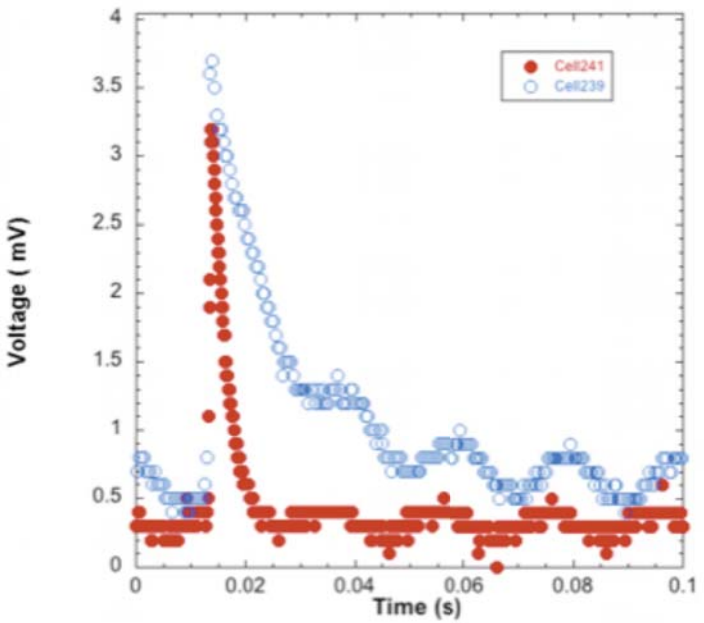

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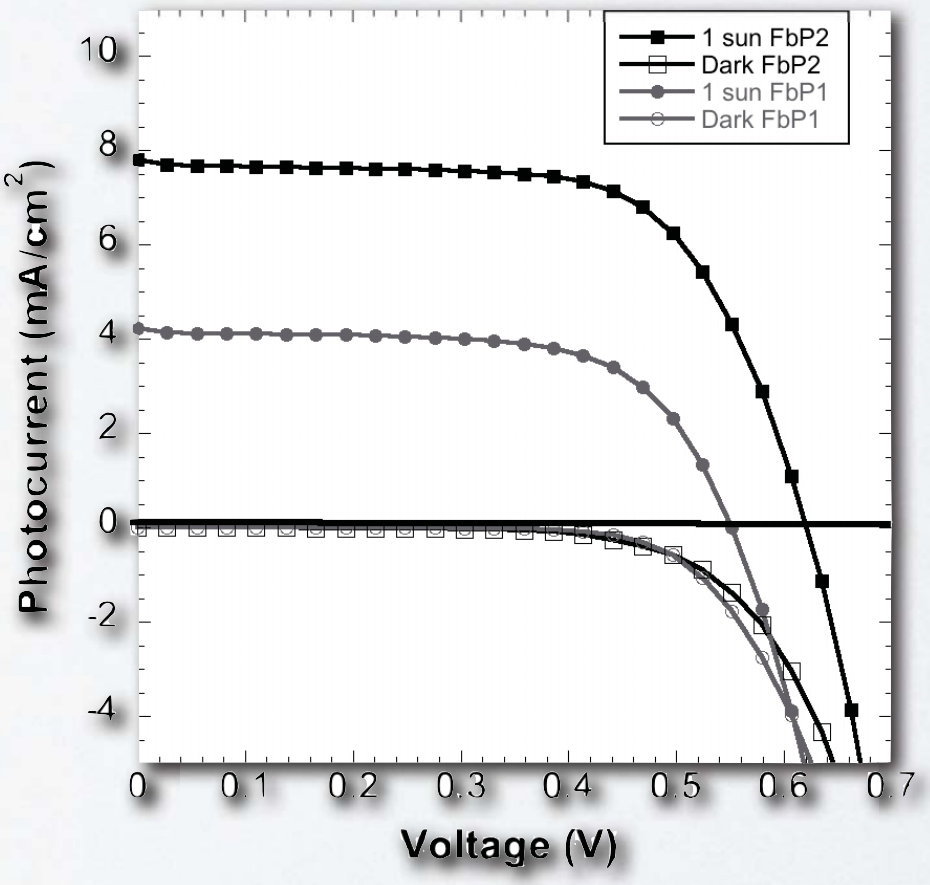
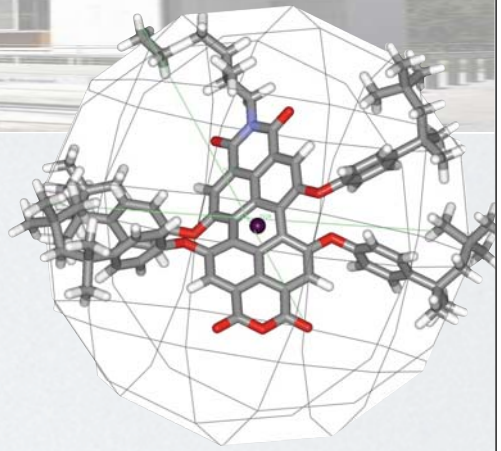


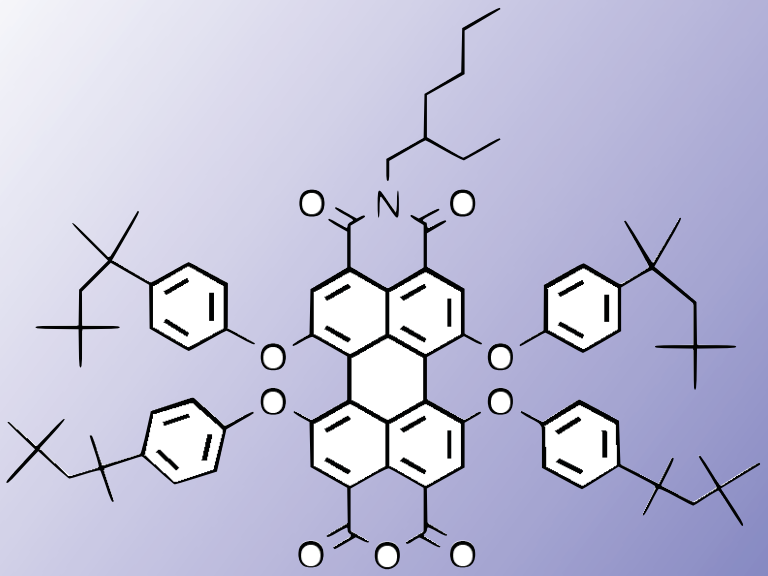
DSSC Devices

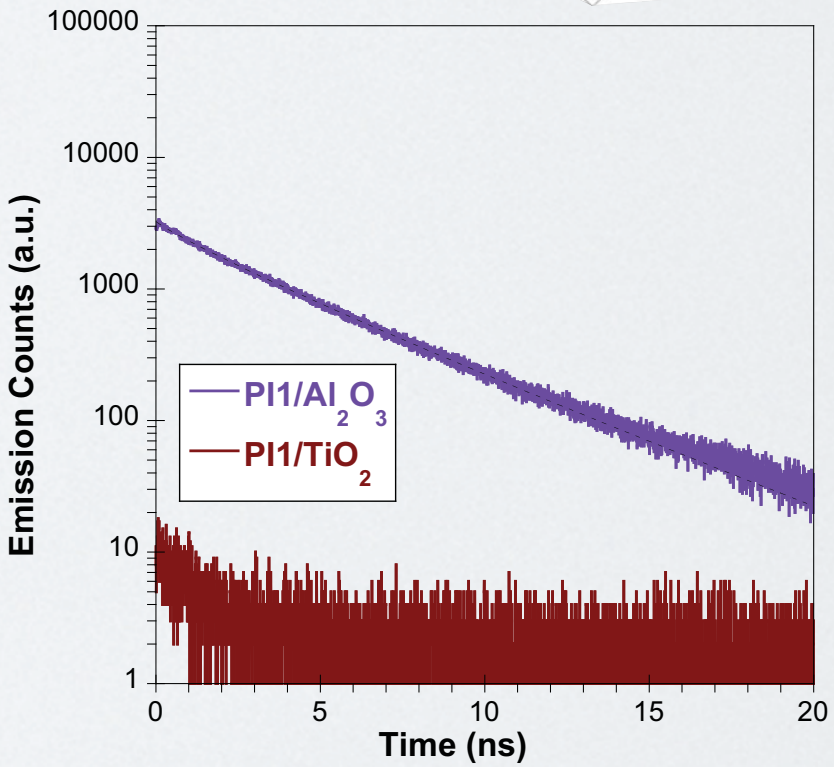
- Increase in Current
- Increase in voltage

