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
Dupont / Uniax, US

Toshiba, Japan

Siemens, Germany

COVION, Germany

DEL polymère sur substrat souple

07, Delaware
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

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Working principles

- **Anode**
- **Substrate**
- **Cathode**
- **EL material**

**ANODE**
- **Hole Injection**

**CATHODE**
- **Electron Injection**

**Transport**

**Recombination electron/hole**

**Exciton**

**Deexcitation**
- **Radiative**
- **Non radiative**

**Fundamental**

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Rubrene LED

Low-threshold EL

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Pac:PTCDI cell - about 2% eff

Properties:
- Voc = 0.415 V
- Jsc = -7.62 mA cm$^{-2}$
- Fill Factor = 0.355
- Efficiency = 1.14%

ITO/PEDOT/PENTACENE:PTCDI-C$_{13}$H$_{27}$ 100 nm/BCP/Ag: in dark and under illumination (mW cm$^{-2}$)

**Graph:**
- Current Density (A cm$^{-2}$) vs. Voltage (V)
- IPCE% vs. Wavelength (nm)

**Results:**
- 82.75% IPCE @ 662 nm

**References:**
- APL 89, 113506, 2006
Rubrene / PDI solar cell

![Rubrene molecule]

![Diagram of PV cell]

**Current (mA/cm²)**

- dark
- sun

**Voltage (V)**

Large $V_{oc}$ PV cell

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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?

Rubrene / C$_{60}$ device

Good PV features (2.9% AM 1.5)
Amaizing EL feature:

EL threshold $\approx$ PV $V_{OC}$

Adv. Mater – in press

Rubrene / C60 device
Auger fountain up-conversion mechanism in heterostructures

FIG. 2. Sketch of the cold Auger process at the GaAs/ GaInP₂ interface, carrier cooling and trapping, and PL from the GaInP₂ with its composite structure.

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 resonantly excited up to the LUMO of rubrene
- Electron recombines radiatively with a hole in the rubrene layer
Charge density & E-field

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 $\sigma$ of the energy exchange
  X life-time $\tau$ of exciplex
  X flux on electrons to interface $j/q$.
That is $R \approx B.\sigma\tau.j/q$.

External quantum efficiency $\eta_{\text{EQE}}$ of up-converted EL is

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

We find experimentally $\eta_{\text{EQE}} = 10^{-4}$ when $j = 1$ A/cm$^2$.
$\eta_{\text{EL}} = 10^{-2}$, is external coupling efficiency rubrene thin film
We finally get CT exciplex $\sigma\tau \approx 1.6 \times 10^{-21}$ cm$^2$s and $\sigma = 10^{-14}$ cm$^2$
That yields $\tau \approx 10^{-7}$ s
Organic Dual Device
Organic materials can be tailored to achieve better functionalities

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