

Les diodes électroluminescentes organiques ou l'émergence de l'électronique organique

Matériaux, dispositifs et applications

Bernard GEFROY

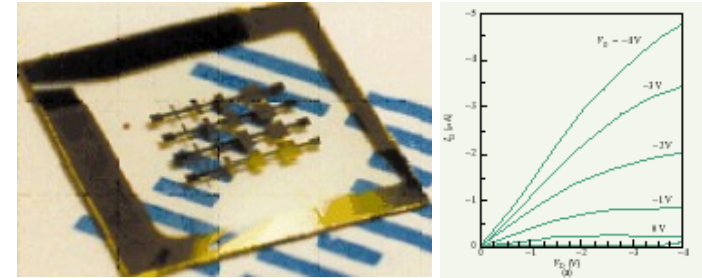
Laboratoire Composants Hybrides

CEA/DRT/LITEN/DTNM

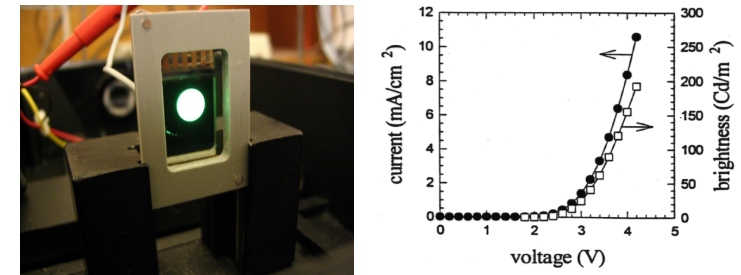
CEA/SACLAY 91191 GIF Sur YVETTE

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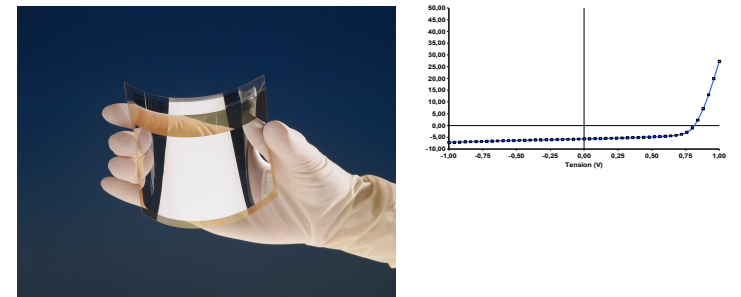
➤ **Les transistors organiques (OTFTs)**



➤ **Les diodes électroluminescentes organiques (OLEDs/PLEDs)**



➤ **Les cellules solaires organiques (OPVs)**



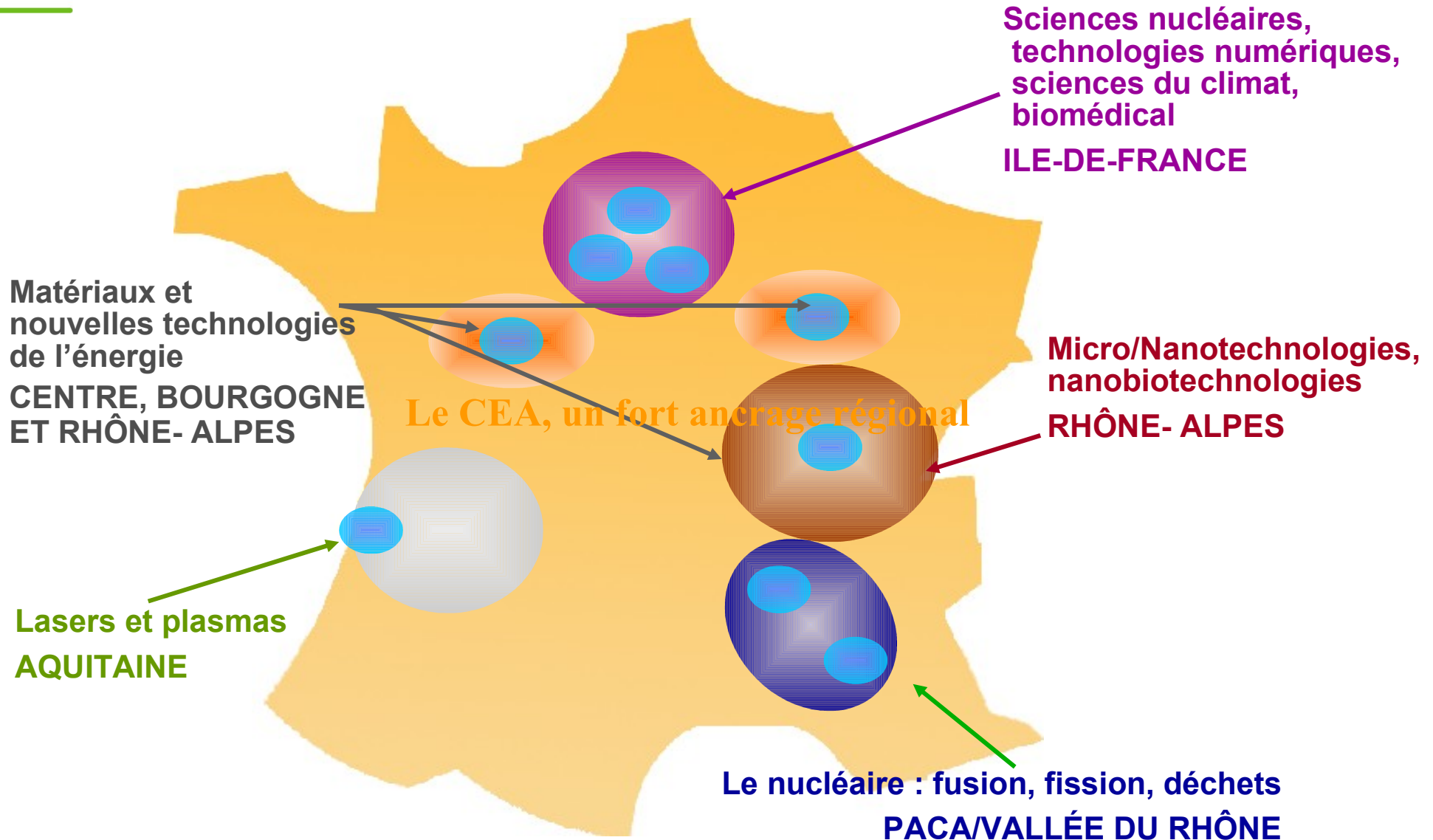
➤ Généralités

➤ Les diodes électroluminescentes organiques

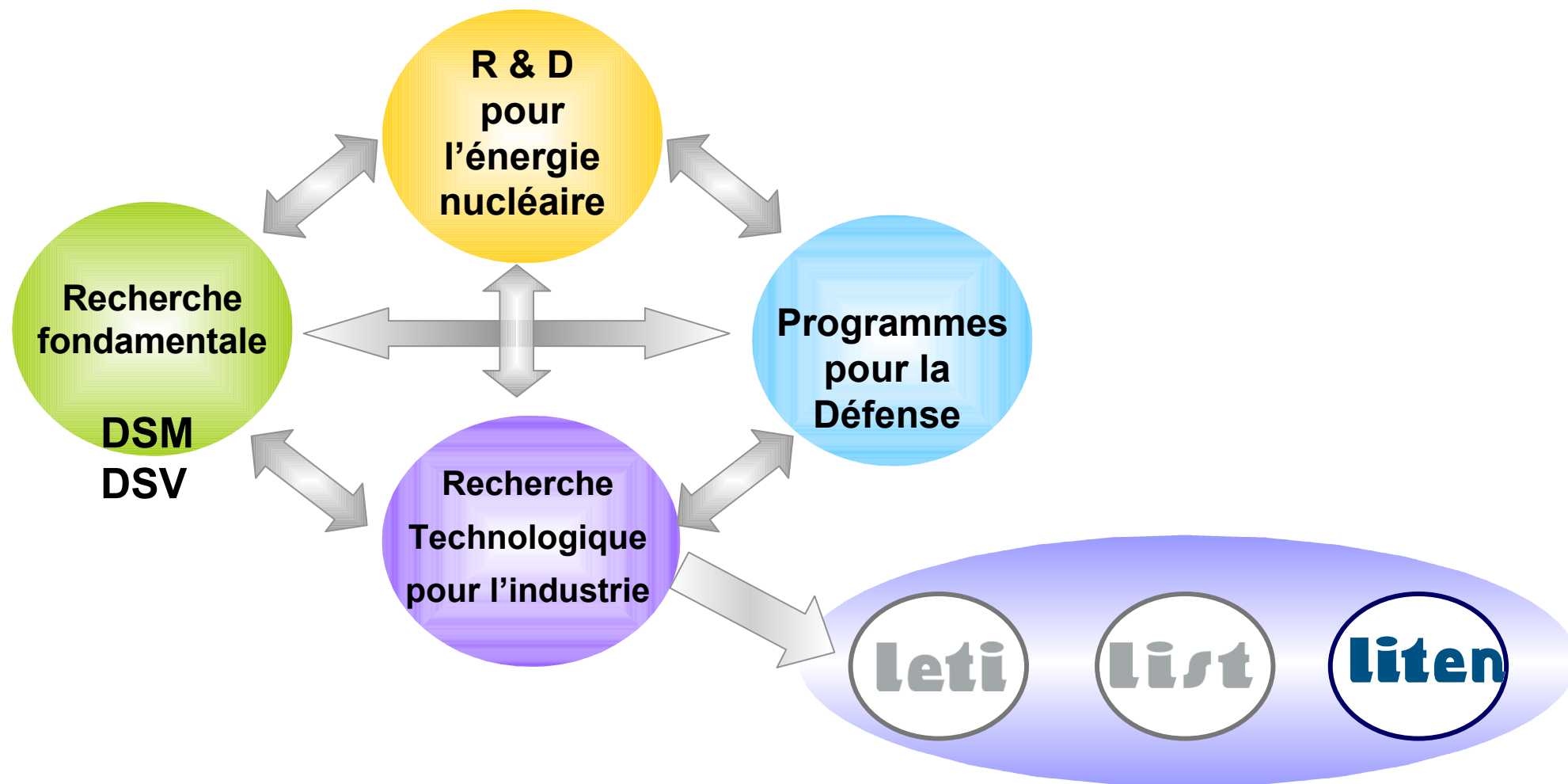
- ✓ Quelques généralités sur les matériaux organiques
- ✓ Principe de fonctionnement des OLEDs
- ✓ Dispositifs et matériaux électroluminescents organiques
- ✓ Adressage des écrans OLEDs
- ✓ Réalisation de dispositifs couleurs
- ✓ Techniques de dépôt des matériaux organiques
- ✓ Démonstrateurs et réalisations industrielles
- ✓ Application à l'éclairage