Enhanced device efficiency

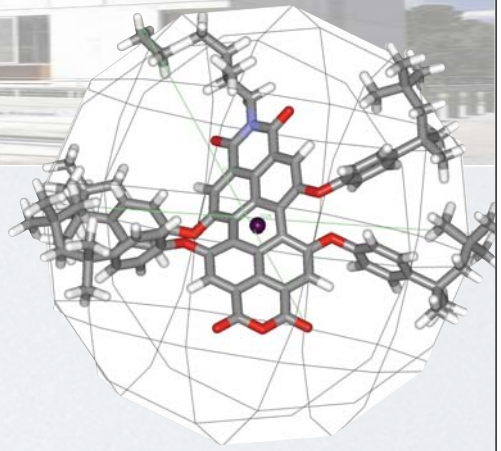
Dye Sensitised Solar Cells

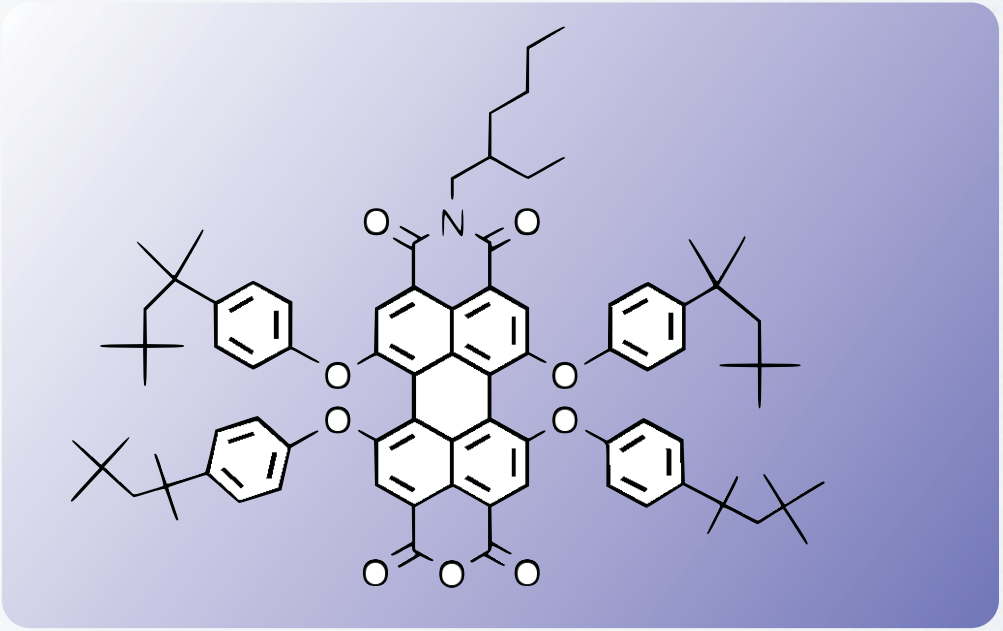


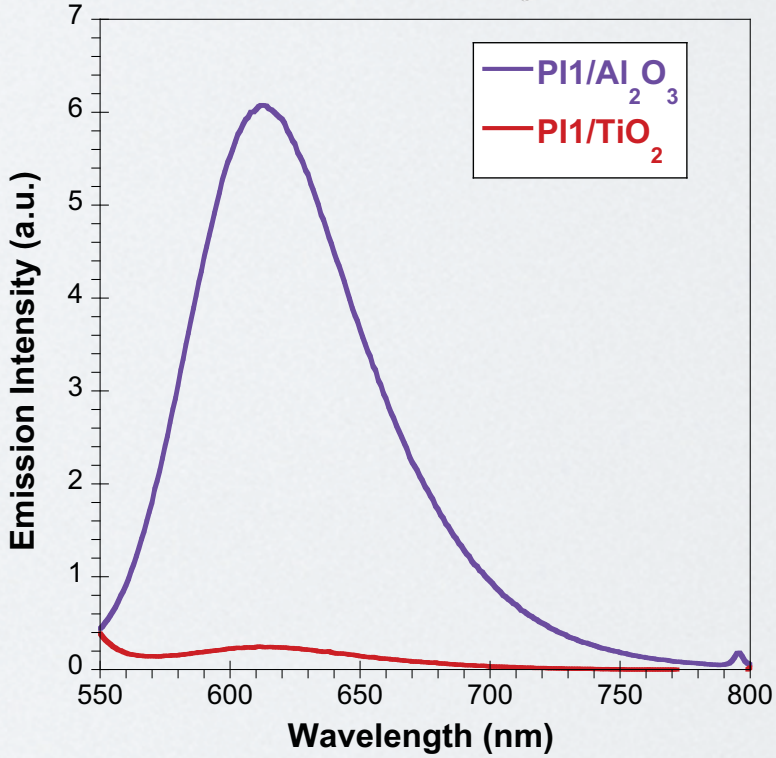


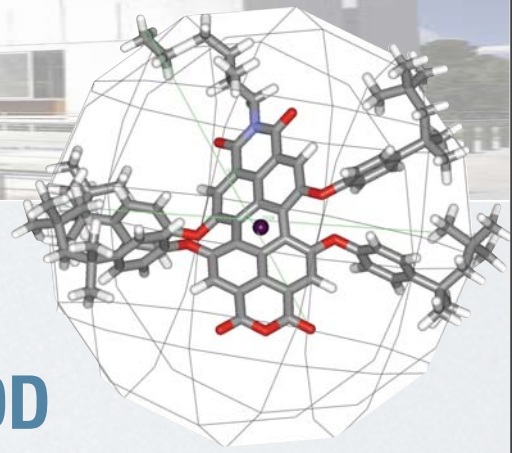


Dye Sensitised Solar Cells



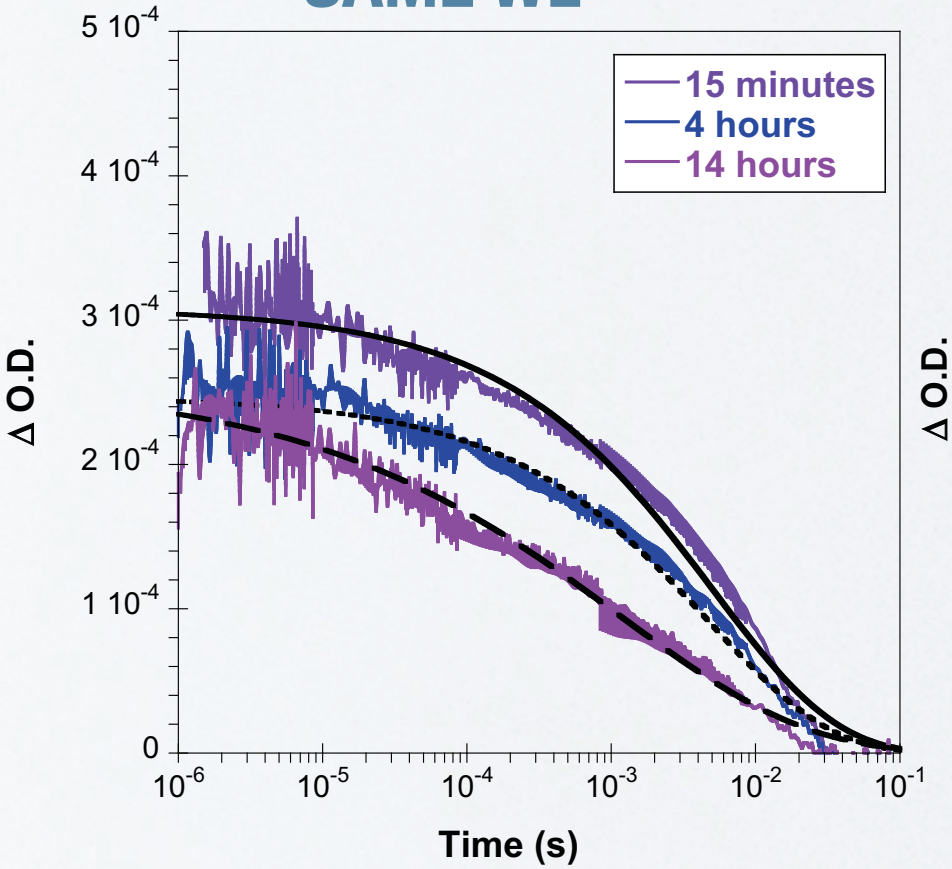




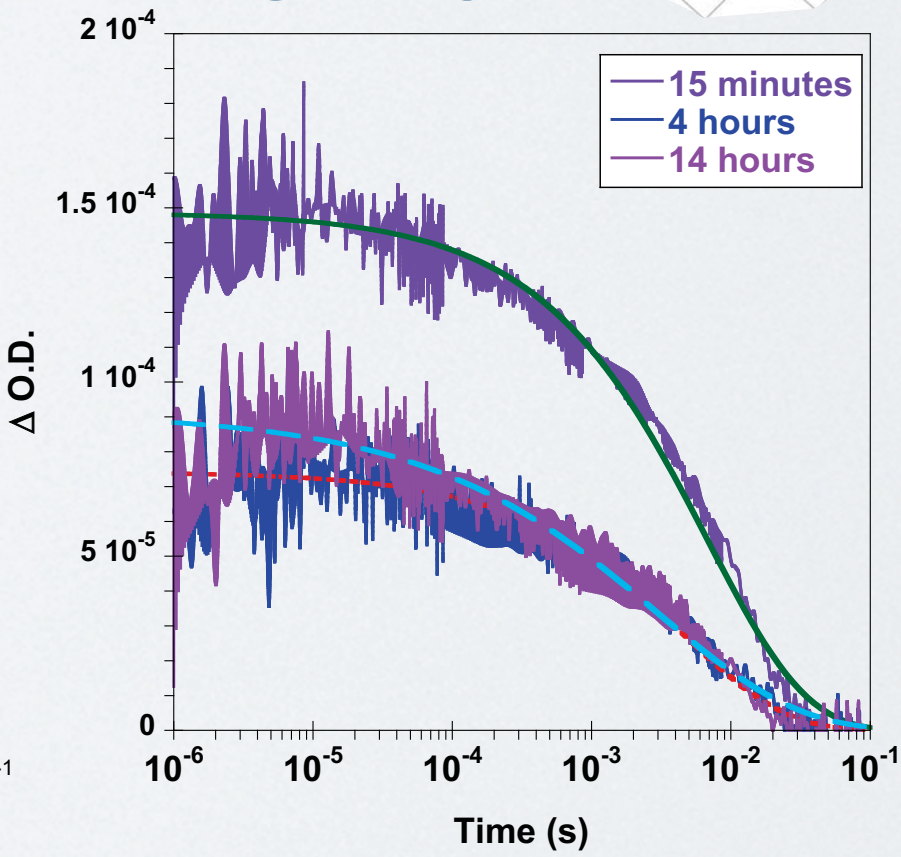


Dye Sensitised Solar Cells

