Features of light to current transformations in organic devices

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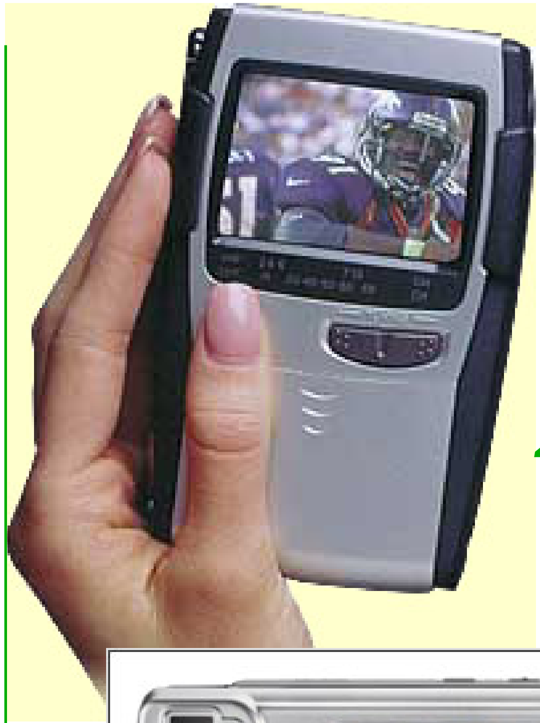
Photovoltaic effect
Auger Fountain electroluminescence