➤ Conclusions

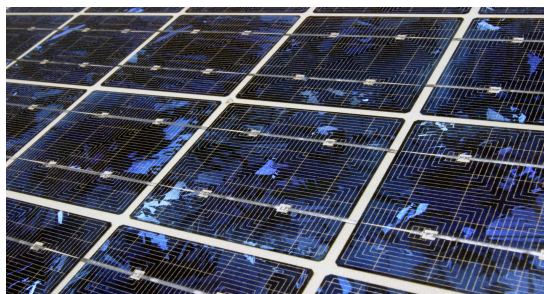
Le CEA, un fort ancrage régional



Les quatre missions du CEA



Laboratoire d'Innovation pour les Technologies des Énergies nouvelles et les Nanomatériaux



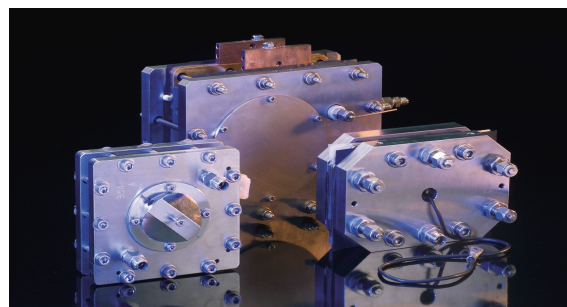
Photovoltaïque et Gestion de l'Énergie pour l'habitat

Le CEA LITEN améliore chaque jour les techniques de maîtrise de l'énergie :
-Résidentiel ou tertiaire
- Vision "système énergétique global".

Cellules PV

- filière silicium
- filière nanocomposites

- Modules PV
- Systèmes
- Stockage de l'énergie



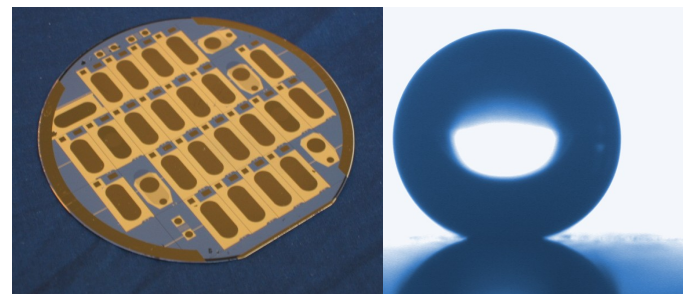
Hydrogène et Pile à combustible pour les transports

Le CEA LITEN développe la filière hydrogène :

- Production
- Transport et stockage

-Conversion

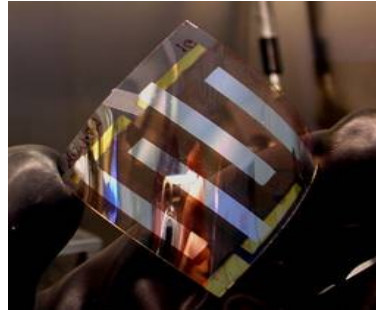
- Production d'hydrogène notamment par électrolyse haute température
- Piles à combustible
 - PEMFC
 - SOFC
- Architecture des systèmes



Nanomatériaux et leur intégration dans l'industrie de pointe

Le CEA LITEN développe les nanomatériaux :

- Synthèse
- Manipulation, sécurité et intégration
- Micro-sources d'énergie à base de nano-objets
 - micro-pile à combustible
 - Micro-batterie
 - Micro générateur thermoélectrique
- Surfaces nanostructurées
 - Énergie de surface
 - Nano-catalyseurs
- Nanopoudres
- Electronique imprimable



Cellule solaire photovoltaïque organique (CEA)



FOLED Universal Display Corporation

Electronique organique (EO)

l'élément actif est un matériau constitué d'une grande assemblée de molécules ordonnées ou non.

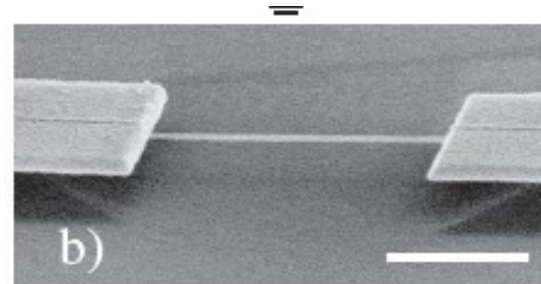
➔ Electronique plastique

i.e. souple, pas nécessairement performante en terme de densité d'intégration, mais facile à produire, **bas coût** et qui vise des applications grand public.

Electronique Moléculaire (EM) basée sur des composants actifs constitués d'un édifice moléculaire : molécule organique (petite molécule, oligomère ou polymère), fullerène, nanotube de carbone ...
L'échelle de ces composants se situe dans la gamme de un à quelques dizaines de nanomètres.

NTC connecté entre deux électrodes métalliques

J. P. Bourgoïn et coll. Phys. Rev. Lett. 95, 185504 (2005)



Source: OMNT Electronique Organique

Les diodes électroluminescentes organiques

Introduction

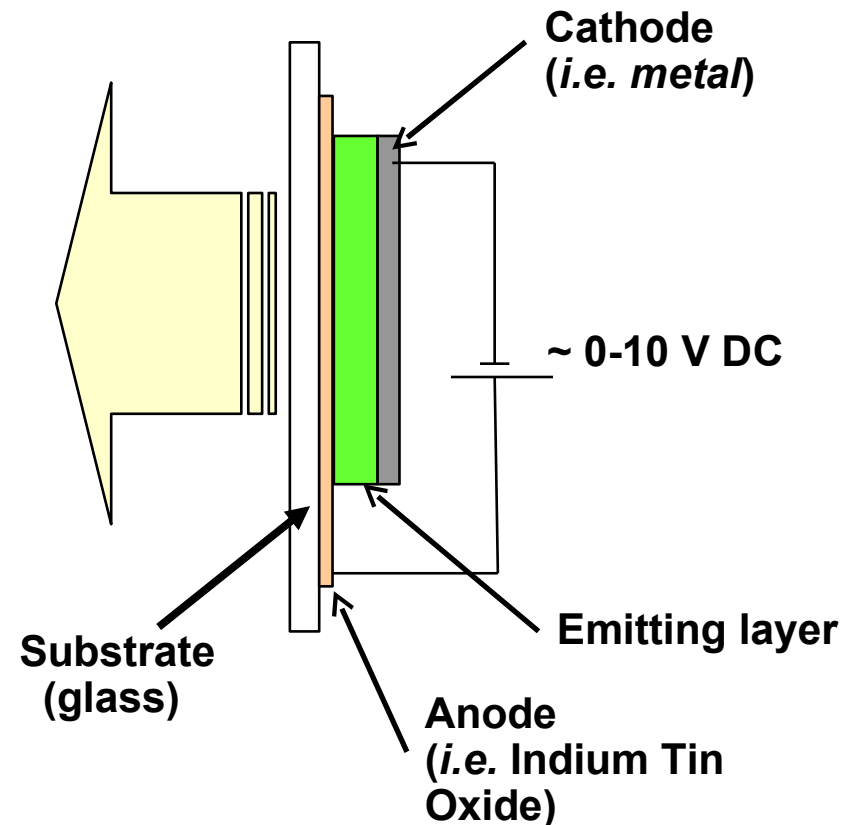
Electroluminescence : Generation of light with electric field

The basic device structure consists of:

3.A transparent electrode (ITO)

4.An emissive layer

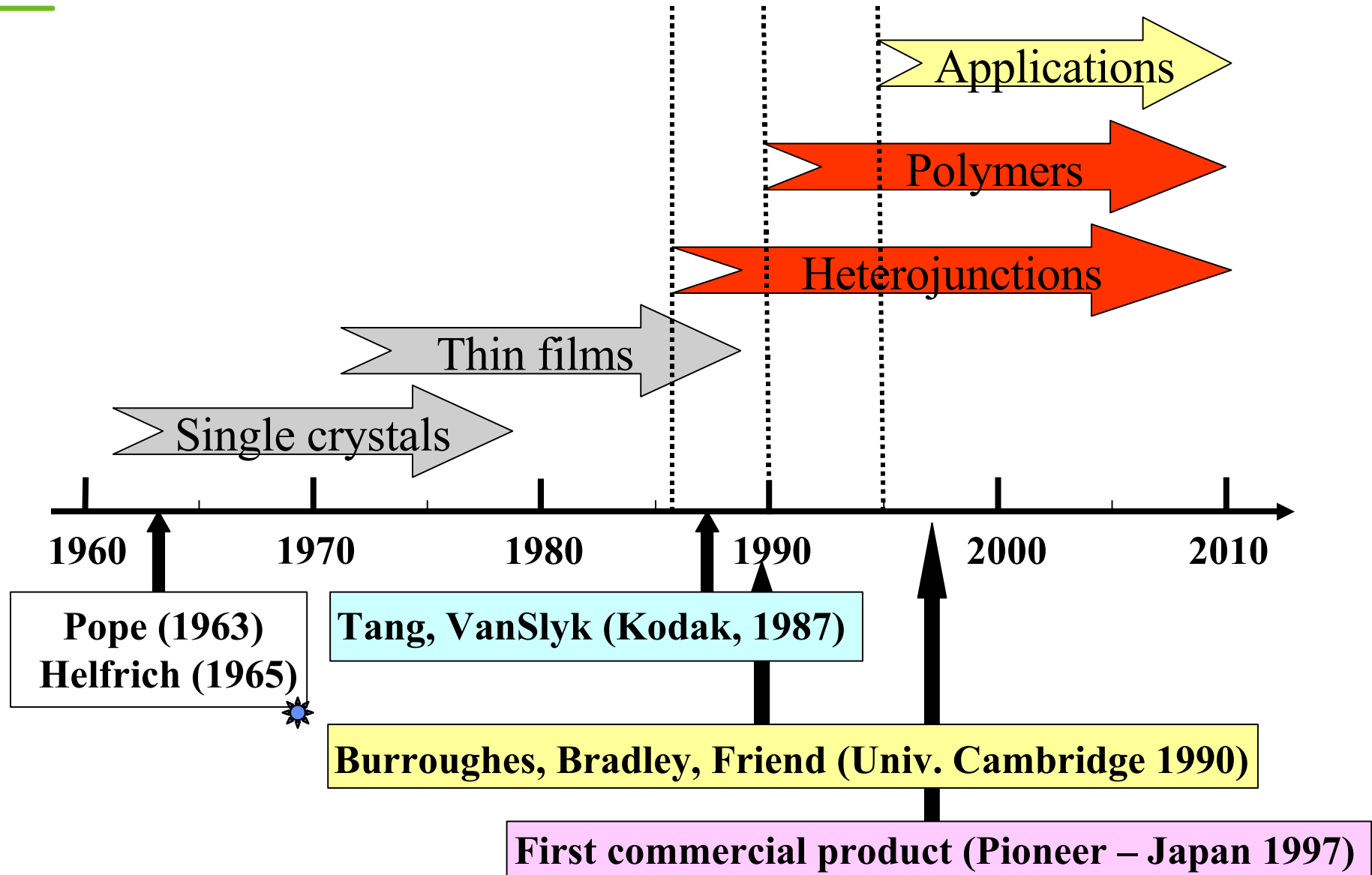
5.A reflective electrode (metal)