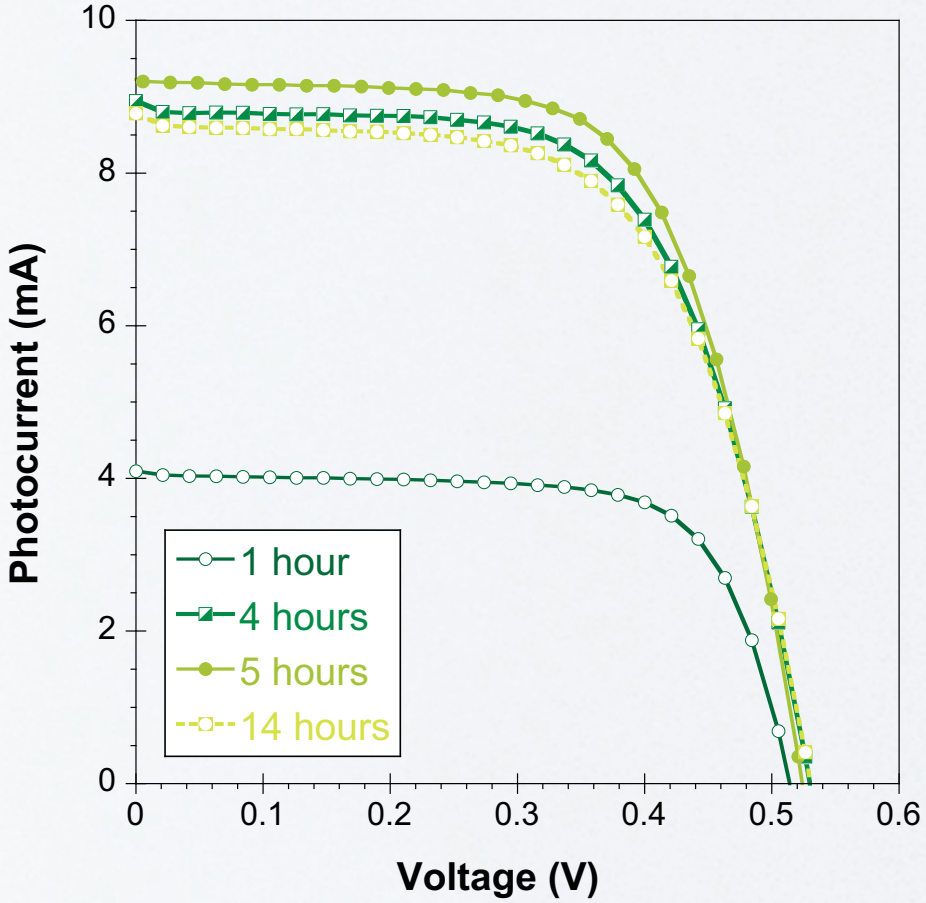
SAME WL

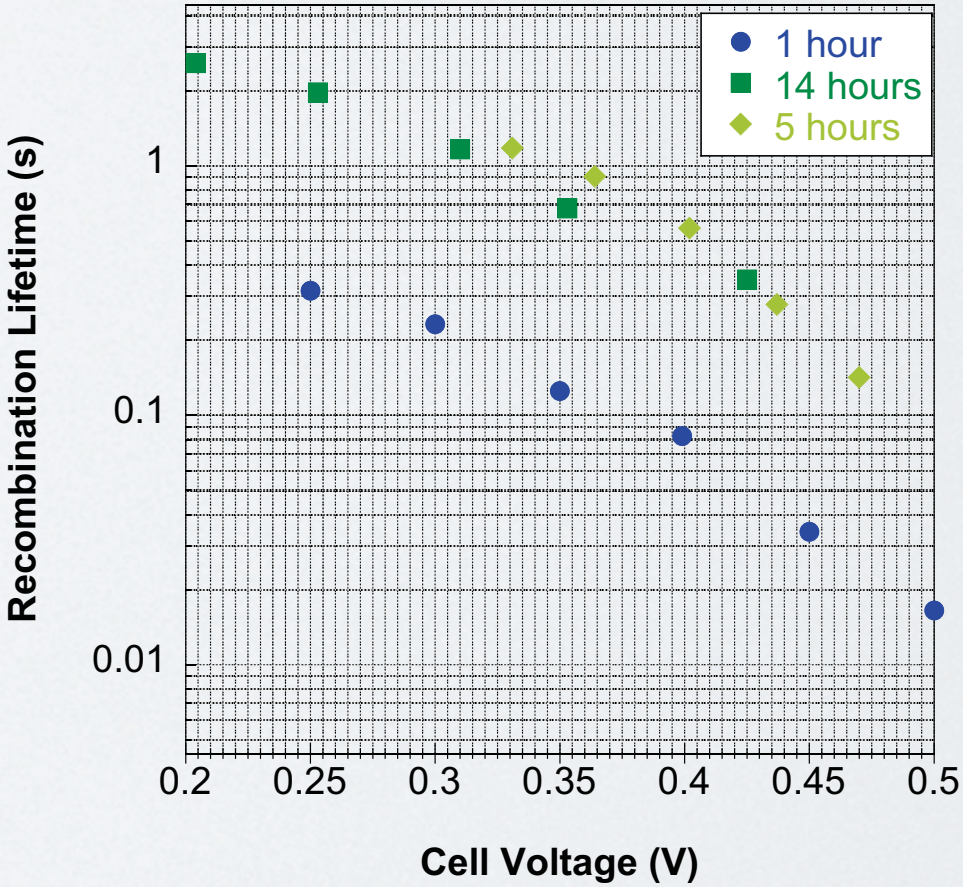


SAME OD



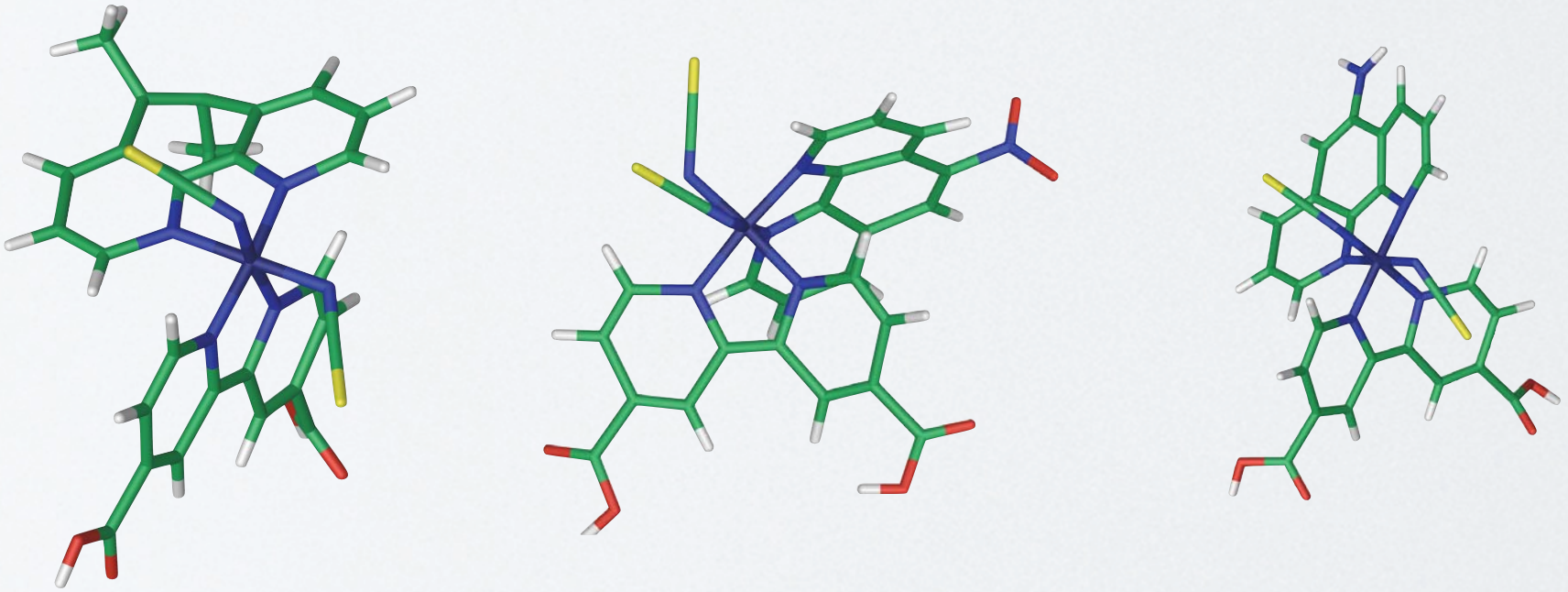
Dye Sensitised Solar Cells





Dye Sensitised Solar Cells

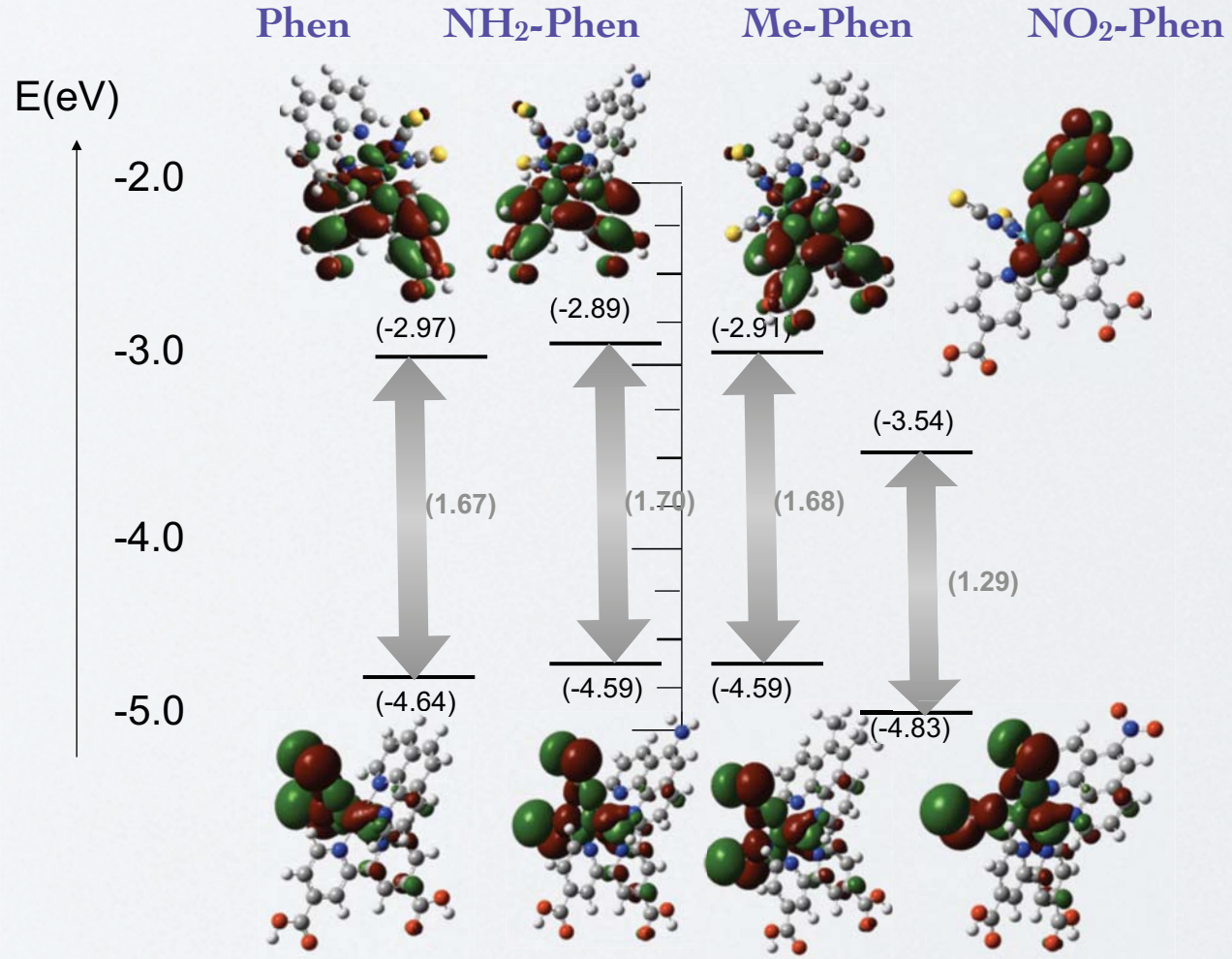
- ICIQ-Dyes



phenanthroline heteroleptic Ru(II) complexes

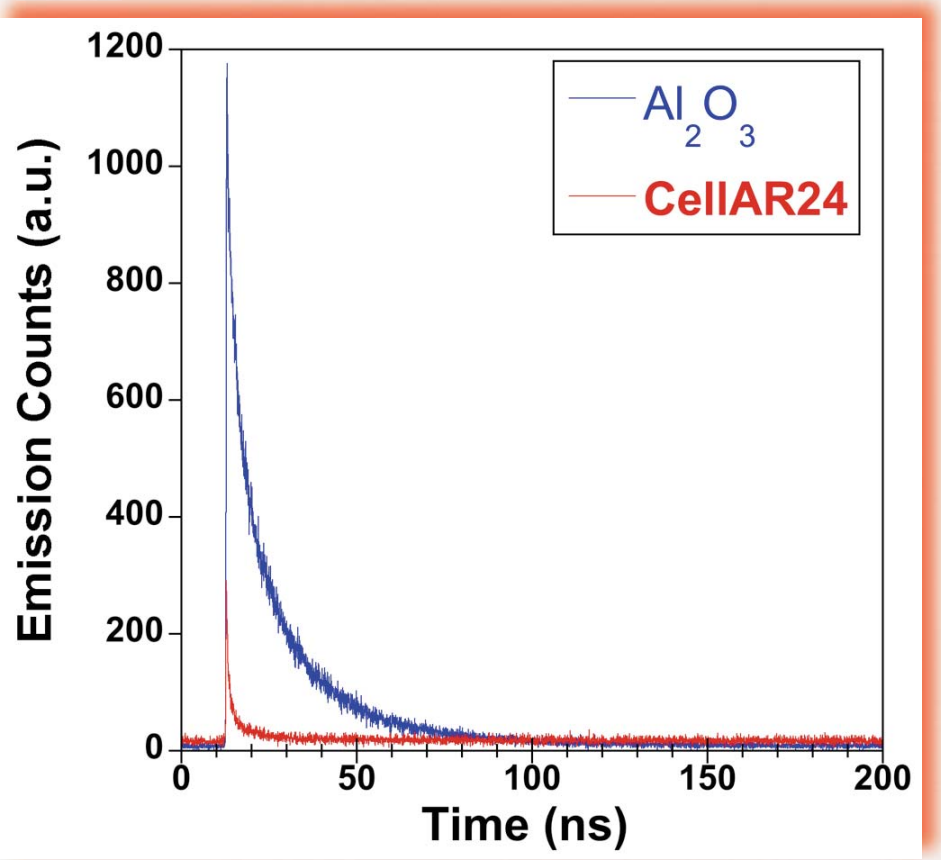