Polymer screens

Seiko-Epson / CDT
June 2000

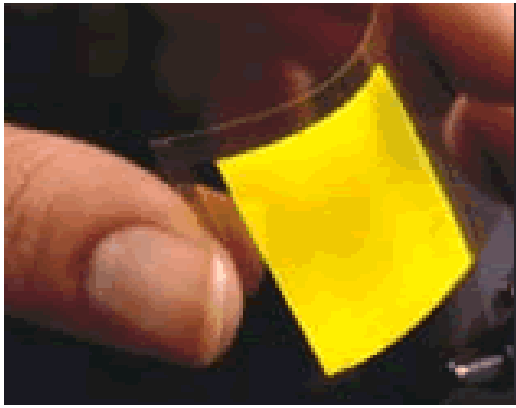


2001

KODAK

2004

Dupont / Uniax, US



Sanyo, Japan

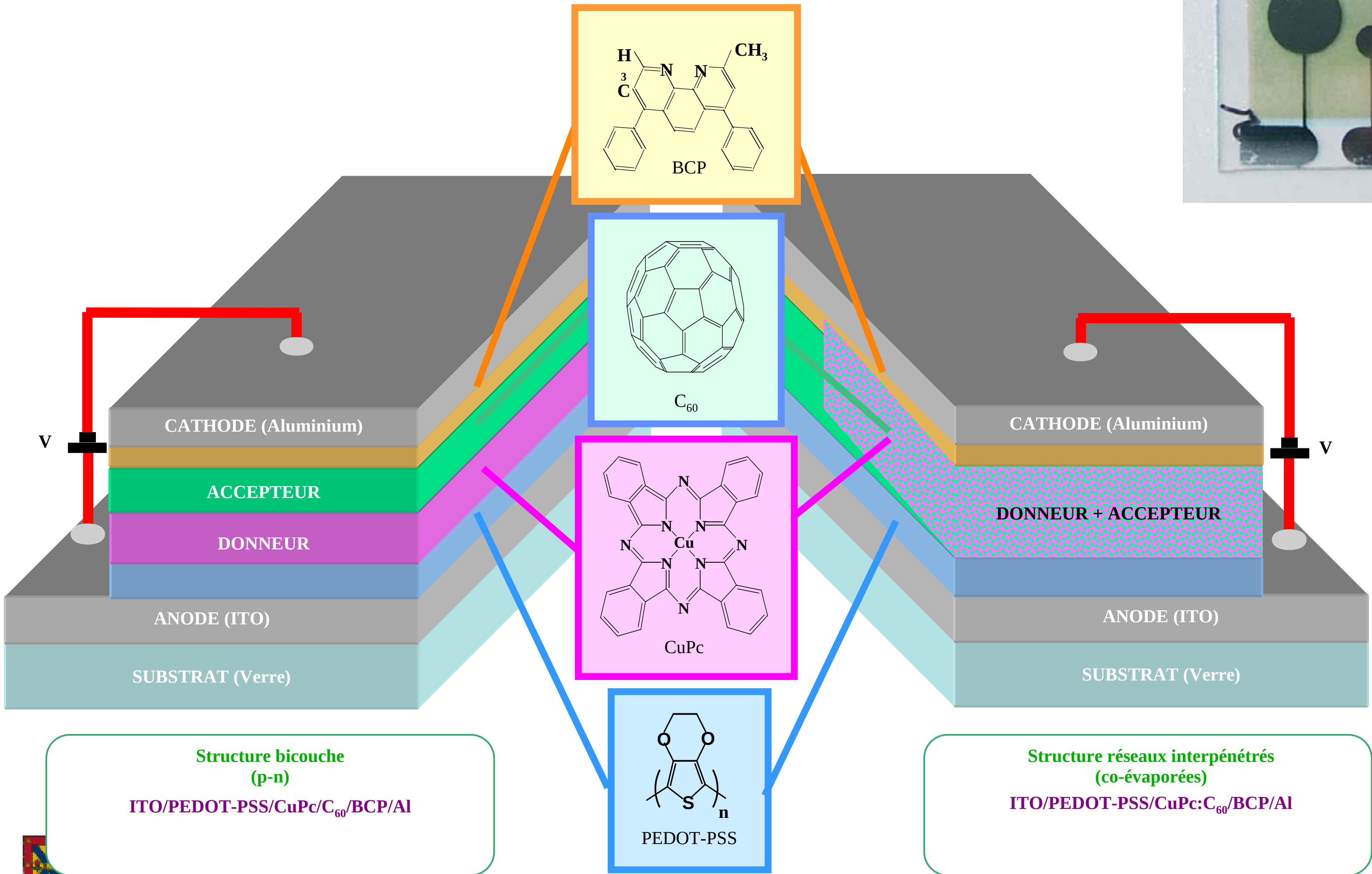
Toshiba, Japan

Siemens, Germany

COVION, Germany

DEL polymère sur substrat souple

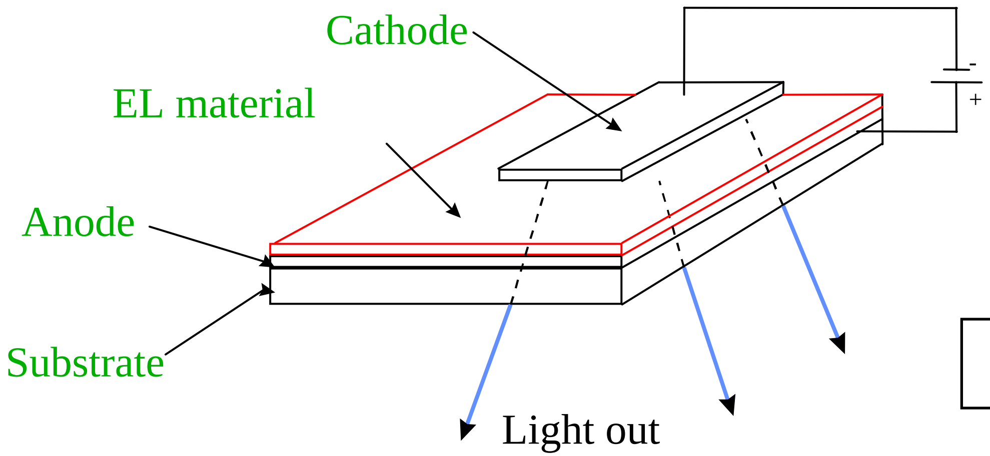
Device structure
Interfaces and junction

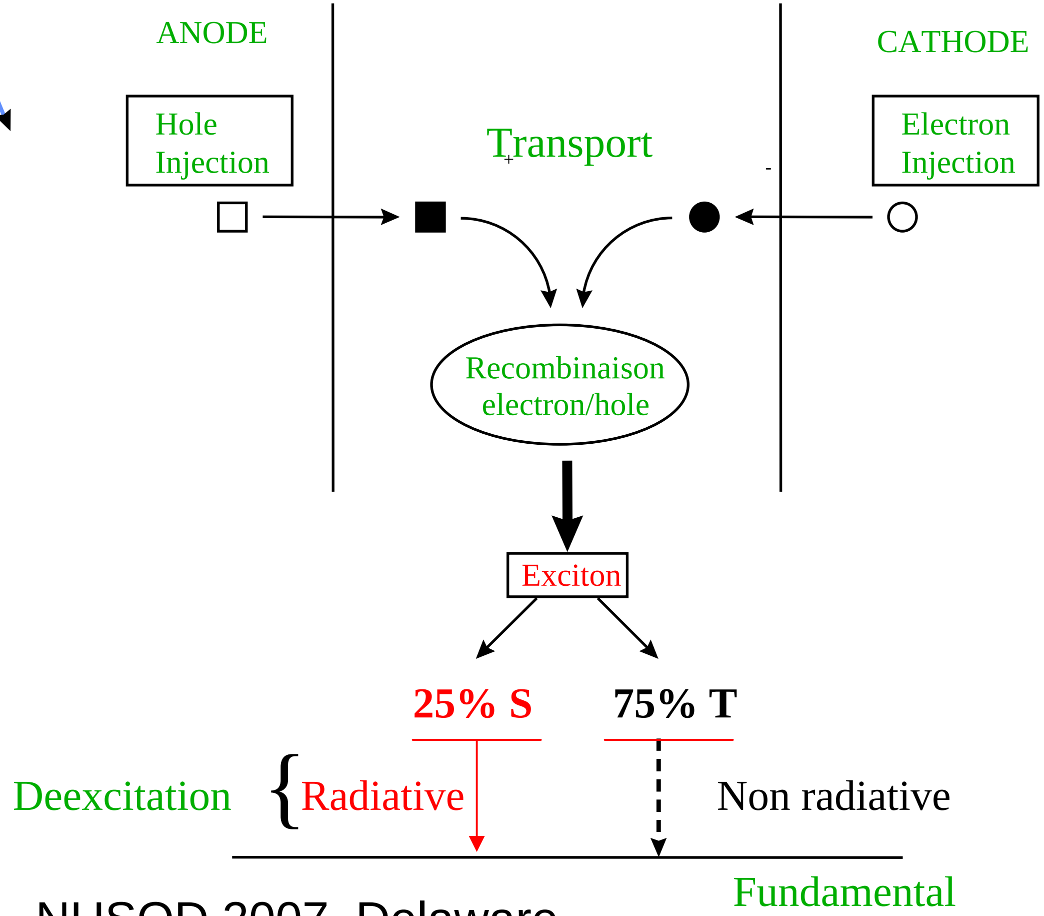


Structure bicouche
(p-n)
ITO/PEDOT-PSS/CuPc/C_{60}/BCP/Al

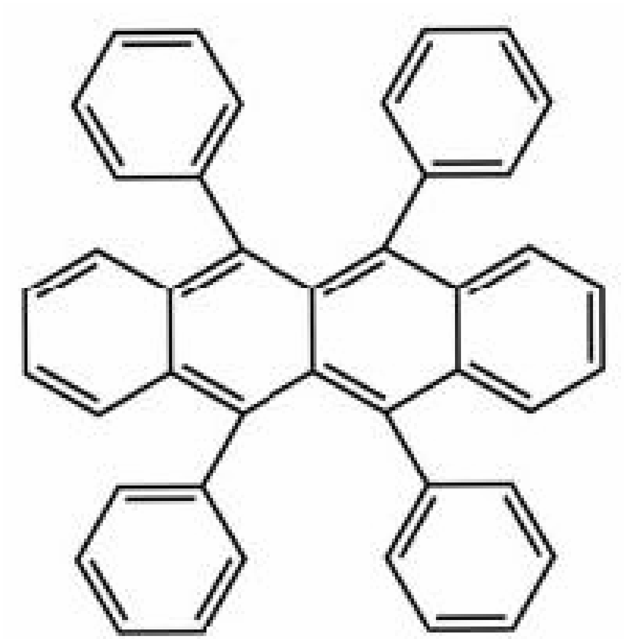
Structure réseaux interpénétrés
(co-évaporées)
ITO/PEDOT-PSS/CuPc:C_{60}/BCP/Al