Thin layer devices from organic dyes or conjugated polymers

Organic layer thickness : ~ 150 nm

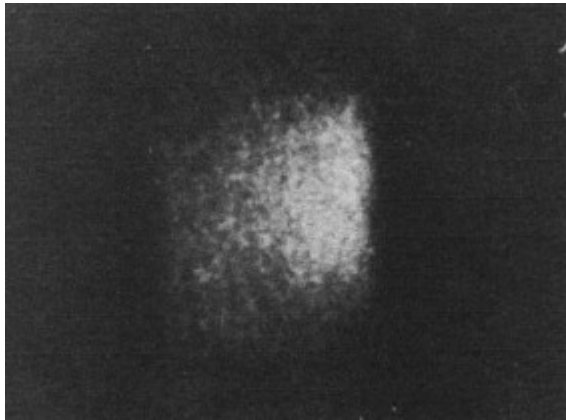
History of organic electroluminescence



Electroluminescence was observed from single crystals of anthracene.

W. Helfrich et al.

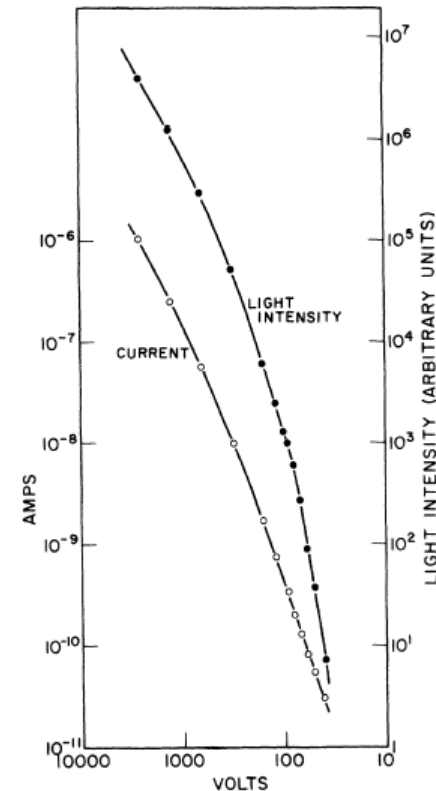
Phys. Rev. Lett. 14, 229 (1965)



5 mm thick crystal

El quantum efficiency ~ 1-5%

High driving voltage



Good understanding of the basic physical processes involved in electroluminescence like double injection, charge carrier migration, electron-hole capture (exciton formation), and light emission (fluorescence)

OLED Roadmap

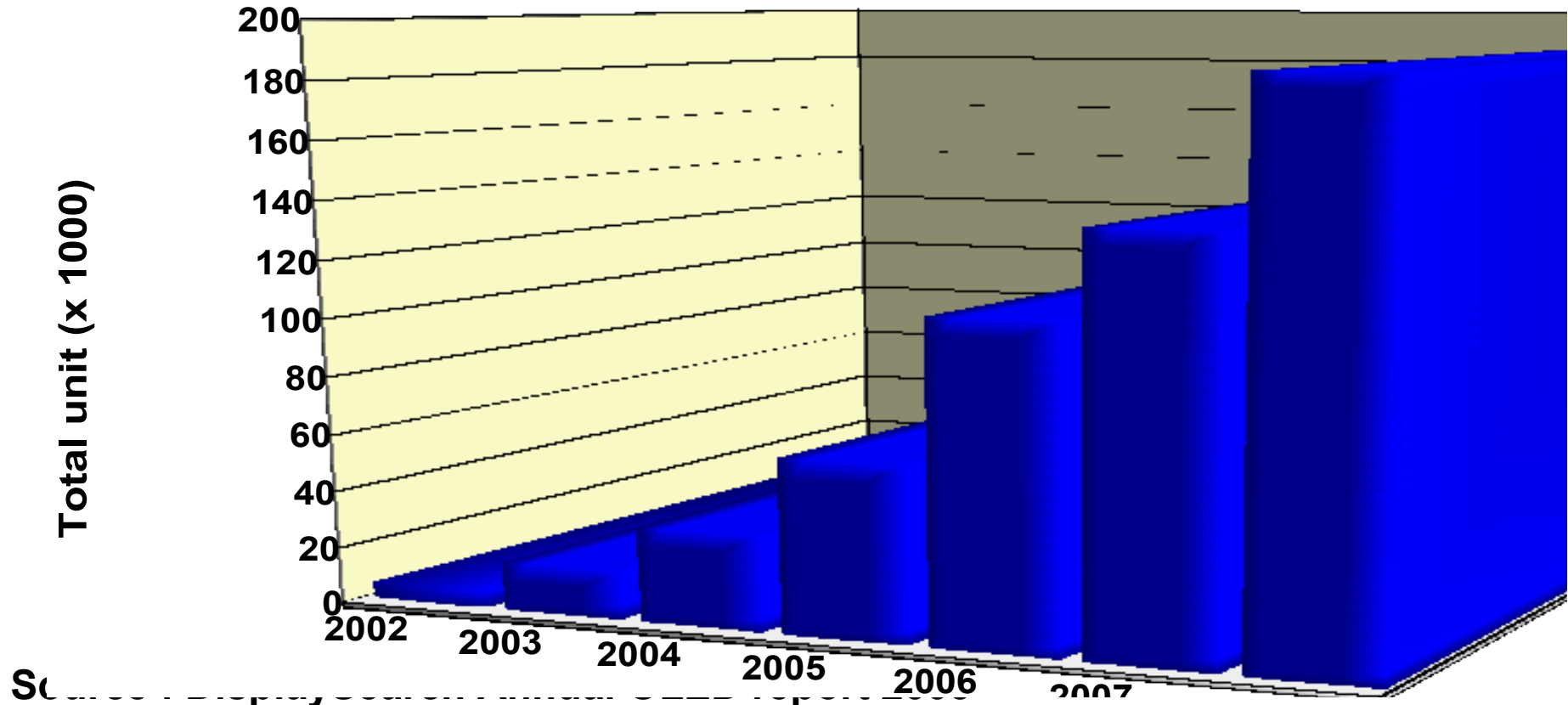


Source :
Universal Display Corporation



Strong increase of OLEDs displays production

OLED unit forecast



Les diodes électroluminescentes organiques

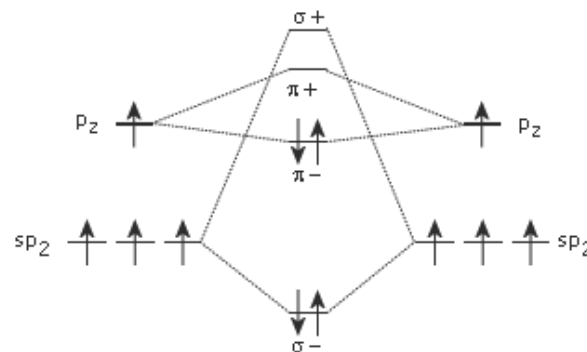
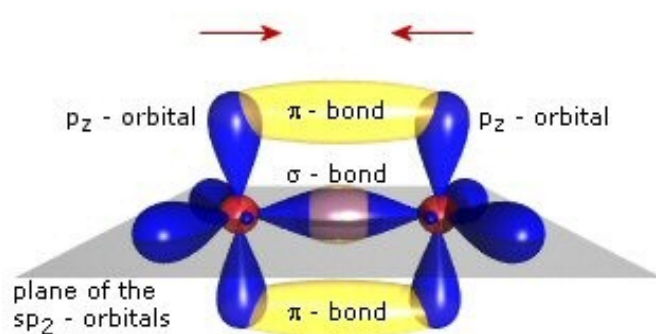
Généralités sur les matériaux organiques

Electronic structure of carbon

Isolated carbon atom: $1s^2 2s^1 2p^3 \rightarrow$ valence of 4

Hybridized sp^n orbitals (superposition of s & 2p orbitals)