Dye Sensitised Solar Cells

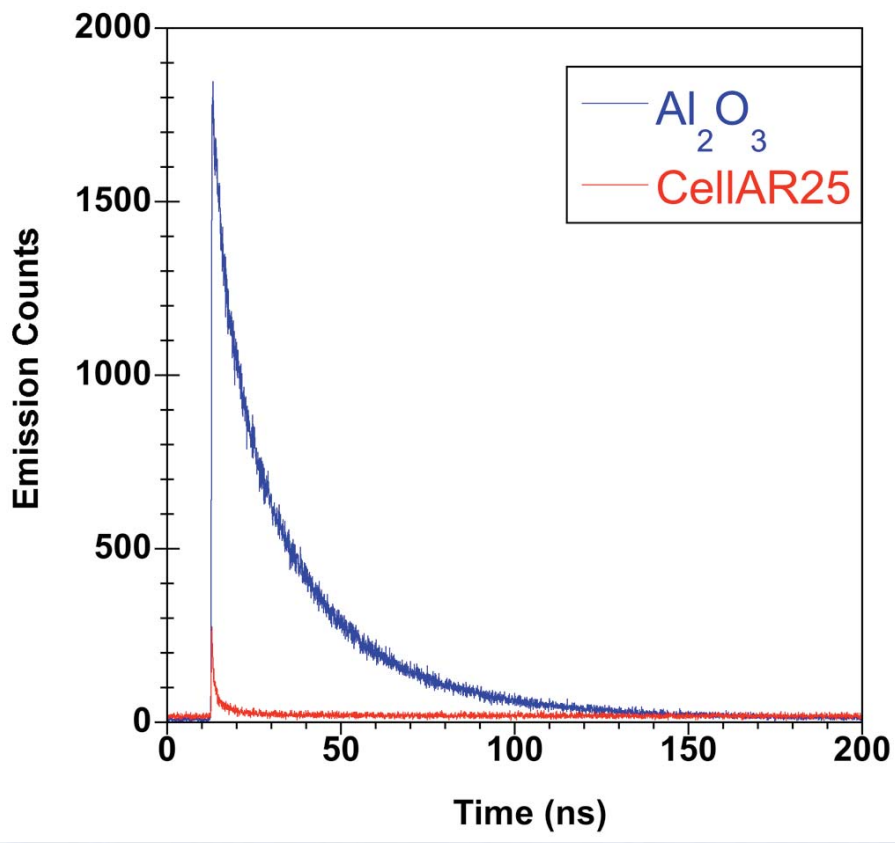
MO



Dye Sensitised Solar Cells

Electron Injection





Dye Sensitised Solar Cells

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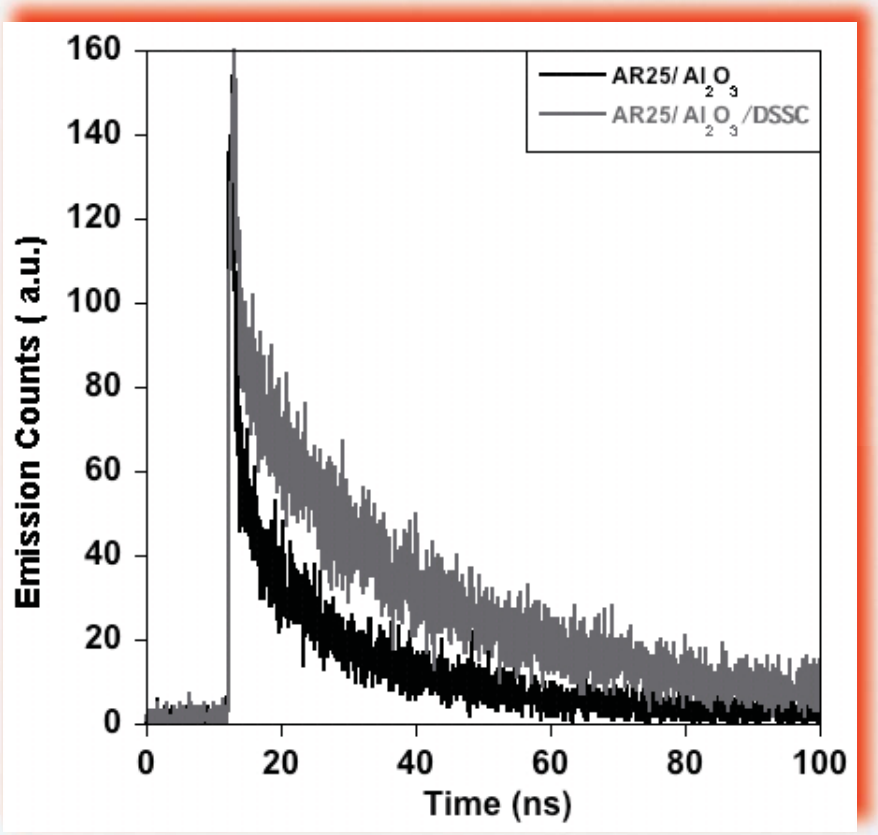
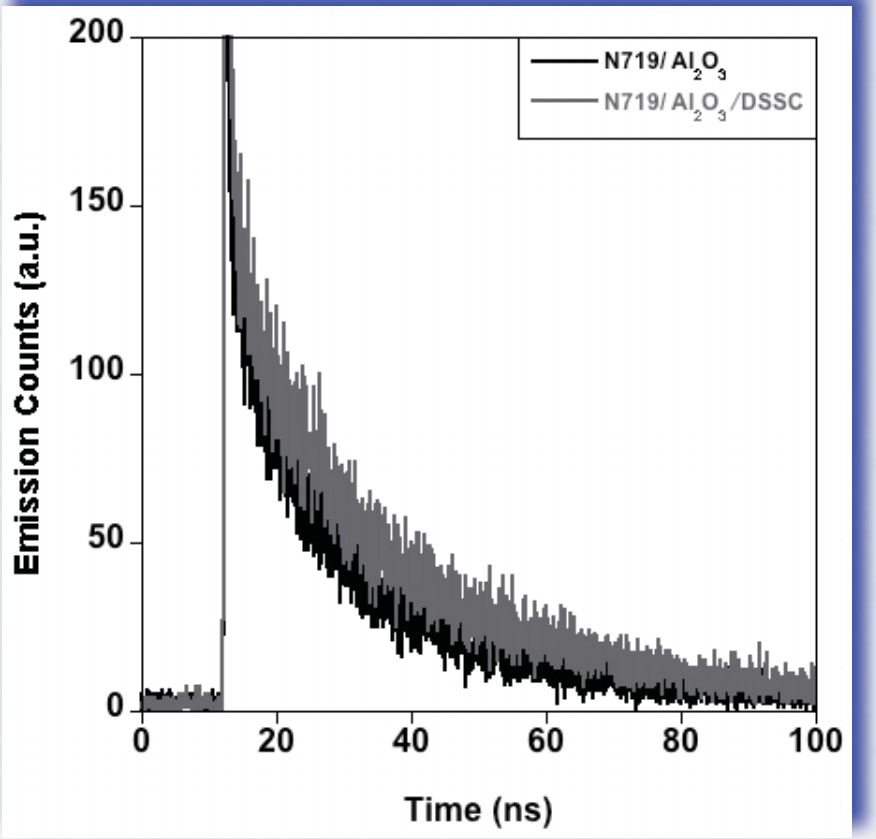
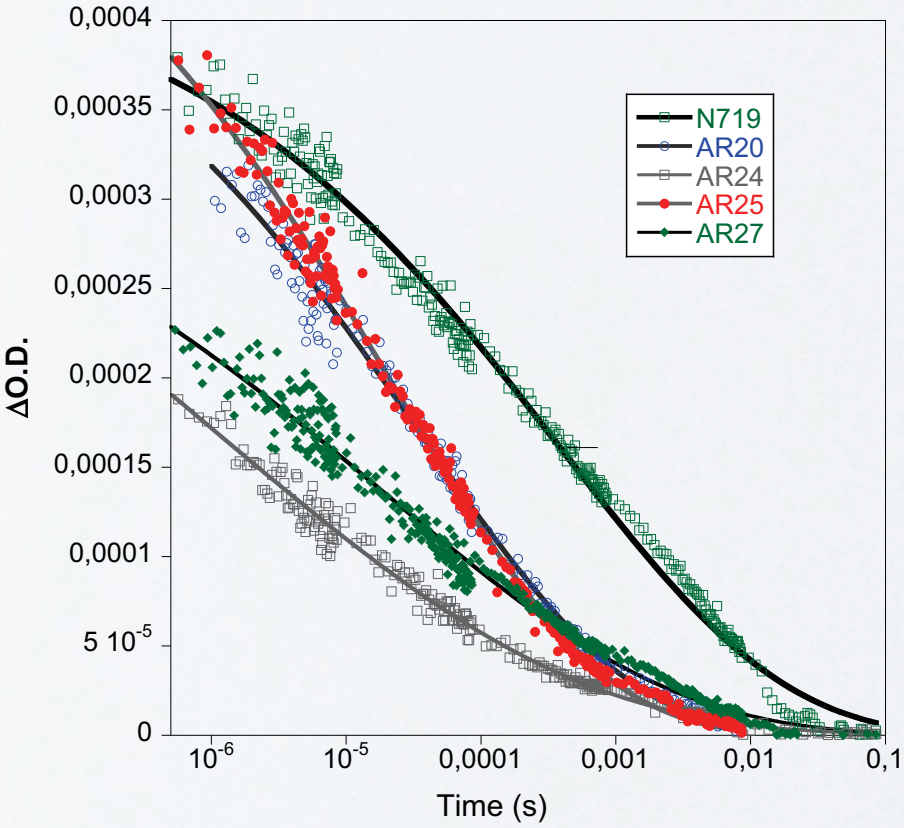
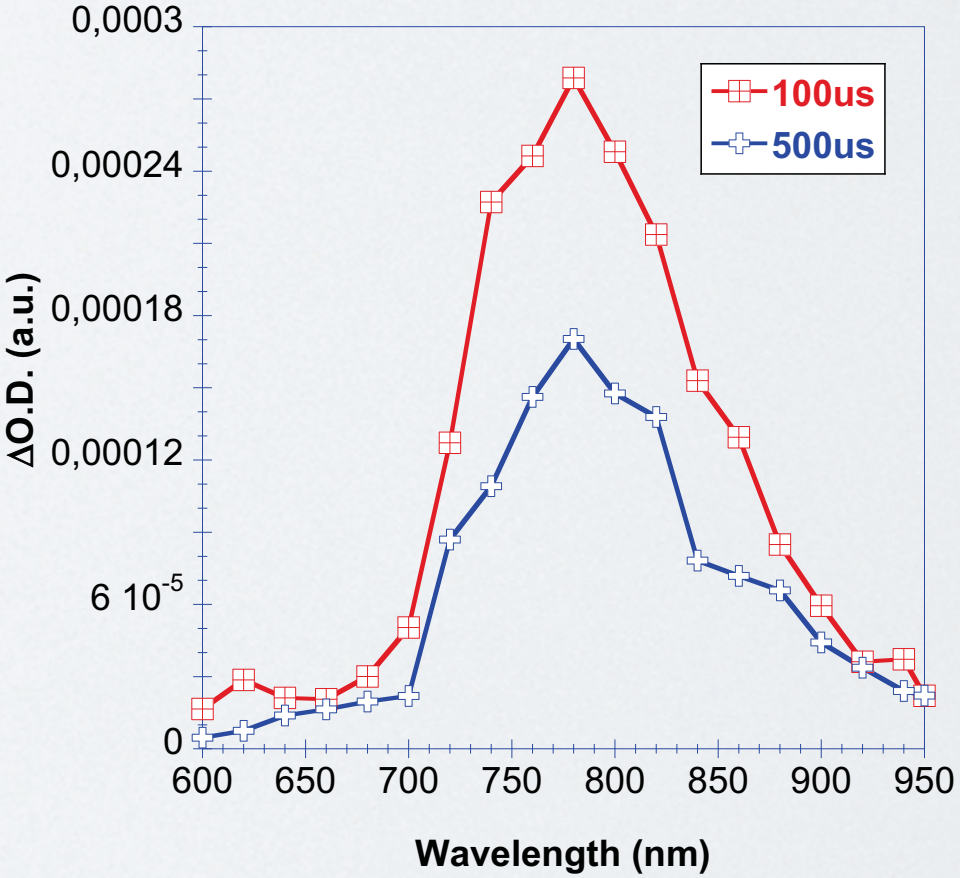