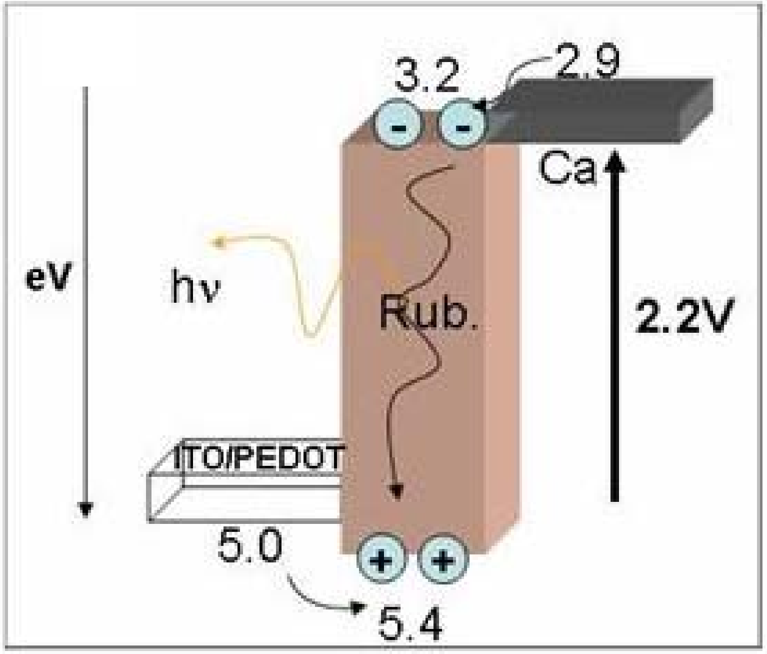
Working principles

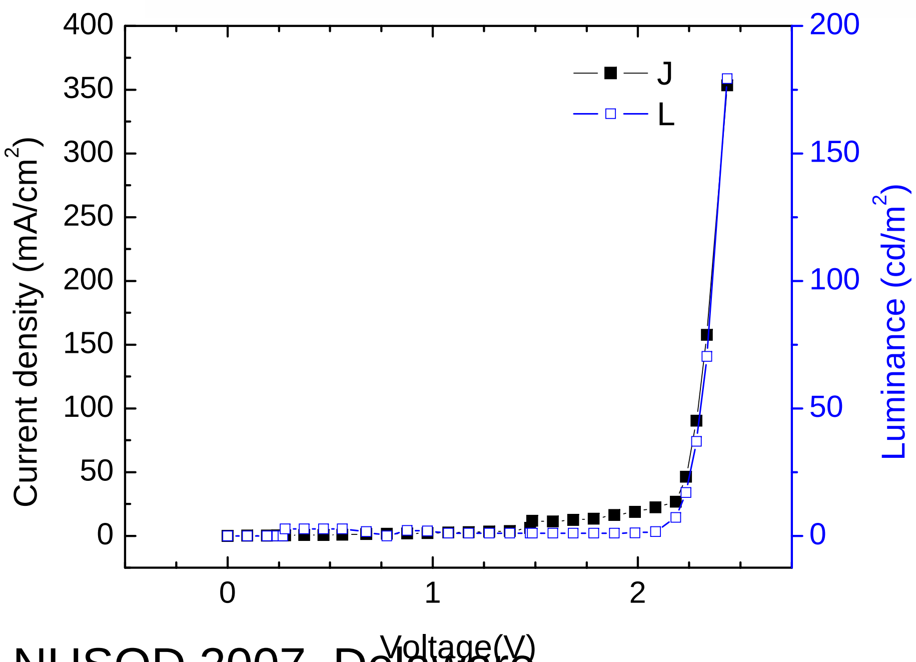




Rubrene LED



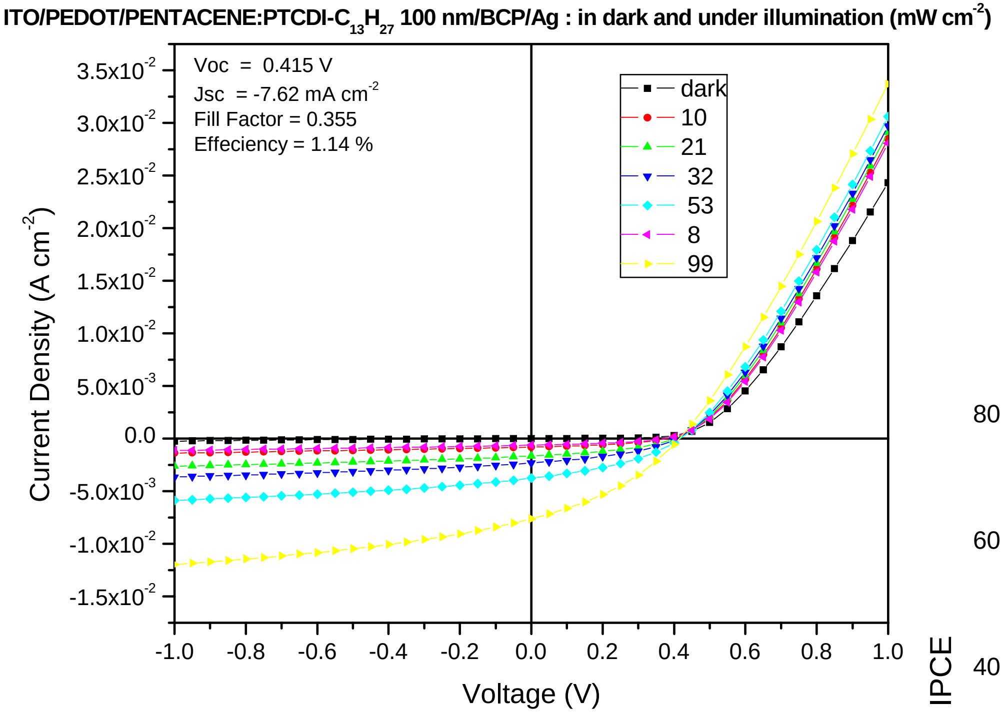


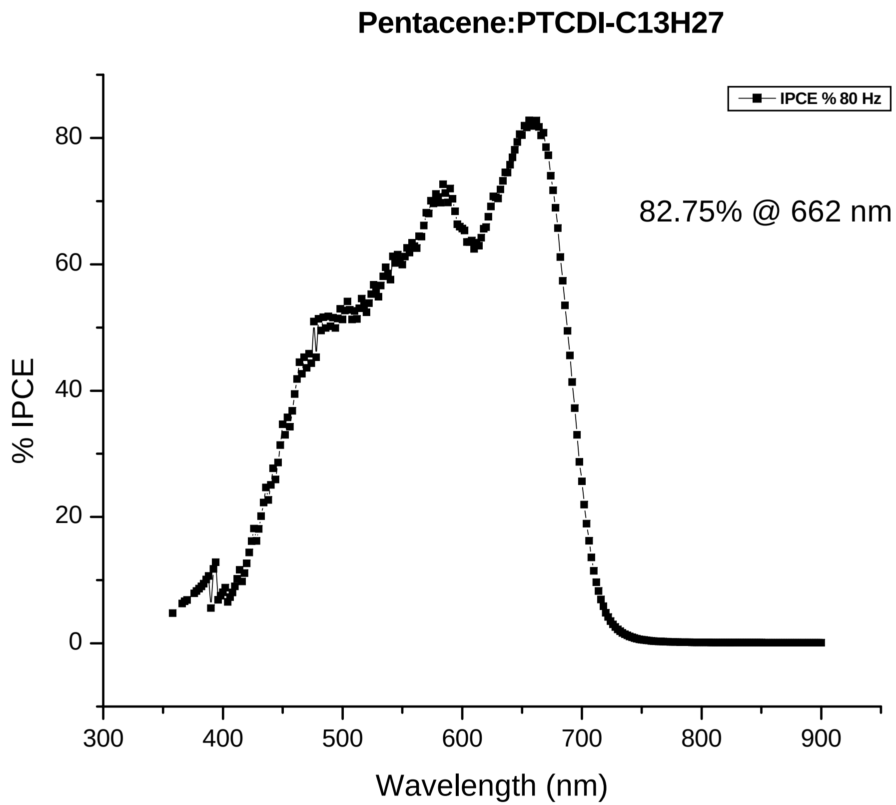


Low-threshold EL

NUSOD 2007, Delaware