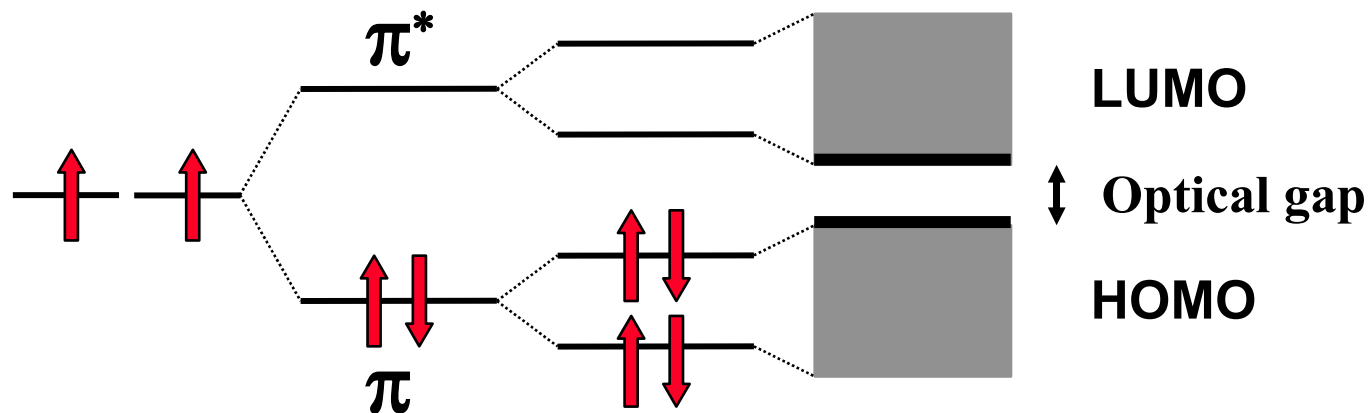
Sp^2 hybridization (double bond)



Source: <http://www.orgworld.de>

Molecules with delocalized π orbitals

HOMO-LUMO Bands



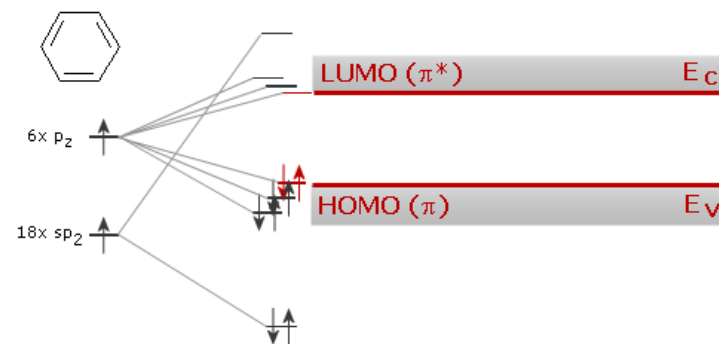
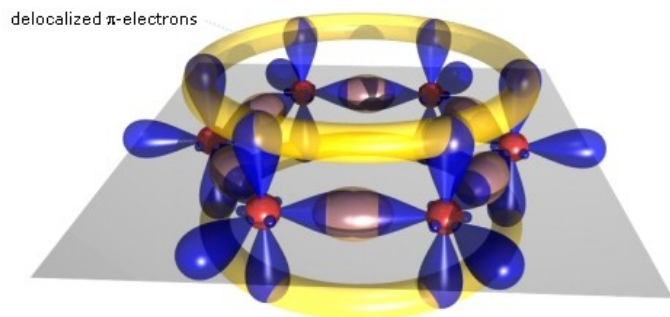
HOMO : Highest Occupied Molecular Orbital

(The highest energy molecular orbital that contains a pair of electrons)

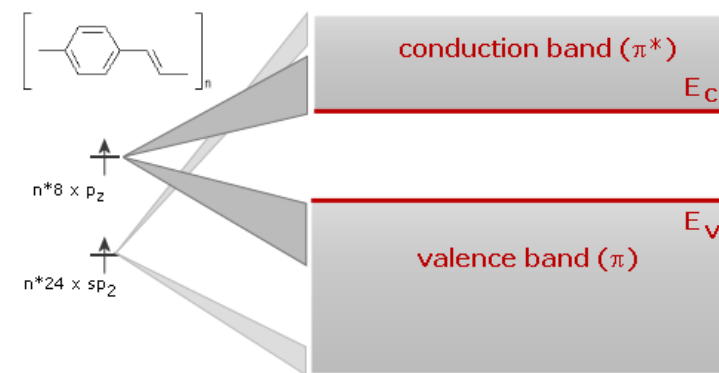
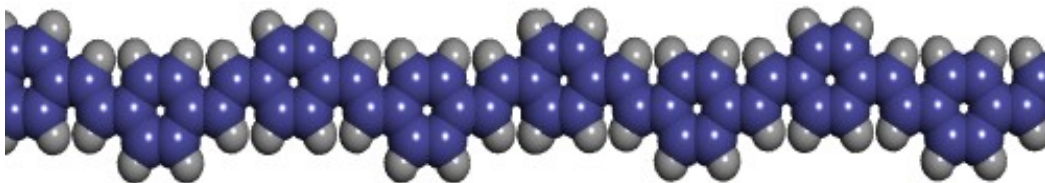
LUMO : Lowest Unoccupied Molecular Orbital

(The lowest energy molecular orbital that contains no electrons)

Small molecule organic semiconductors



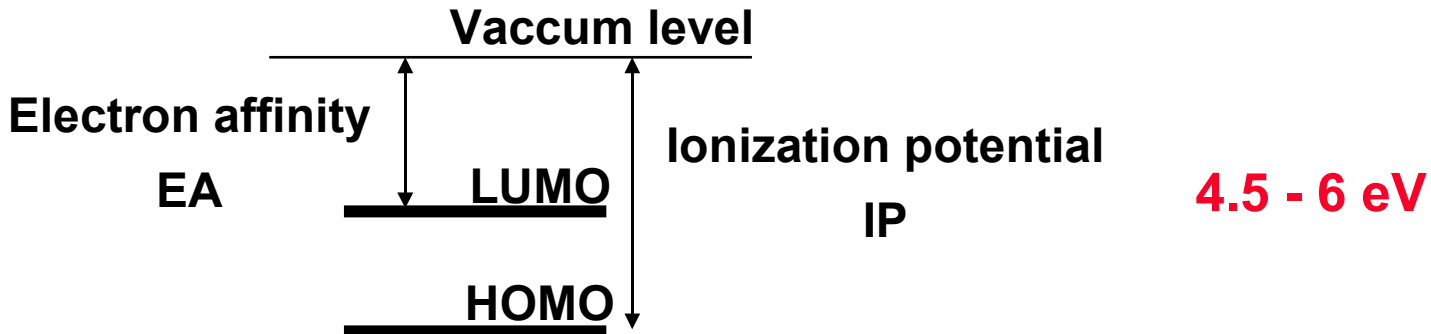
Polymer organic semiconductors



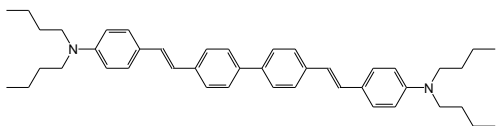
Source: <http://www.orgworld.de>

Electron affinity & ionization potential

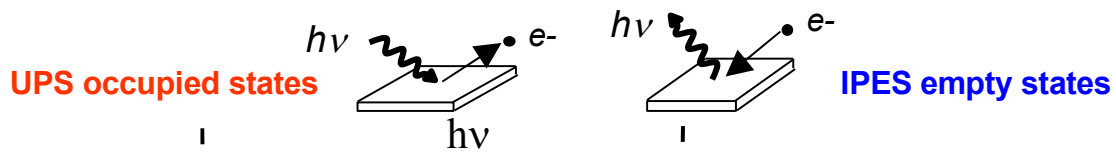
2.5 – 3 eV



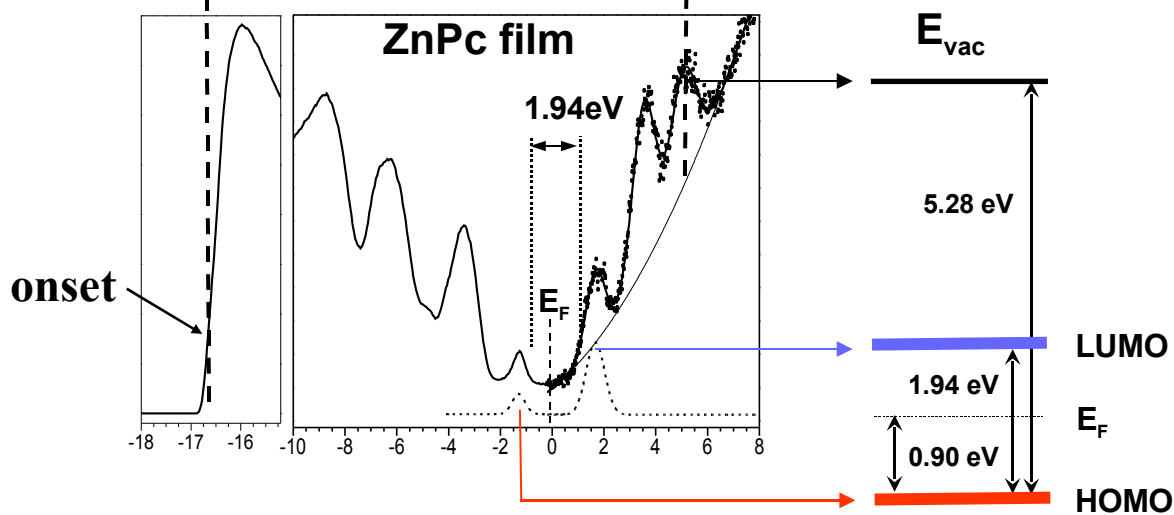
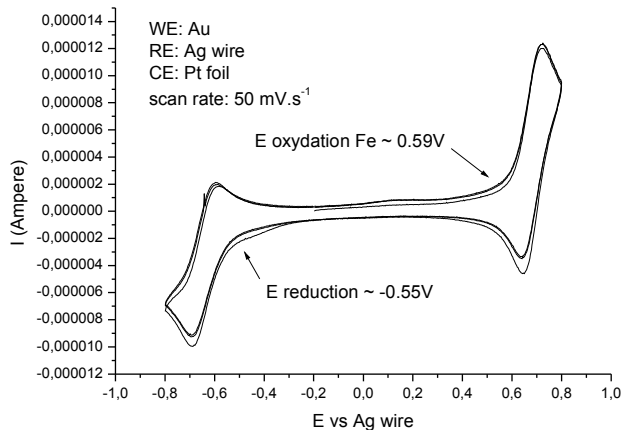
Evaluated by cyclic voltametry in solution