Dye Sensitised Solar Cells

e^--TiO_2/Dye^+ Recombination





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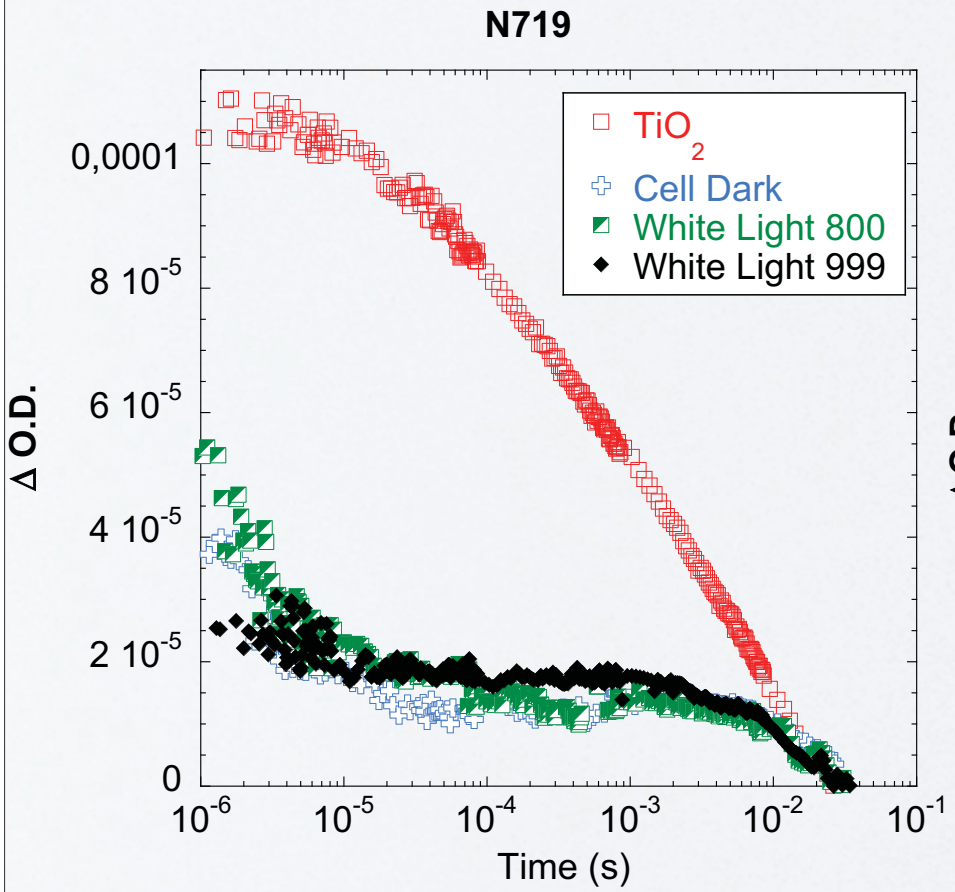