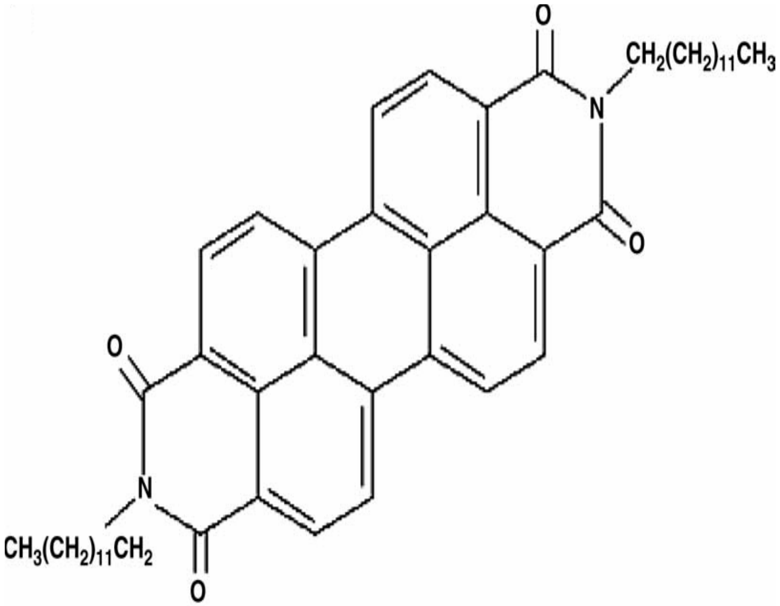
Pac:PTCDI cell - about 2% eff

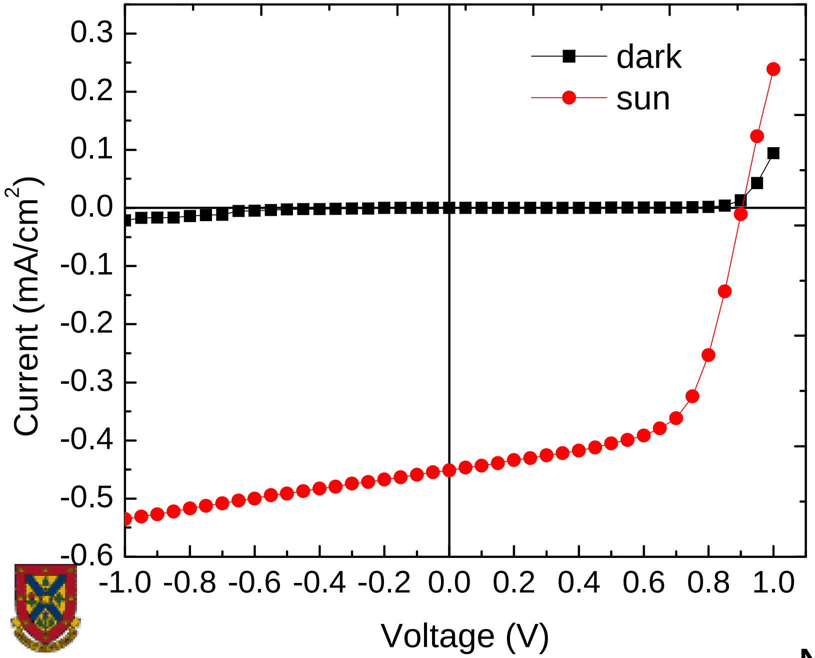


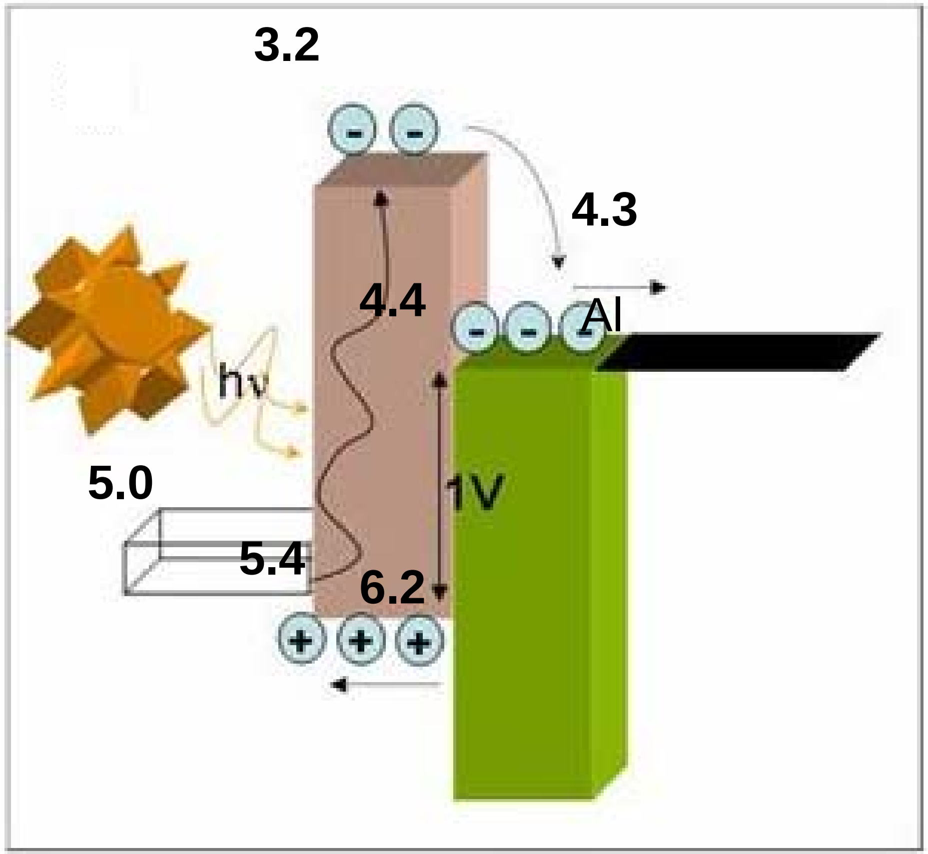


APL 89, 113506, 2006

Rubrene / PDI solar cell

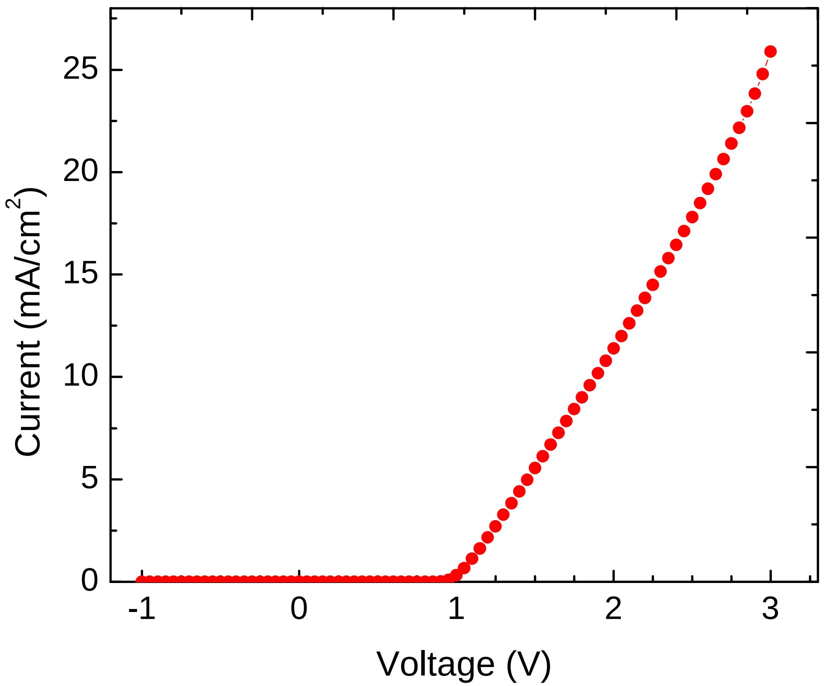