or photoelectron spectroscopy

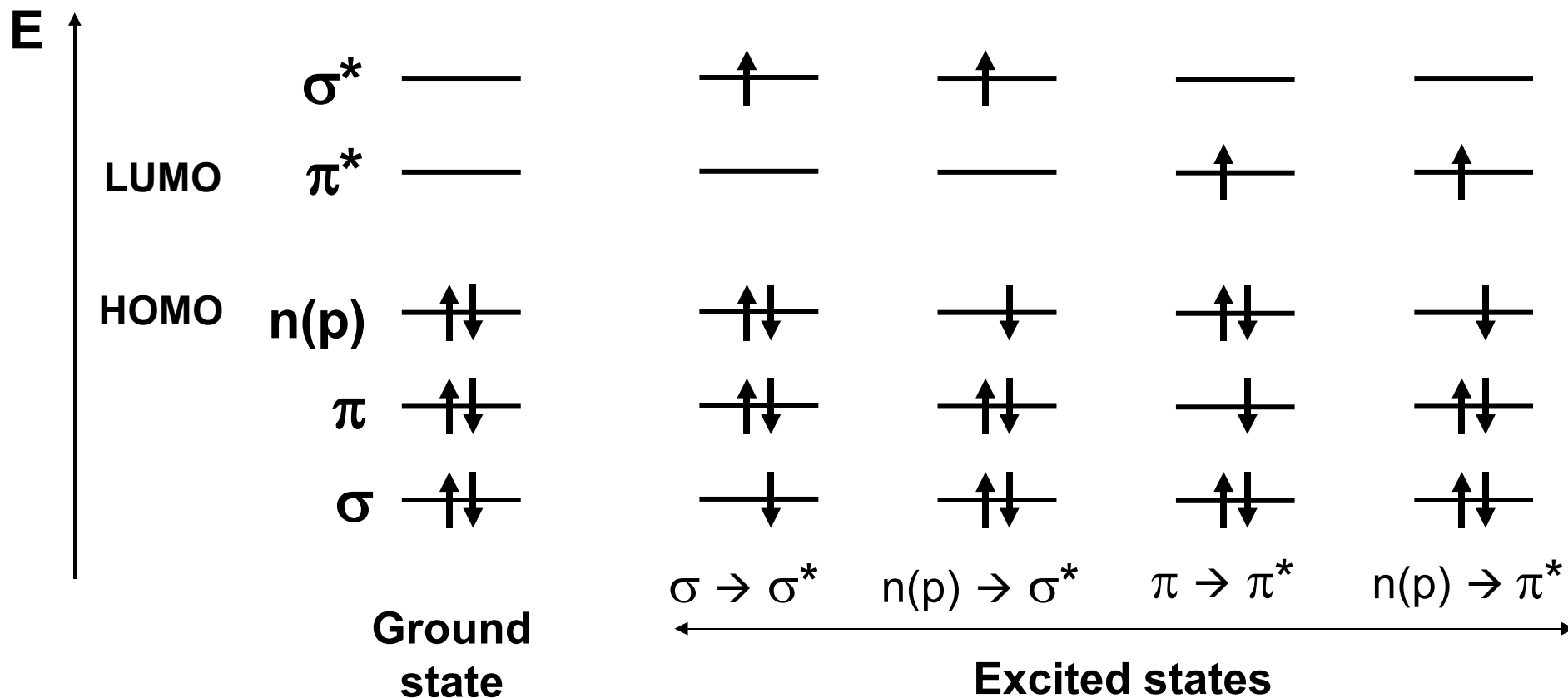
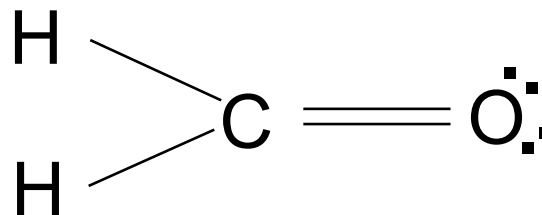


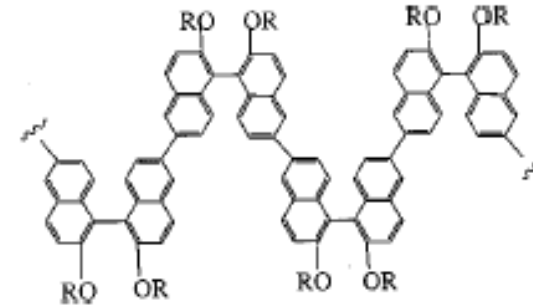
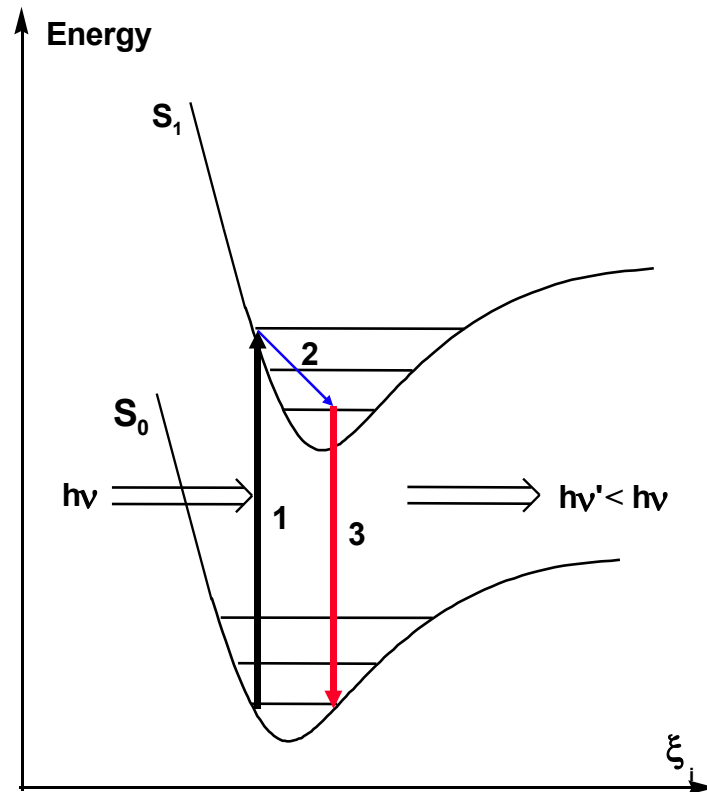
Voltammogram of PR3200 (5.10^{-4} M) and NEt_4BF_4 (0.1M) in DMF with ferrocene



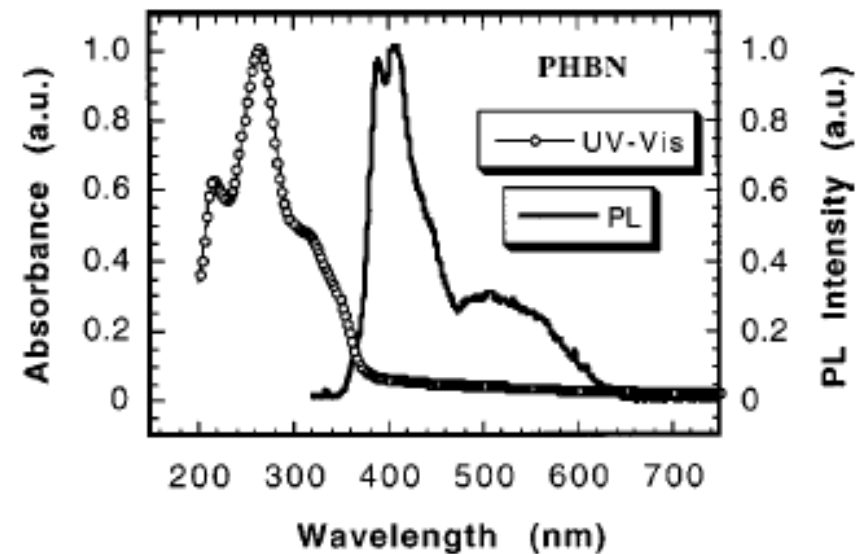
Source: A. Kahn, Summer school, Aussois, 2005

Polyatomic molecule



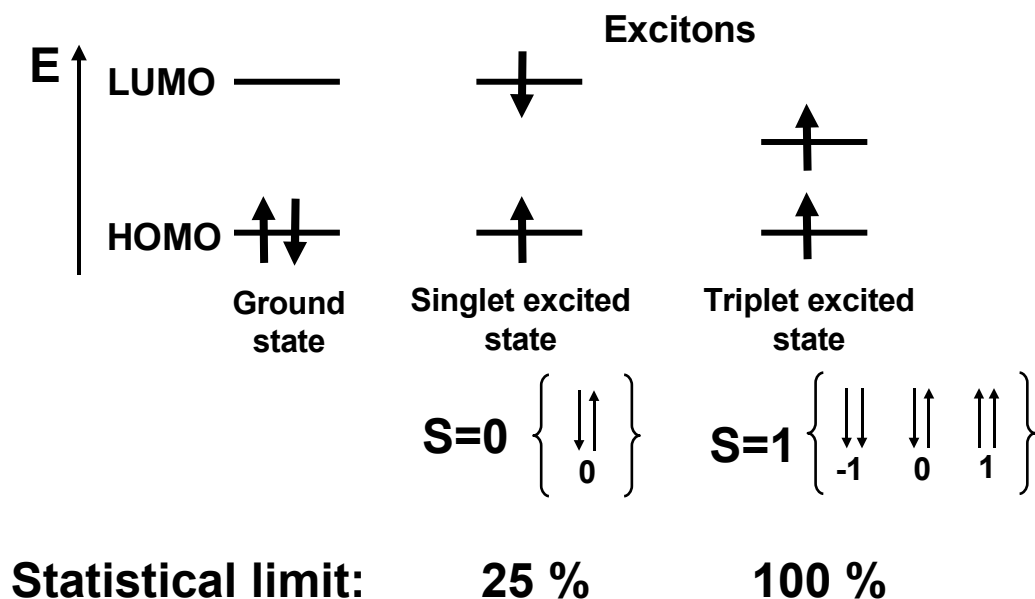
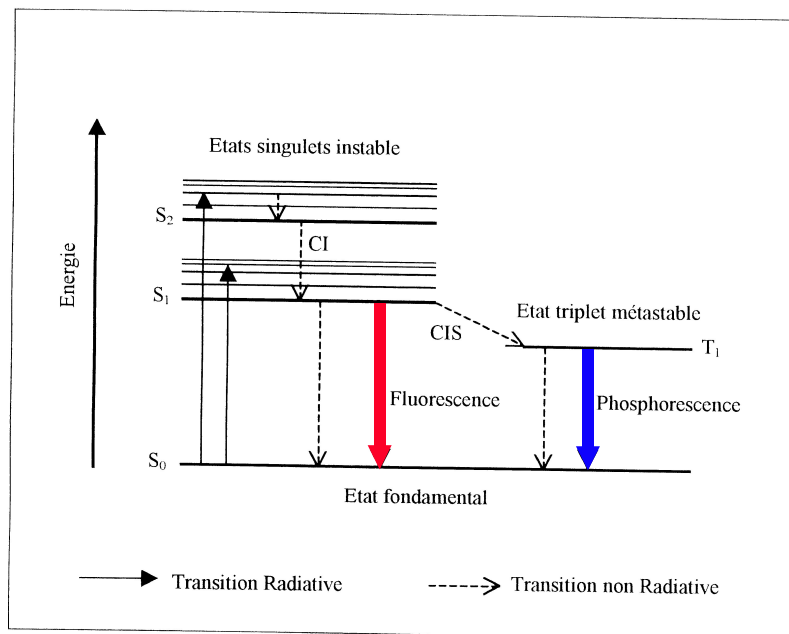