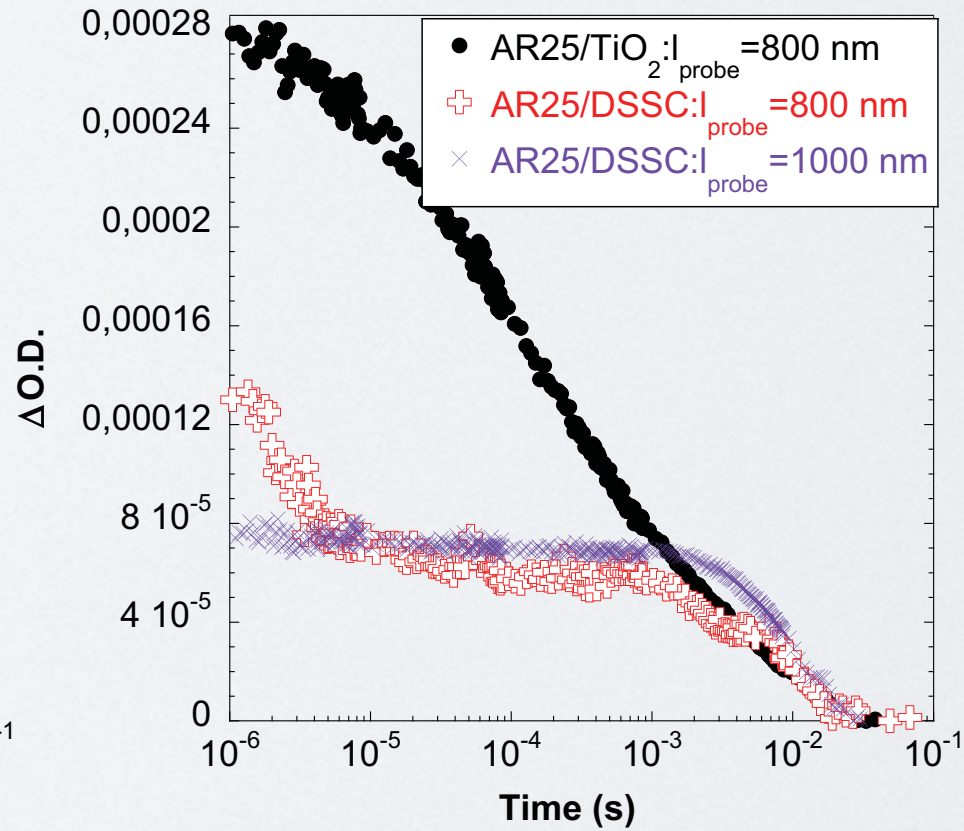

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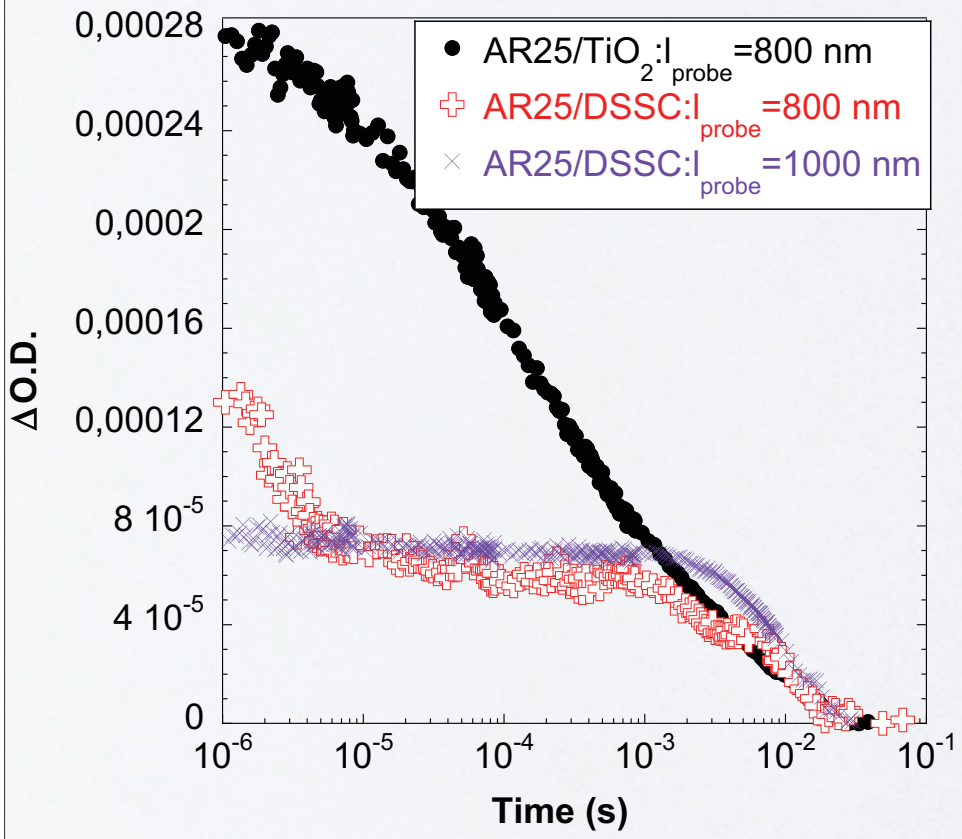
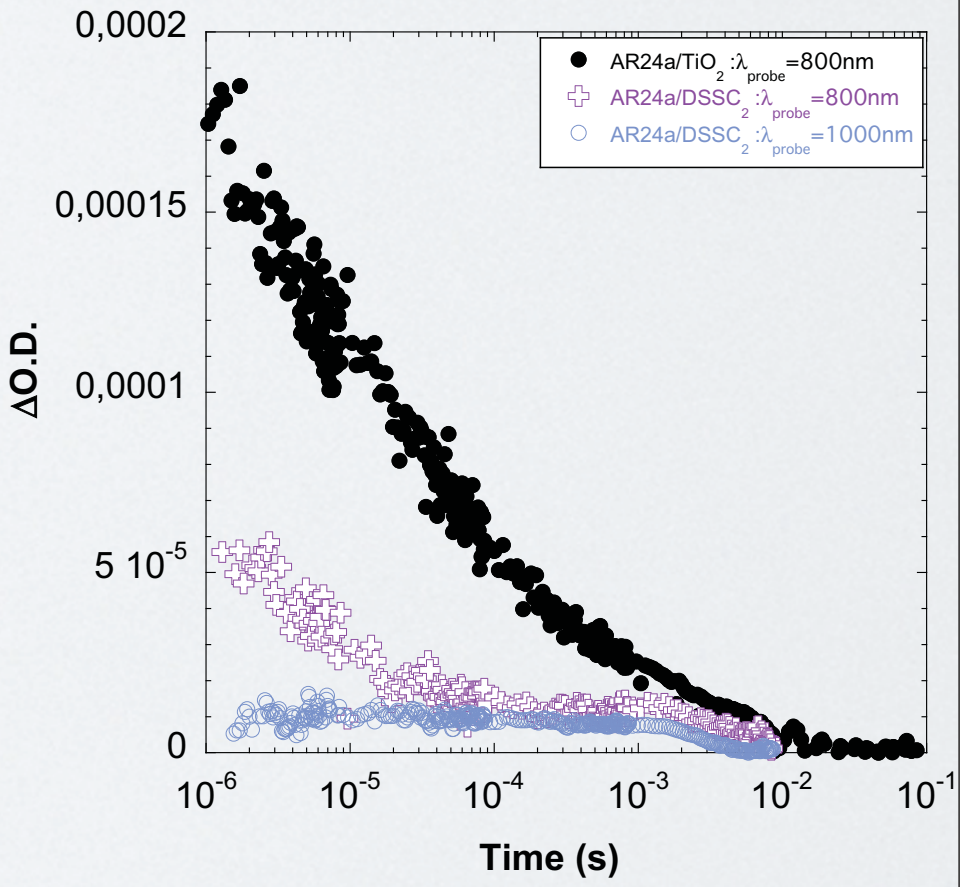
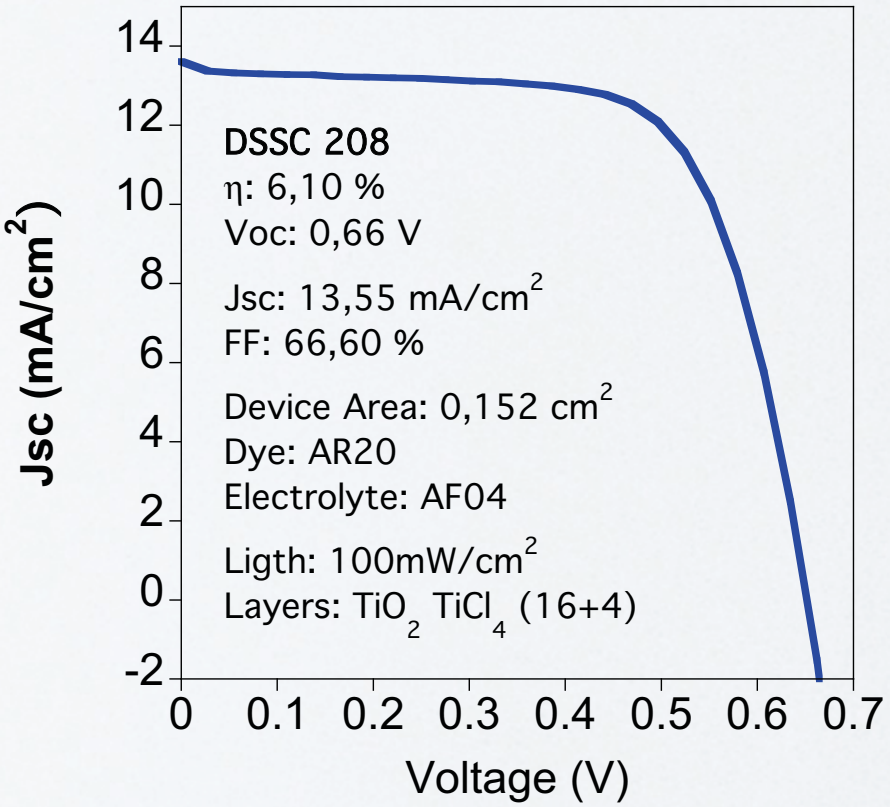
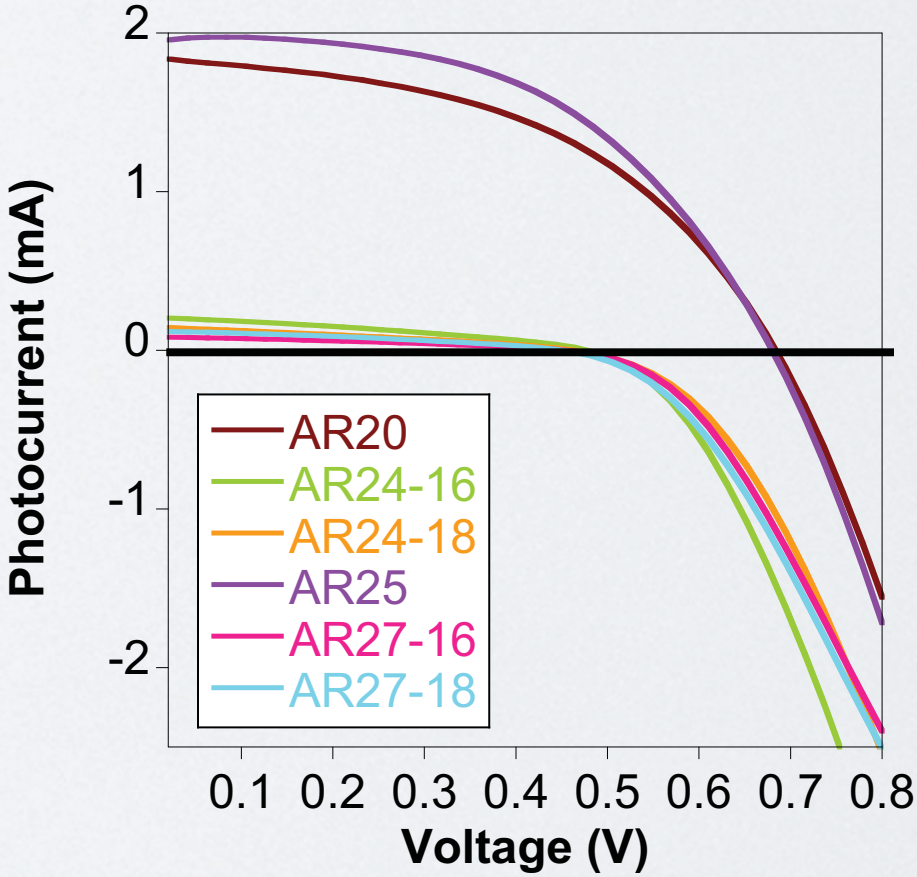