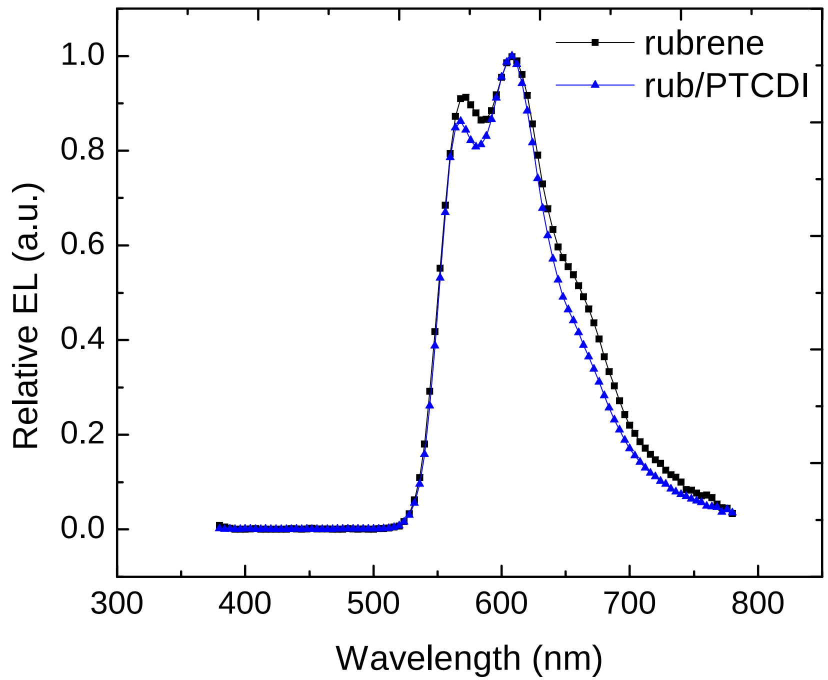




Large V_{OC} PV cell

Rubrene / PDI solar cell in dark under higher fw bias





Same light as Rubrene LED
But injection and EL start at 1V!

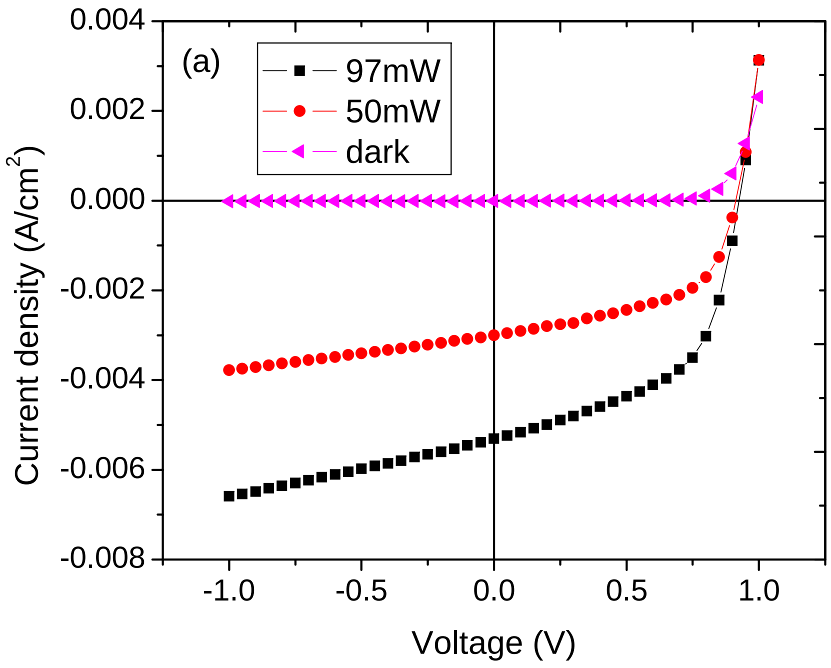
New up-conversion mechanism?