PHBN : R=n-hexyl



Organic materials are characterized by a large Stokes shift between absorption and emission spectra \rightarrow they are almost transparent to their own emitted light

Singlet – triplet states

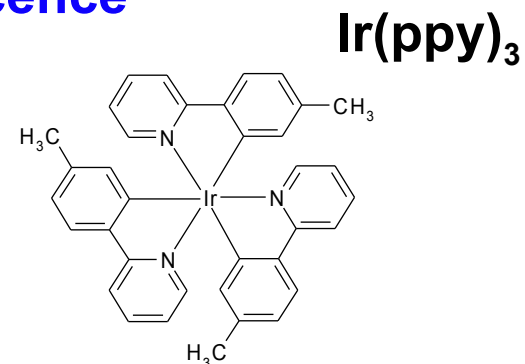


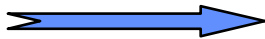




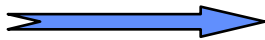
Singlet decay (radiative) is called **fluorescence**

Triplet decay (forbidden process) is called **phosphorescence**

Strong spin-orbit coupling mixes singlet and triplet states

Heavy metals (Ir, Pt...) improve triplet emission



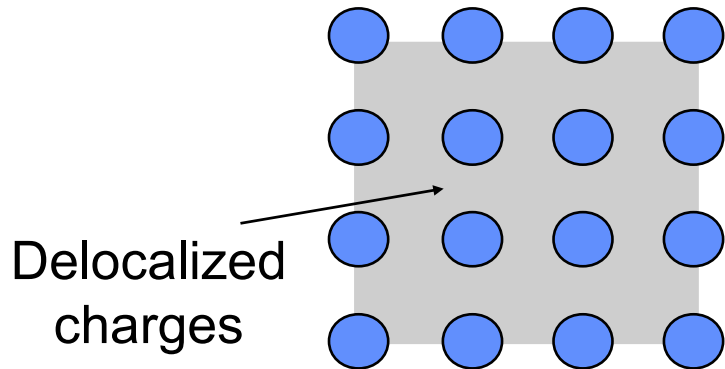
Absorption		10^{-15} s
Vibrational relaxation		10^{-12} - 10^{-10} s
Internal conversion		10^{-11} - 10^{-9} s
Fluorescence (decay of excited state S_1)		10^{-10} - 10^{-7} s
Intersystem crossing (ISC)		10^{-10} - 10^{-8} s
Phosphorescence (decay of excited state T_1)		10^{-6} - 1 s

Effect of molecular structure on fluorescence

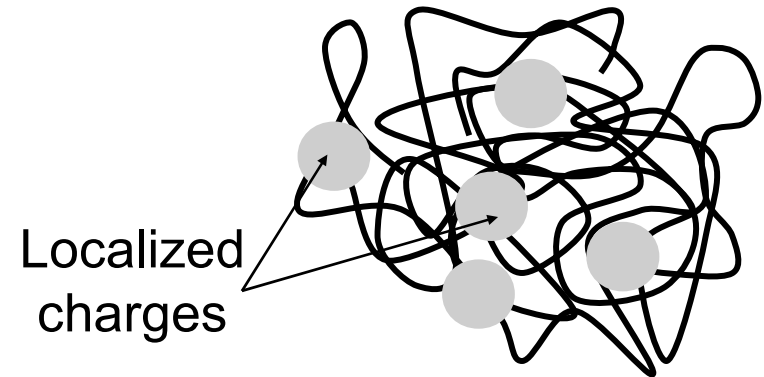
Molecule	Φ_f	Φ_p	τ_T (s)
Naphthalene	0.55	0.051	2.3
1-Fluoronaphthalene	0.84	0.056	1.5
1-Chloronaphthalene	0.06	0.30	0.29
1-Bromonaphthalene	0.0016	0.27	0.02
1-Iodonaphthalene	< 0.0005	0.38	0.002

Source Wehry 1990

Periodic lattice



Amorphous lattice



Crystals : periodic structures

band model (conduction & valence bands)

delocalized charges (electrons in CB, holes in VB)

Amorphous organic materials :

band model ?

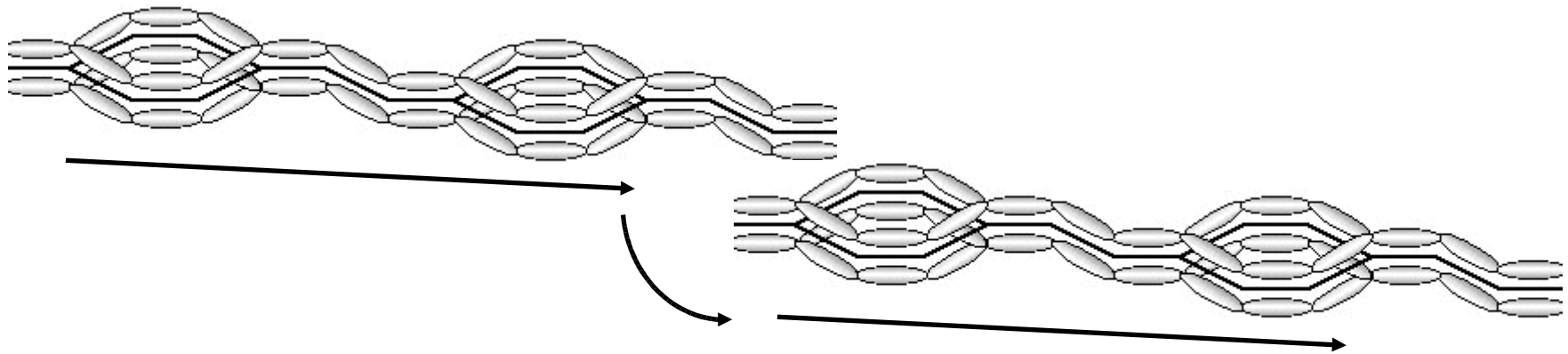
localized charges (radical ions)

transport through intersite hopping

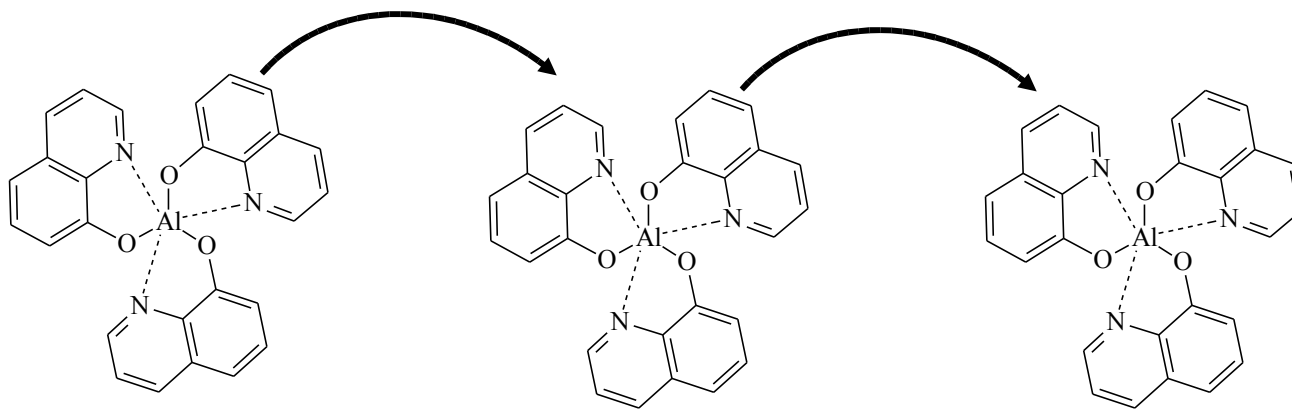
charge traps (defects)

In conjugated polymers the charges are partially transported via delocalisation along the HOMO and LUMO levels.

Transport properties are usually determined by defects in the 1D-chains (intra molecular) or by hopping from chain to chain (inter molecular)



Charge transport in small molecules is via hopping, i.e. the charges have to jump from one molecule to the neighbouring one to be transported.