Dye Sensitised Solar Cells

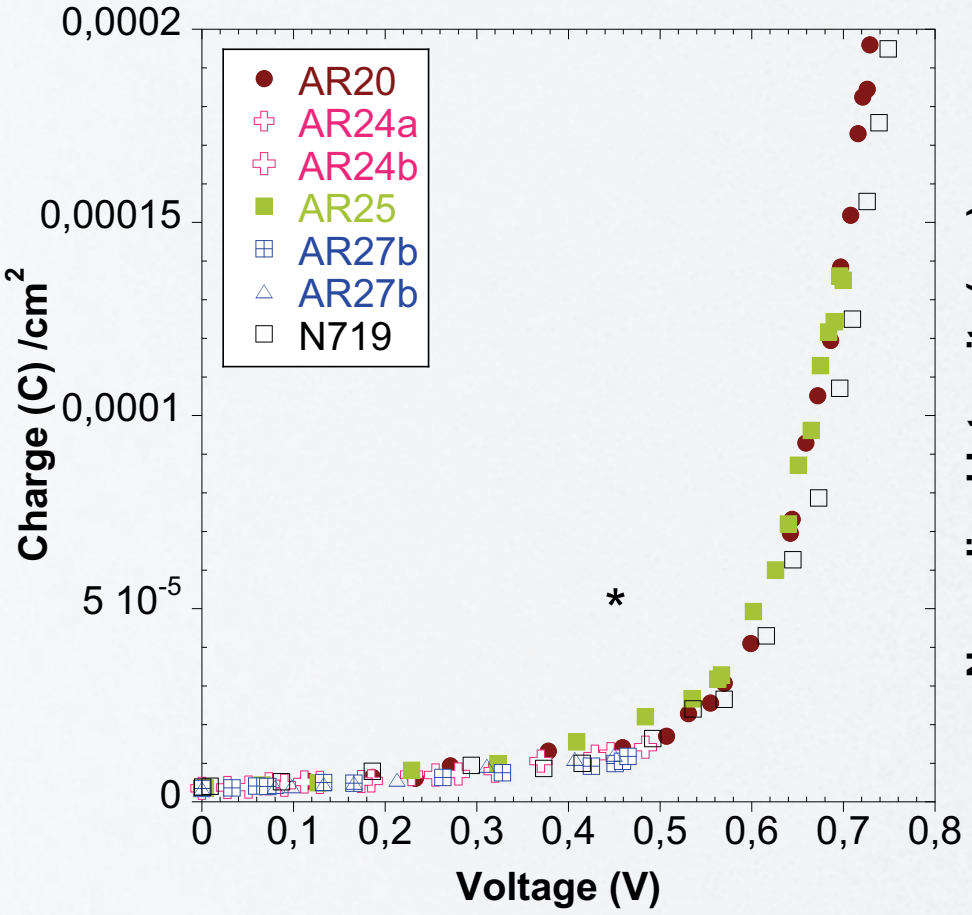
Cell Characterisation

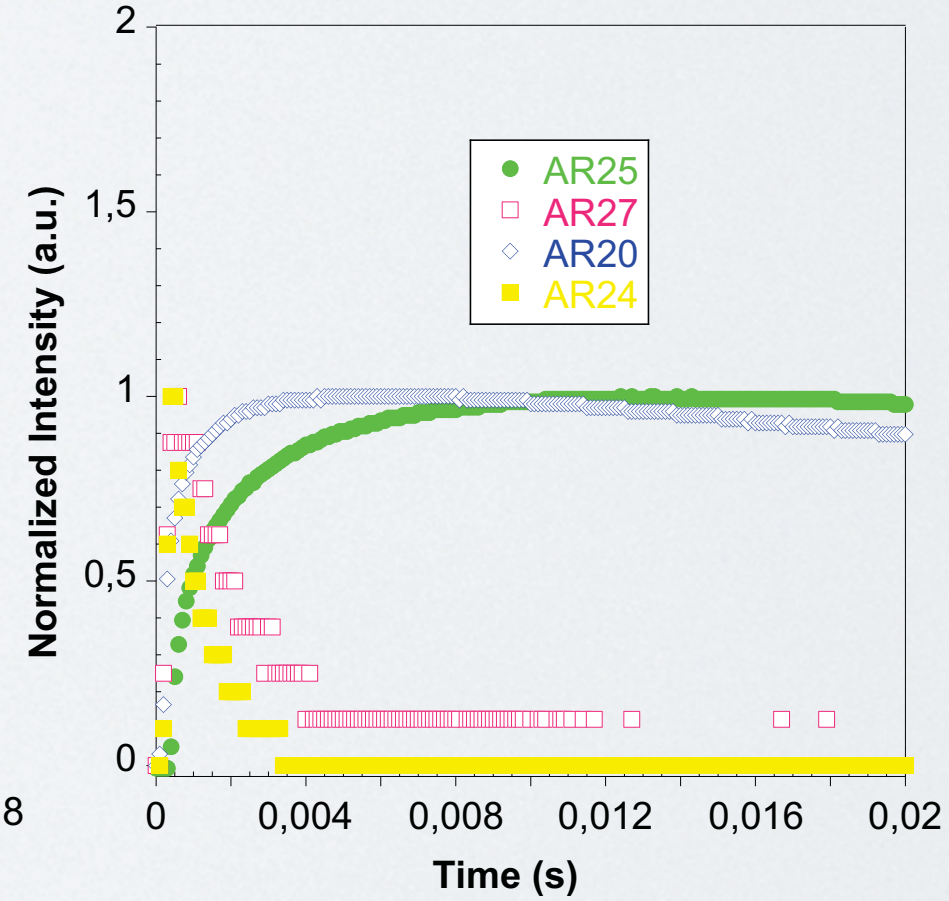




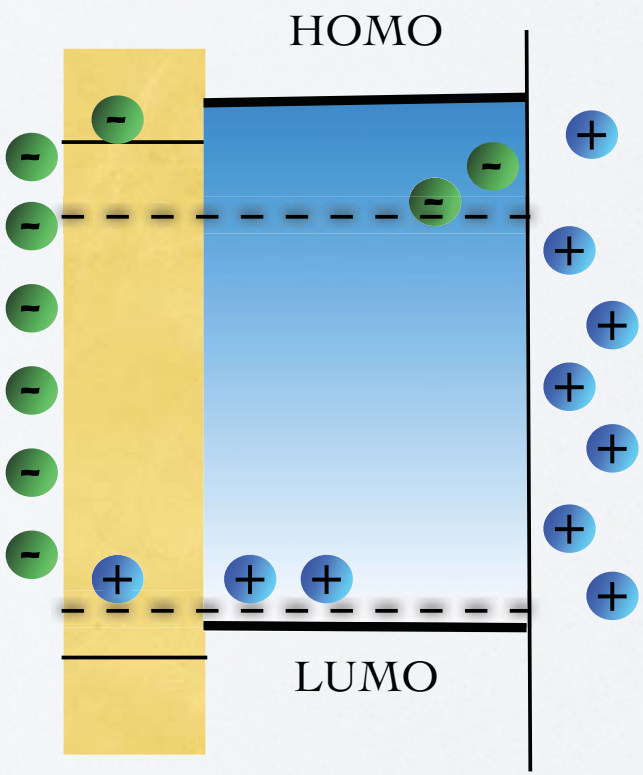
Dye Sensitised Solar Cells

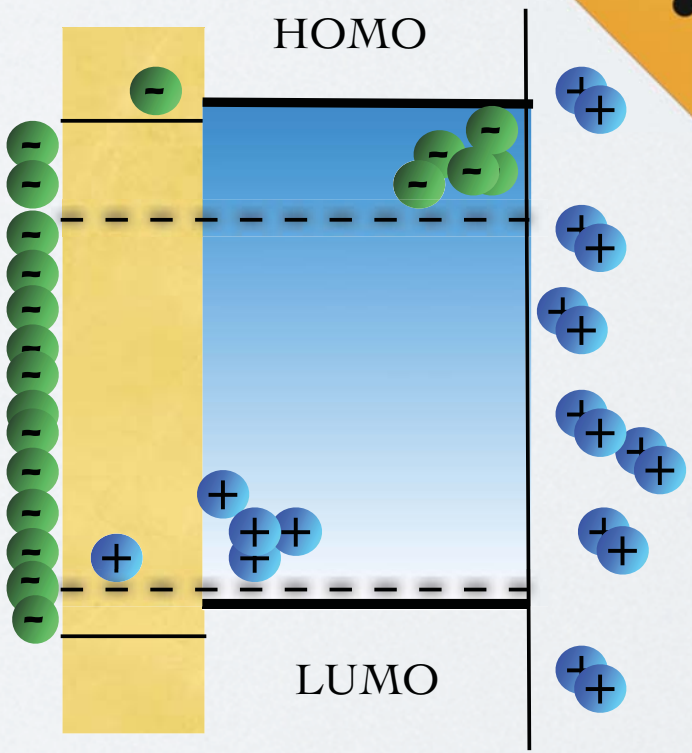
e^--TiO_2/Electrolyte$^+$ Recombination





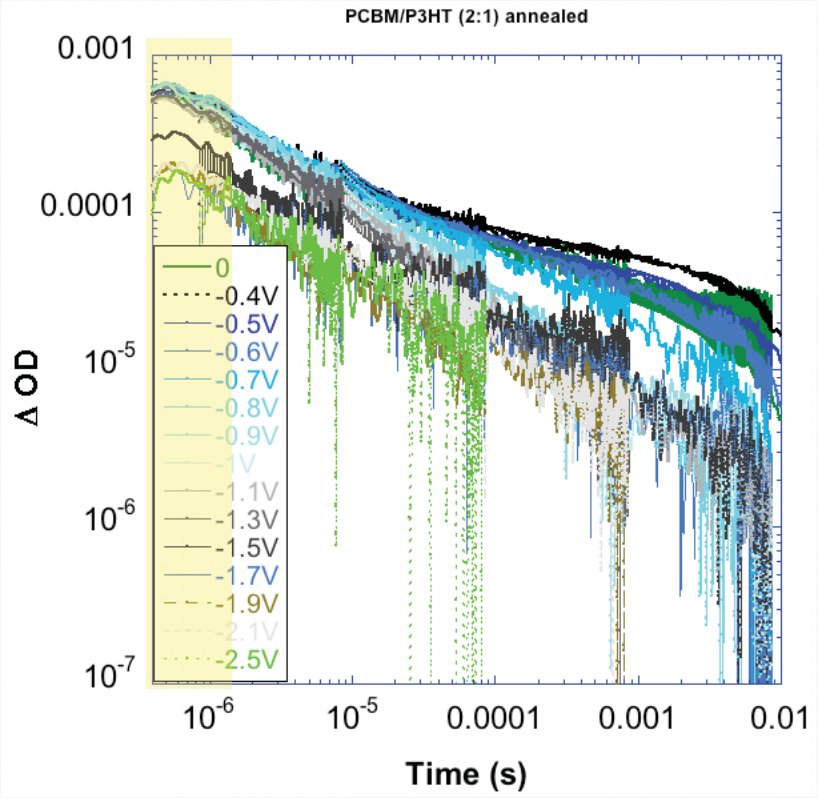
Organic solar cells



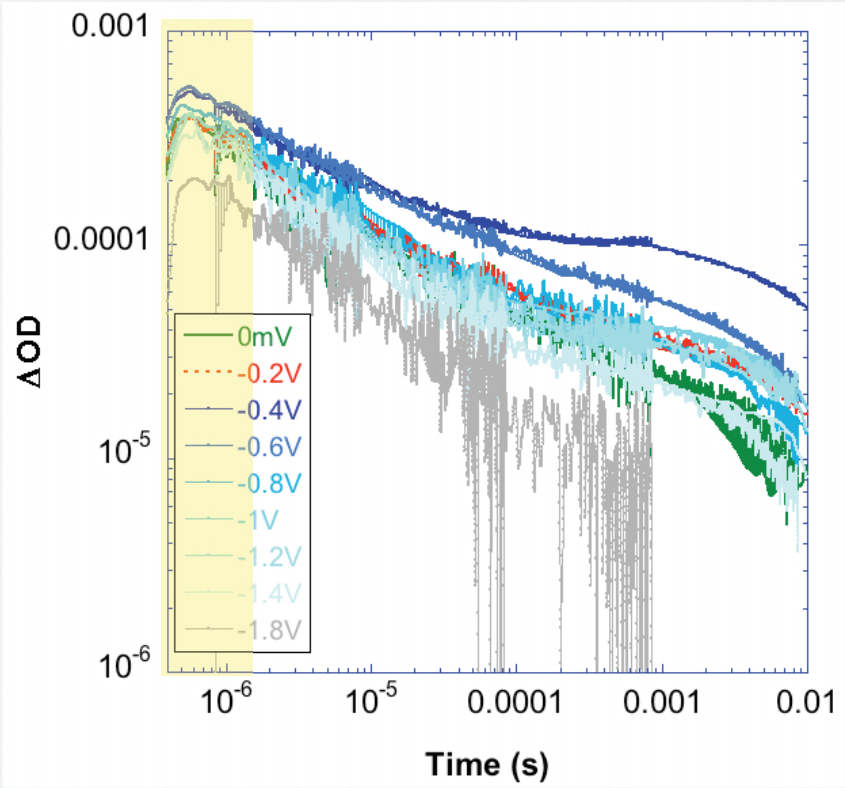


Organic solar cells

P3HT/PCBM

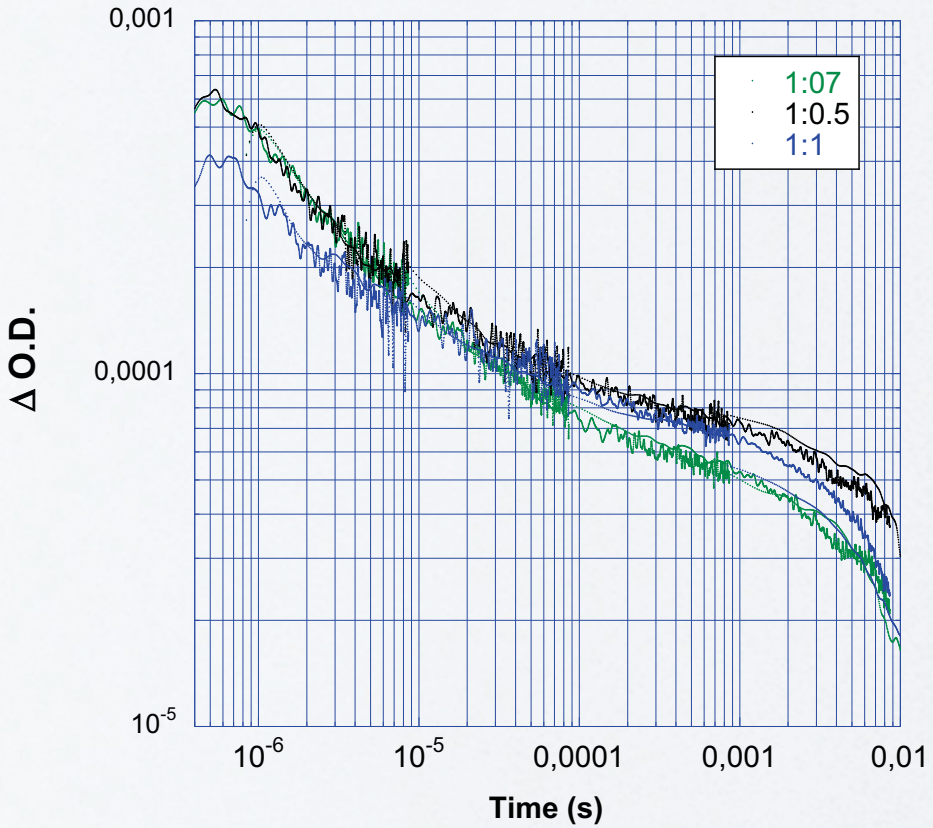


d-TiO_2/ P3HT/PCBM



Organic solar cells