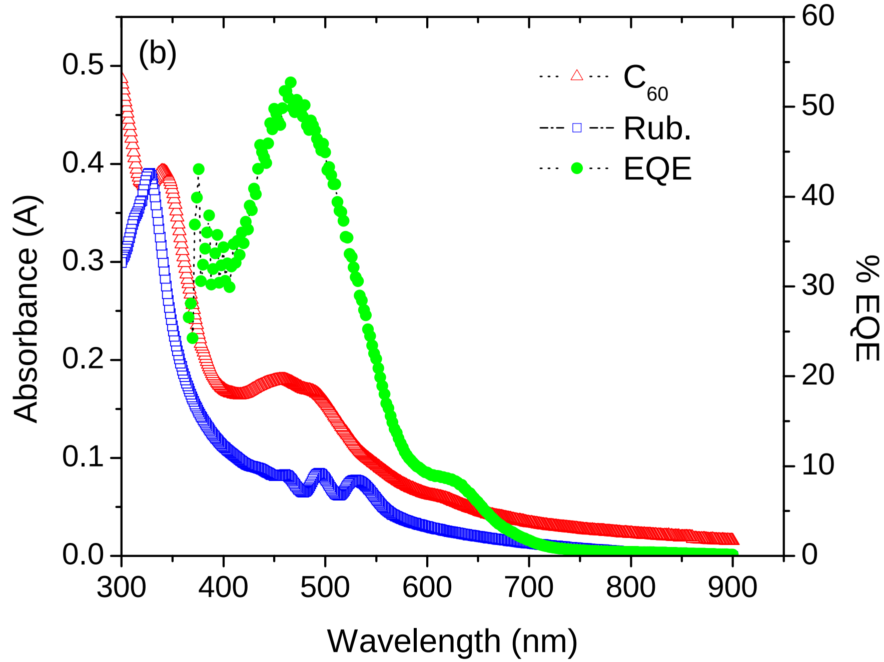
Ajay Pandey, Appl. Phys. Lett. (2007)

Queen's UNIVERSITY

NUSOD 2007, Delaware

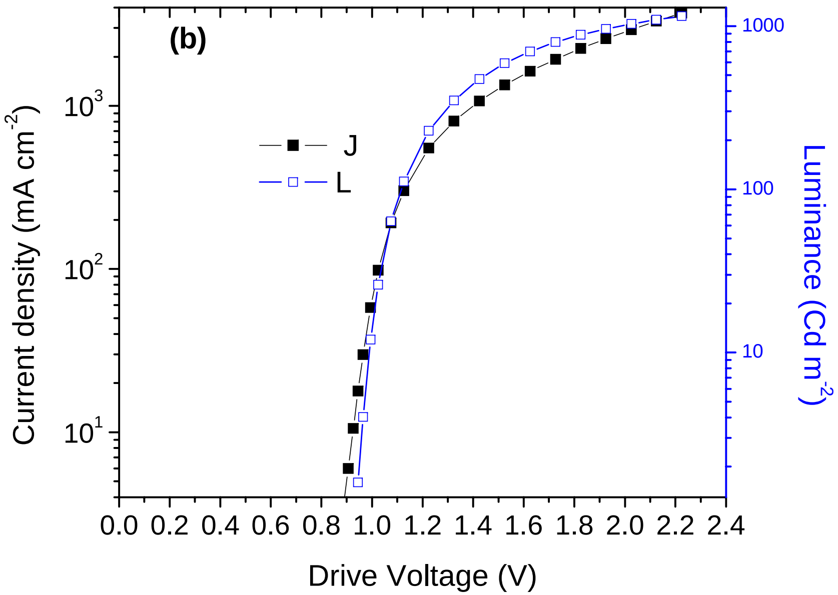
Rubrene / C_{60} device

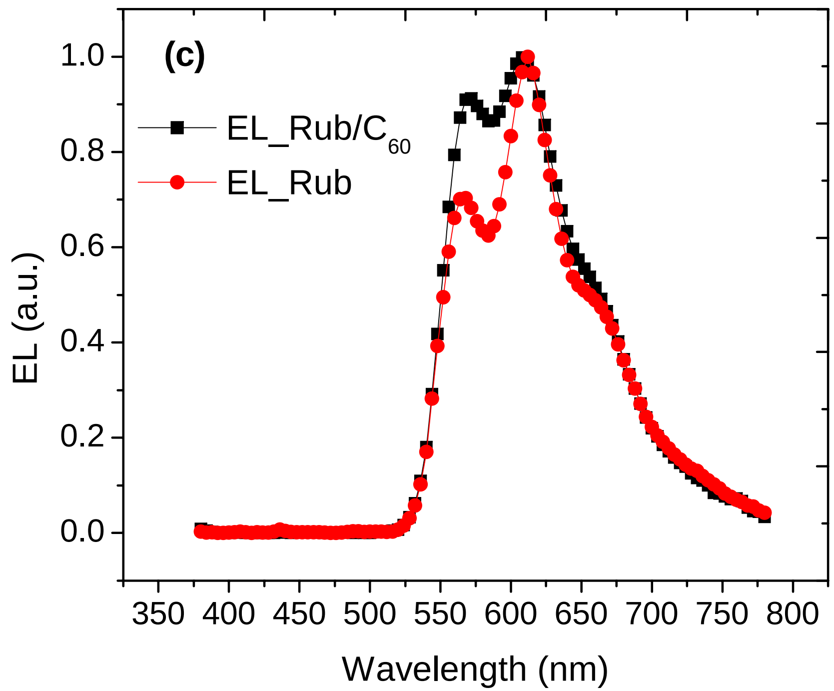




Good PV features (2.9% AM 1.5)

Rubrene / C60 device





Amaizing EL feature:

EL threshold ≈ PV V_{OC}

Adv. Mater – in press

Auger fountain up-conversion mechanism in heterostructures

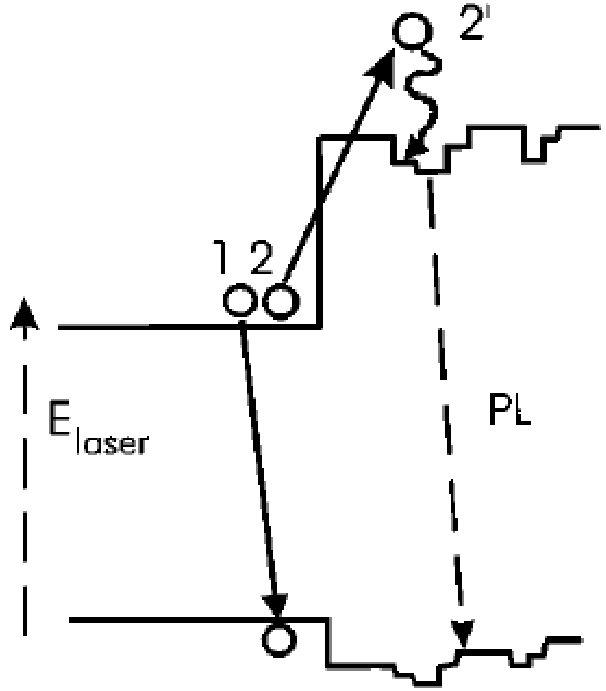
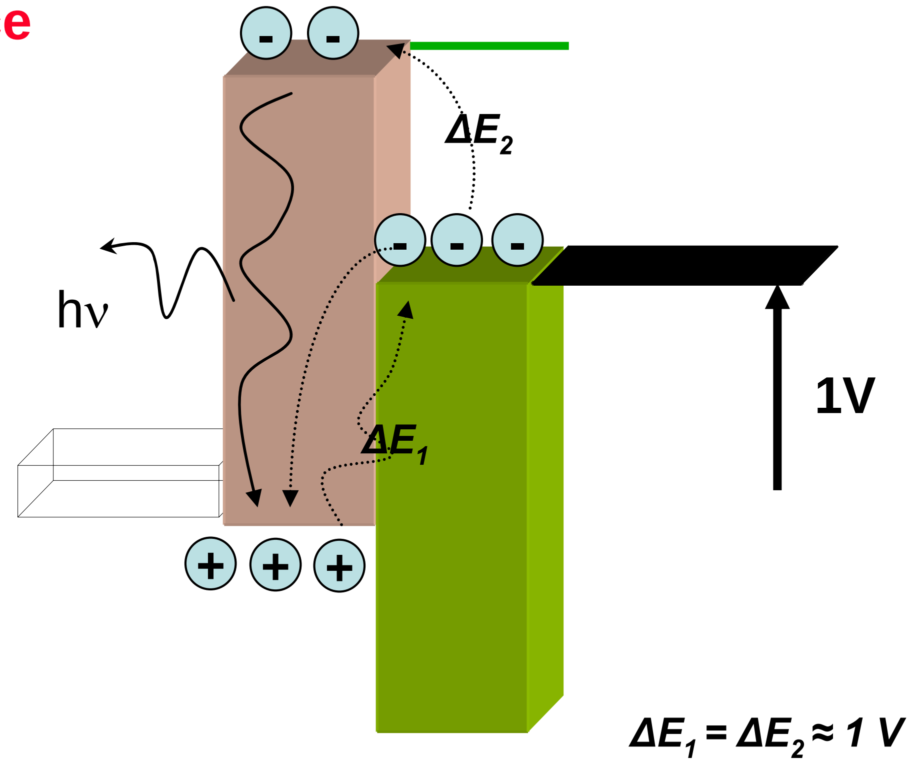


FIG. 2. Sketch of the cold Auger process at the GaAs/ $GaInP_2$ interface, carrier cooling and trapping, and PL from the $GaInP_2$ with its composite structure.

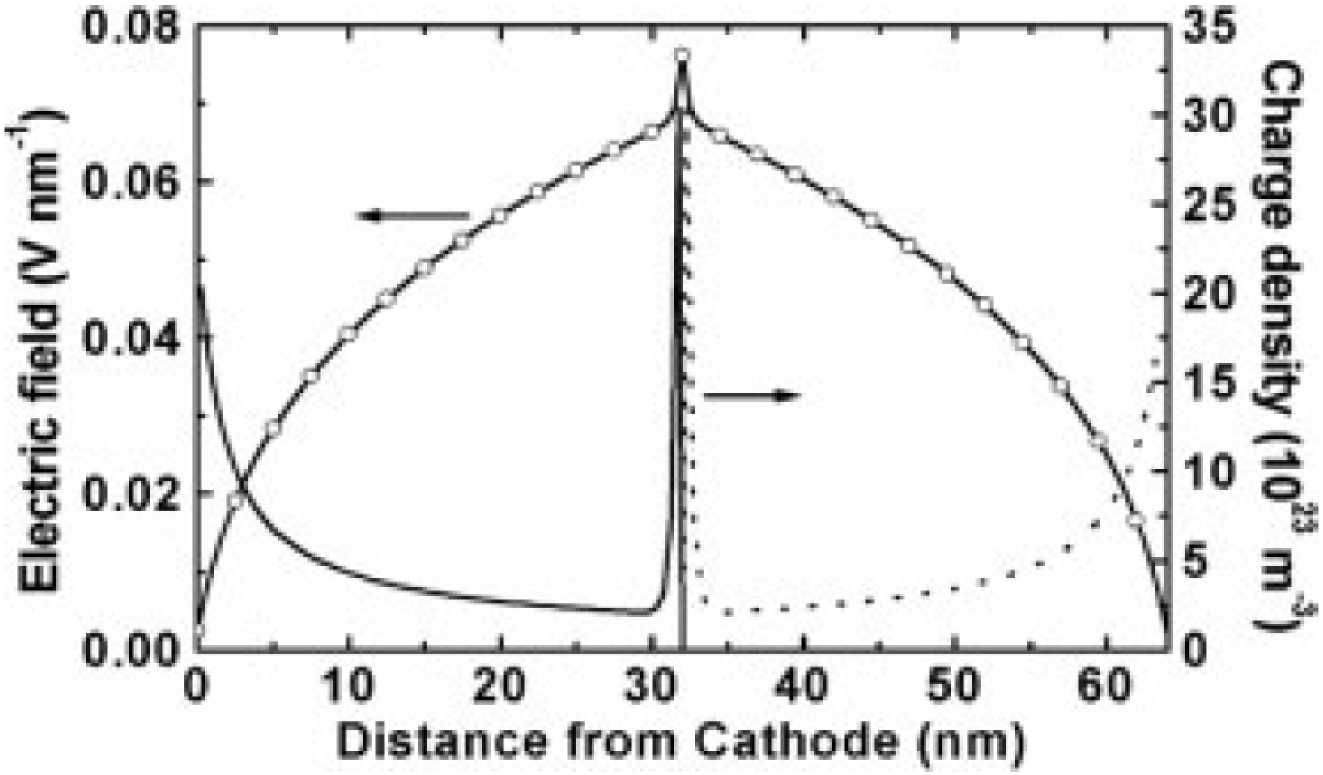
F. A. J. M. Driessen, Appl. Phys. Lett. **67** (1995) ware