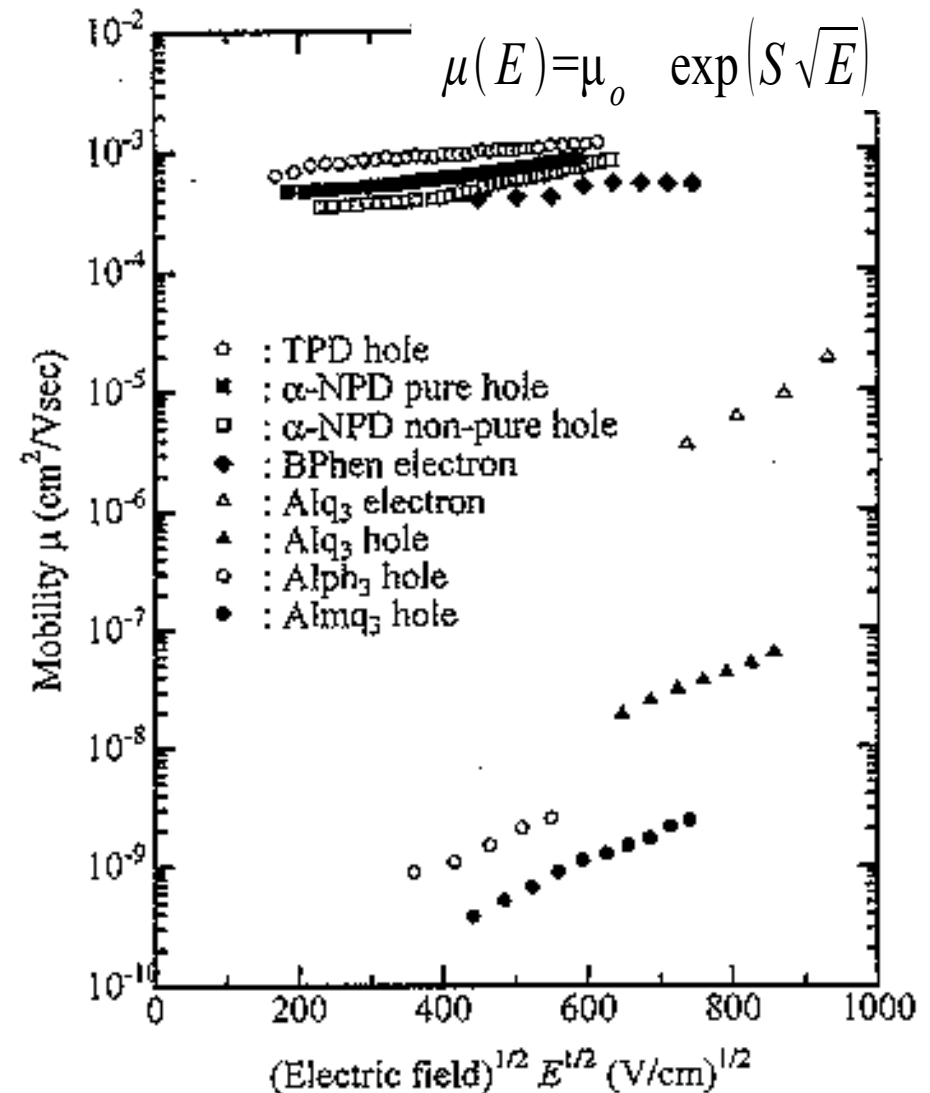


☀ Charge transport via hopping

☀ Low mobility (disorder)

☀ $\mu_{h+} \neq \mu_{e-}$

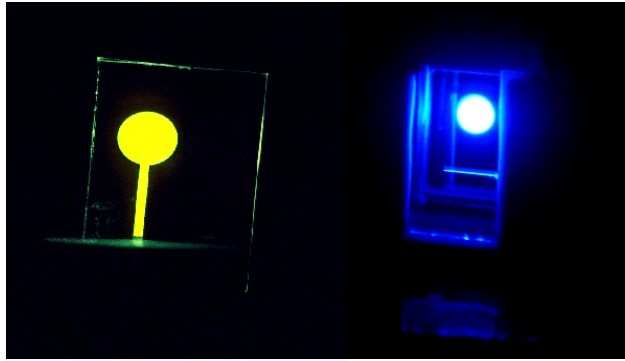
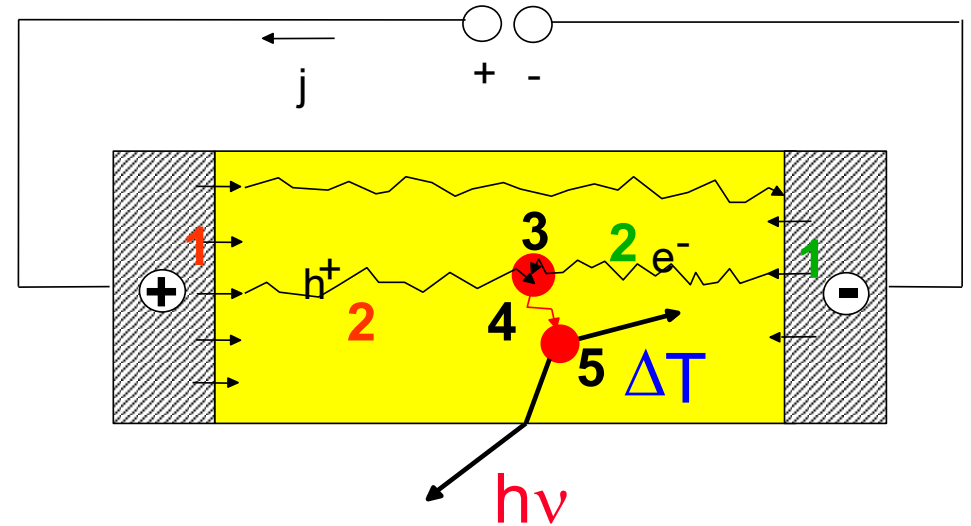
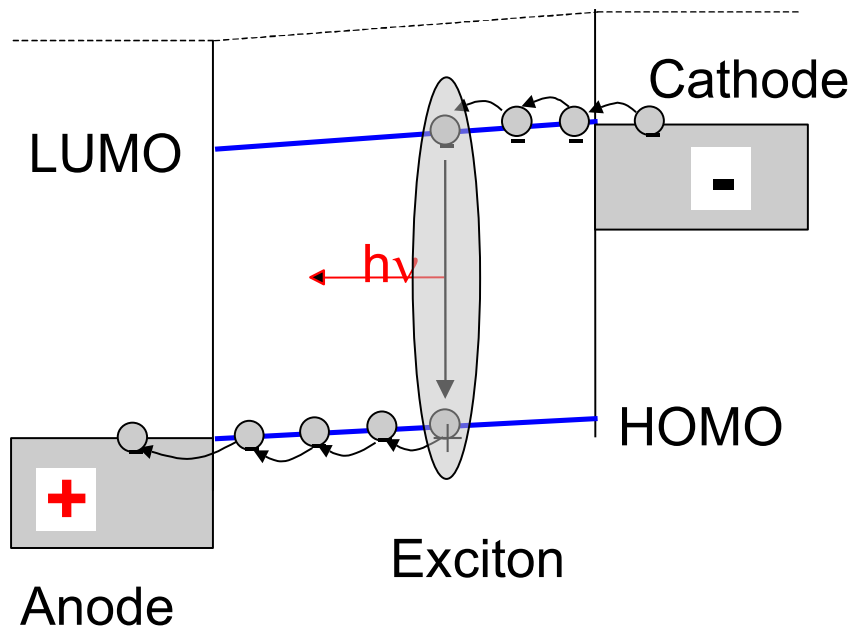
➡ Challenge for High EL efficiency : Charge Carrier Balance