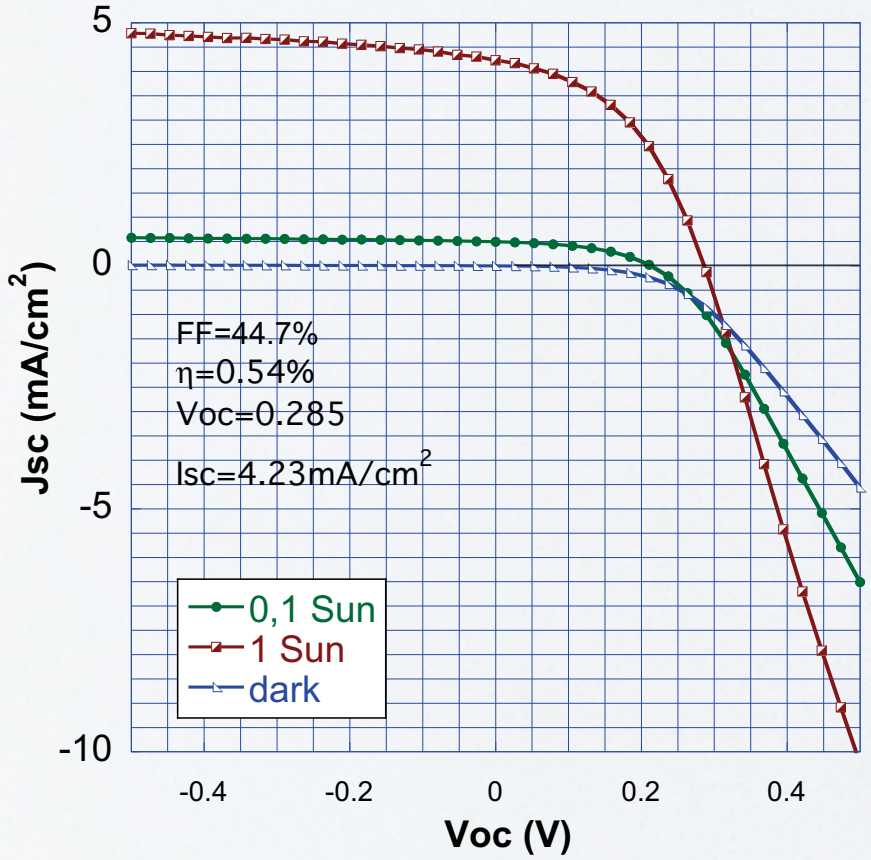
P3HT/PCBM

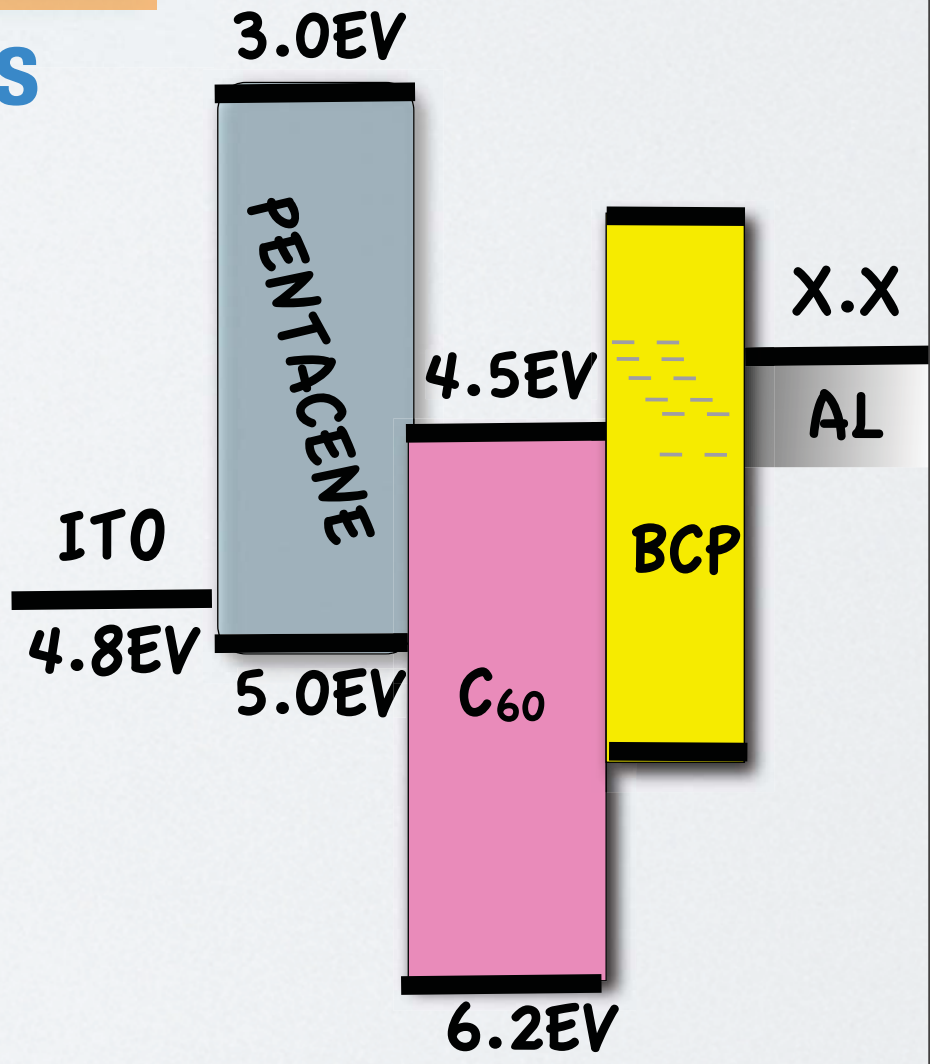


Charge recombination dynamics dependent on P3HT/PCBM ratio

Organic solar cells

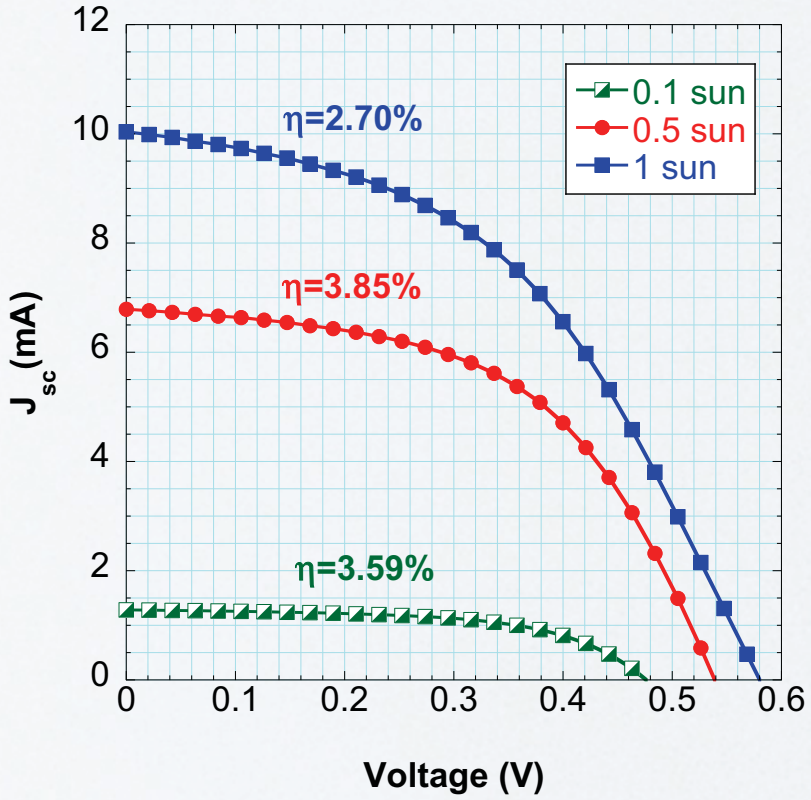
ITO/pentacene/C_{60}/BCP/Al

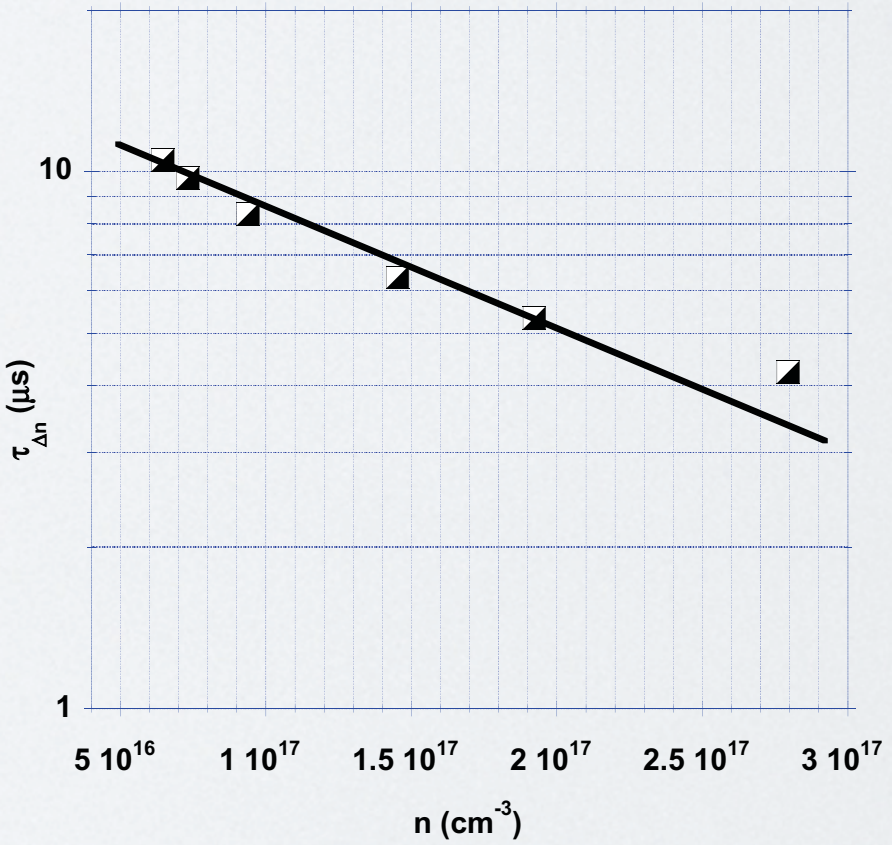




Organic solar cells

ITO/C_{60}: ZnPc/DINPB/NDP2-DiNPB/NDP2-ZnPc/Au/Ag/Au





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- Research Group Members and collaborators

- Funding Agencies

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