Auger fountain electroluminescence



- Charges of both signs accumulate at the interface under 1V-bias
- (-) from C_{60} recombine with (+) from rubrene, exciting CT interface states
- Energy stored at the interface is subsequently transferred to an electron in C_{60}
- Electron is <u>resonantly</u> excited up to the LUMO of rubrene
- Electron recombines radiatively with a hole in the rubrene layer

Charge density & E-field



A.C. Morteani et al., *Adv. Mater*. 2003, 15, 1708

Current density $j = n.q.\mu.E$ across the device is a constant

No net charges cross:

rate of bimolecular recombination per unit surface is exactly $B = j/q$.

Rate R of electron up-conversion to the LUMO of rubrene estimated as:

B times cross section σ of the energy exchange

X life-time τ of exciplex

X flux on electrons to interface j/q.

That is $R \approx B.\sigma\tau.j/q$.

External quantum efficiency η_{EQE} of up-converted EL is

$$\eta_{EQE} \approx R.\ \eta_{EL} / (j/q) = B.\sigma\tau\eta_{EL}$$

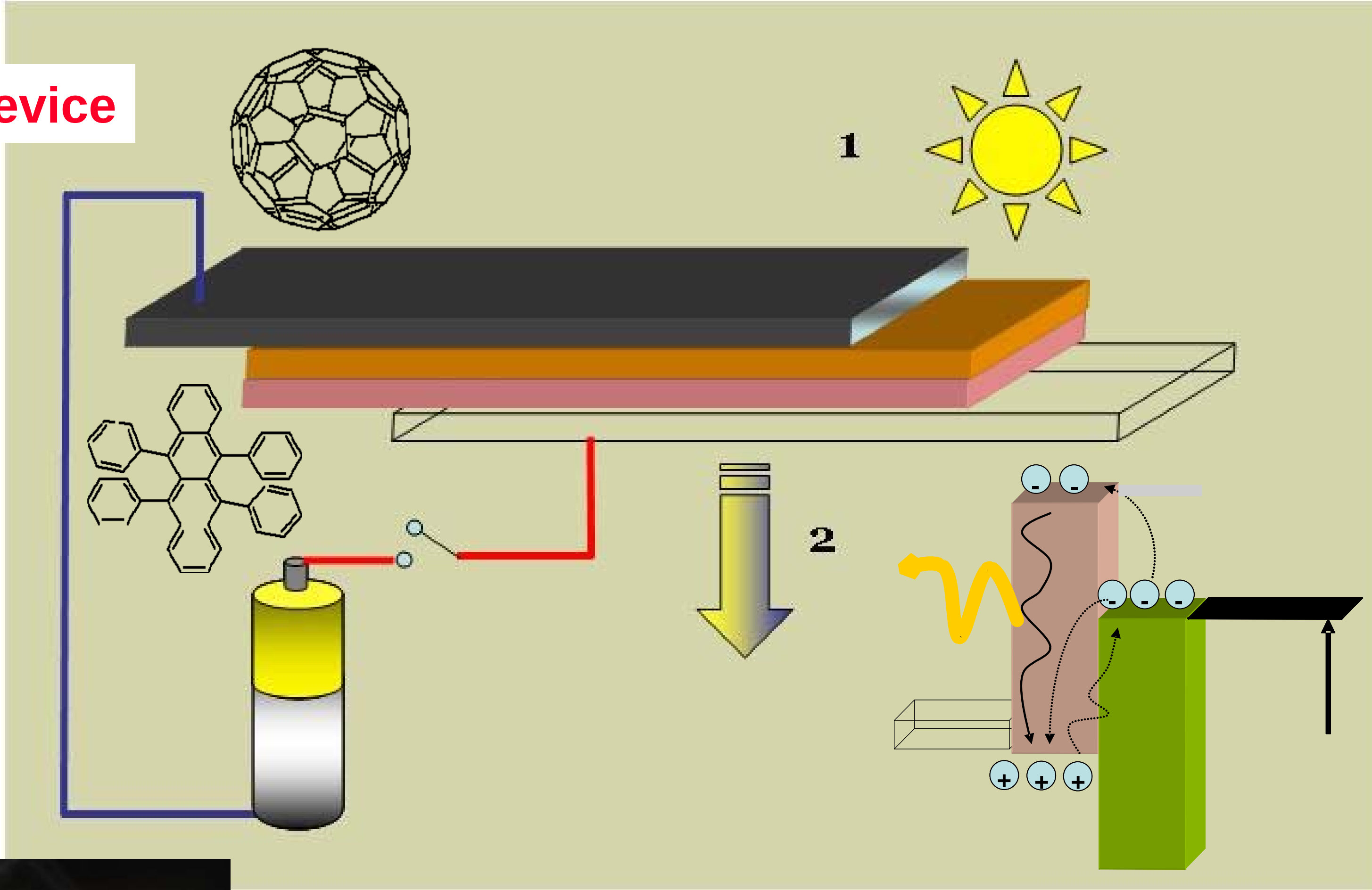
We find experimentally $\eta_{EQE} = 10^{-4}$ when $j = 1\ A/cm^2$.

$\eta_{EL} = 10^{-2}$, is external coupling efficiency rubrene thin film

We finally get CT exciplex $\sigma\tau \approx 1.6\ 10^{-21}\ cm^2s$ and $\sigma = 10^{-14}\ cm^2$

That yields $\tau \approx 10^{-7}$ s

Organic Dual Device



Organic materials can be taylored to achieve better functionalities

Acknowledgments: U-Angers, ANR, EC
CRC, NSERC, Faculty of Arts and Sciences at Queen’s U