Les diodes électroluminescentes organiques

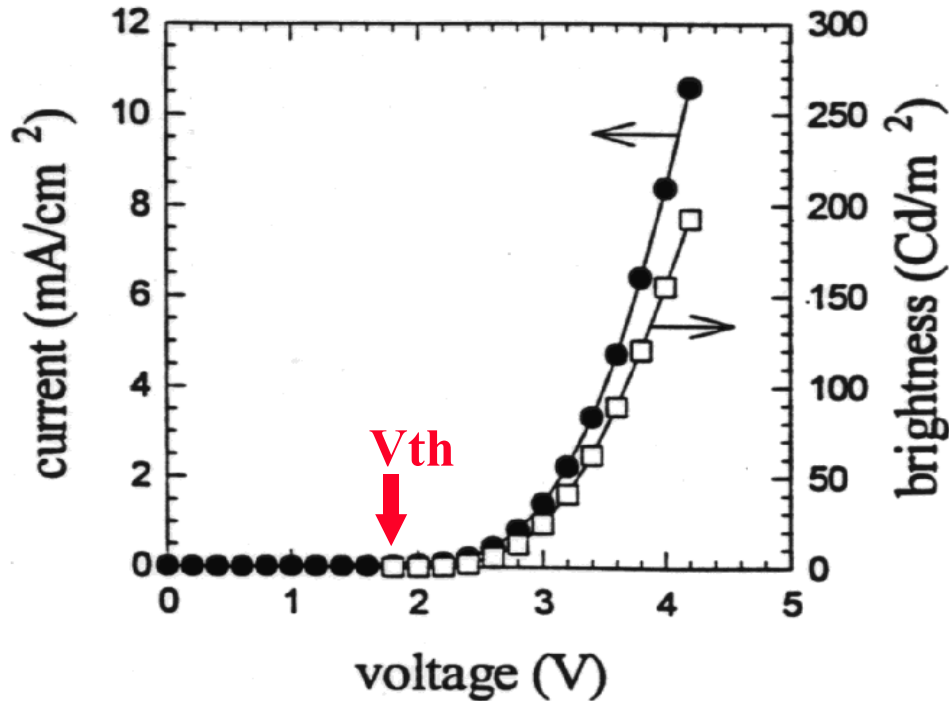
Principe de fonctionnement des OLEDs

Organic Light Emitting Diode : Principle



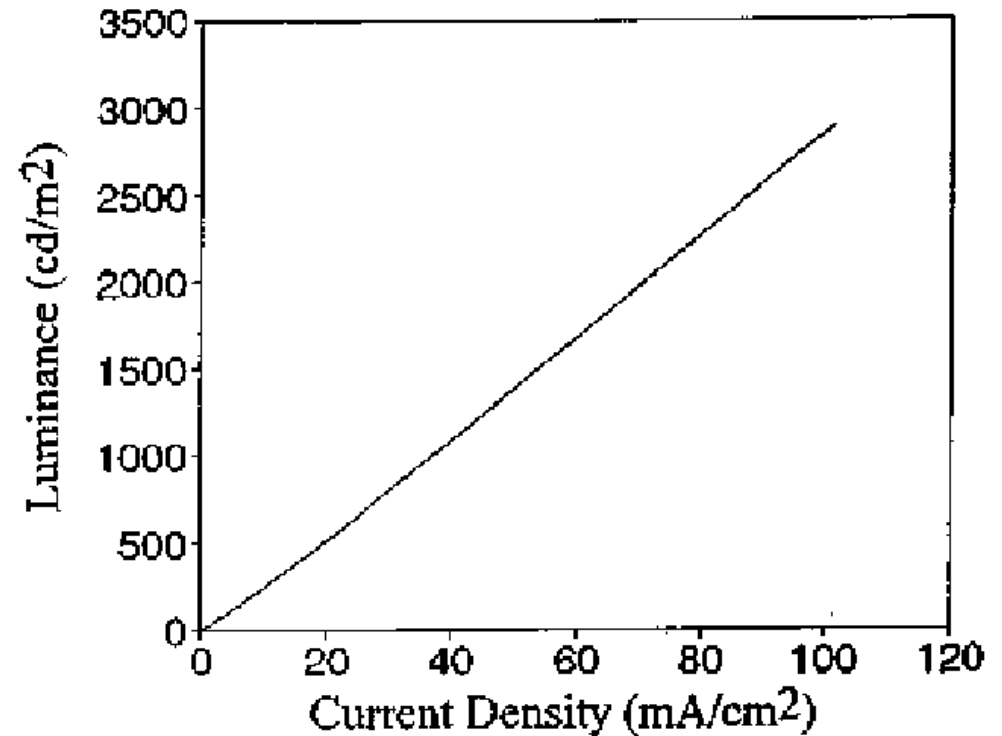
- 1 → Charge carrier injection
- 2 → Charge carrier transport
- 3 → Charge recombination (exciton formation)
- 4 → Exciton diffusion
- 5 → Exciton recombination and photon emission

Diode behavior



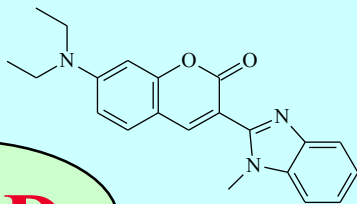
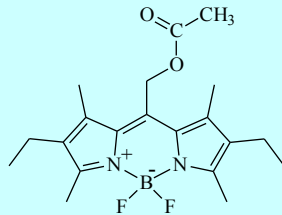
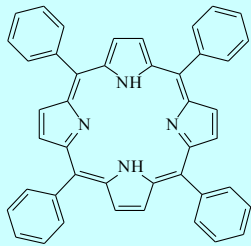
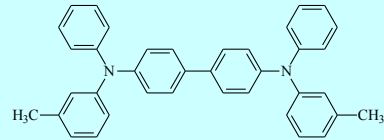
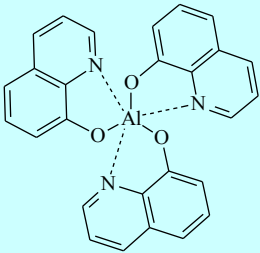
OLEDs conduct in forward bias and do not conduct under reverse bias. The impedance drops exponentially with V for $V > V_{th}$.

Brightness is proportional to the current flow



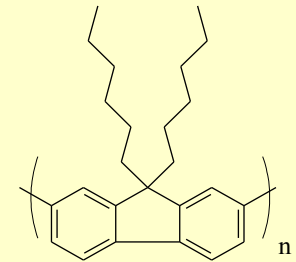
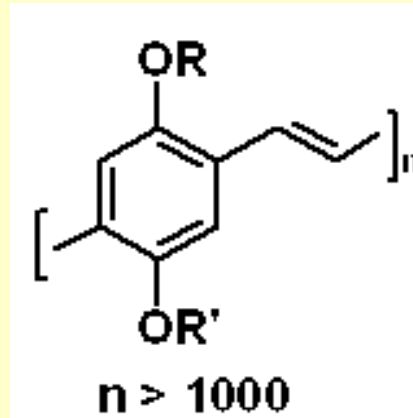
'Small molecules'

M ~ <800

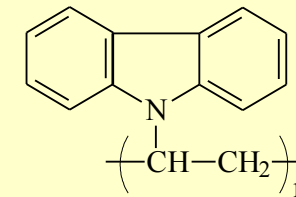


OLEDs

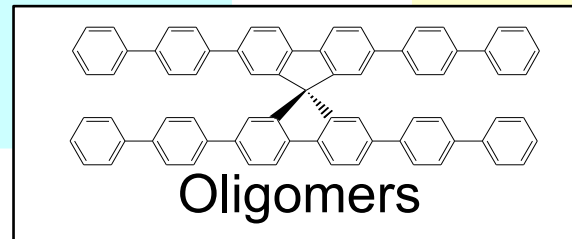
Polymers



POLYFLUORENE



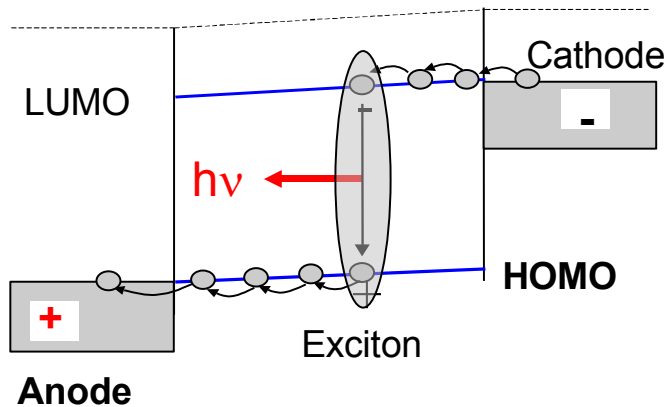
PLEDs



Vacuum deposition

Spin-coating deposition

Anode : ITO



Need ITO surface treatment to enhance holes injection (i.e. Oxygen plasma treatment), ITO fermi level stabilization around 5 eV.

Small barrier for holes injection into HOMO level of HTL organic material

Use of materials with high work function (ideal ~ 5 eV)

Typically use of transparent ITO as anode

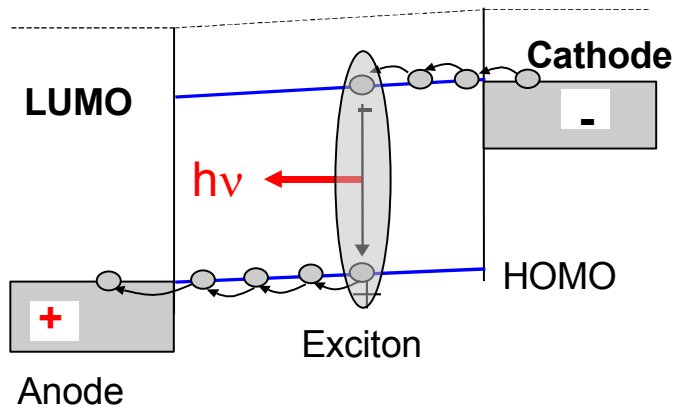
ITO	Treatment	Lifetime h	Charge density 10^3 C/cm ²	Eff (@200 cd/m ²) lm/W (cd/A)	Eff at peak lm/W (cd/A)	Voltage at 200 cd/m ²	Voltage increase rate mV/h
ITO1	(b) Oxygen plasma	240	3.40	4.0(5.1)	8.2(7.3)	4.0	13.5
	(a) As-received	120	1.65	3.5(4.9)	6.0(6.7)	4.4	19.0
	(d) Oxygen/aquaregia	80	1.45	2.8(4.0)	4.8(5.6)	4.6	36.0
	(c) Aquaregia	<0.15	<0.01	0.5(0.87)	4.7(5.6)	5.5	630.5
	(e) Aquaregia/oxygen	<1 ^b	0.20	0.2(0.08) ^a	5.7(6.4)	>8.1 ^a	>10 ³
ITO2	(b) Oxygen plasma	335	4.90	3.5(5.0)	5.5(6.0)	4.45	12
	(e) Aquaregia/oxygen	92	1.50	3.3(4.4)	5.5(6.2)	4.3	24.3
	(a) As-received	65	1.00	2.7(4.7)	3.1(4.2)	5.5	55.5
	(d) Oxygen/aquaregia	25	0.55	2.0(3.3)	4.9(5.4)	5.4	77
	(c) Aquaregia	<0.005 ^b	<0.001	0.13(0.05) ^a	4.6(5.4)	>9.1 ^a	>10 ⁶

^aValues for 100 cd/m².

^bTime required to half an initial luminance of 100 cd/m².

Réf.: Kim et al., Appl. Phys. Lett., **74**, N°21 (1999) 3084

Cathode

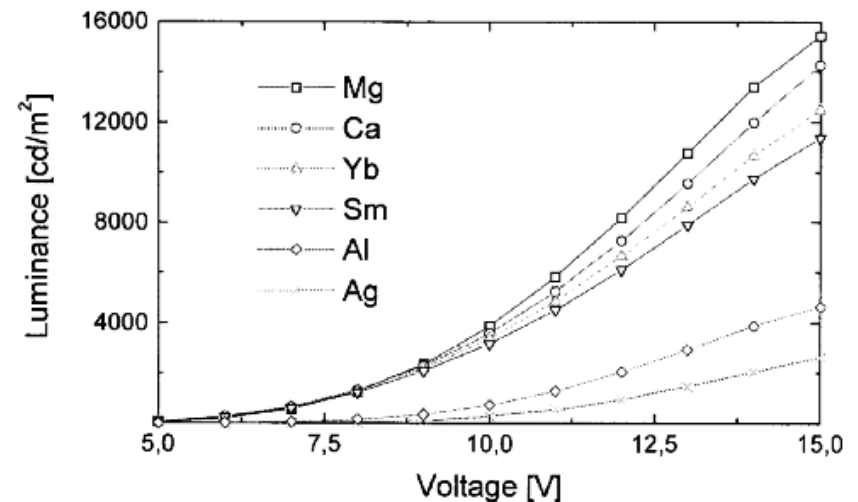


Small barrier for electrons injection into LUMO level of ETL organic material (ideal ~ 2.5 to 3 eV)

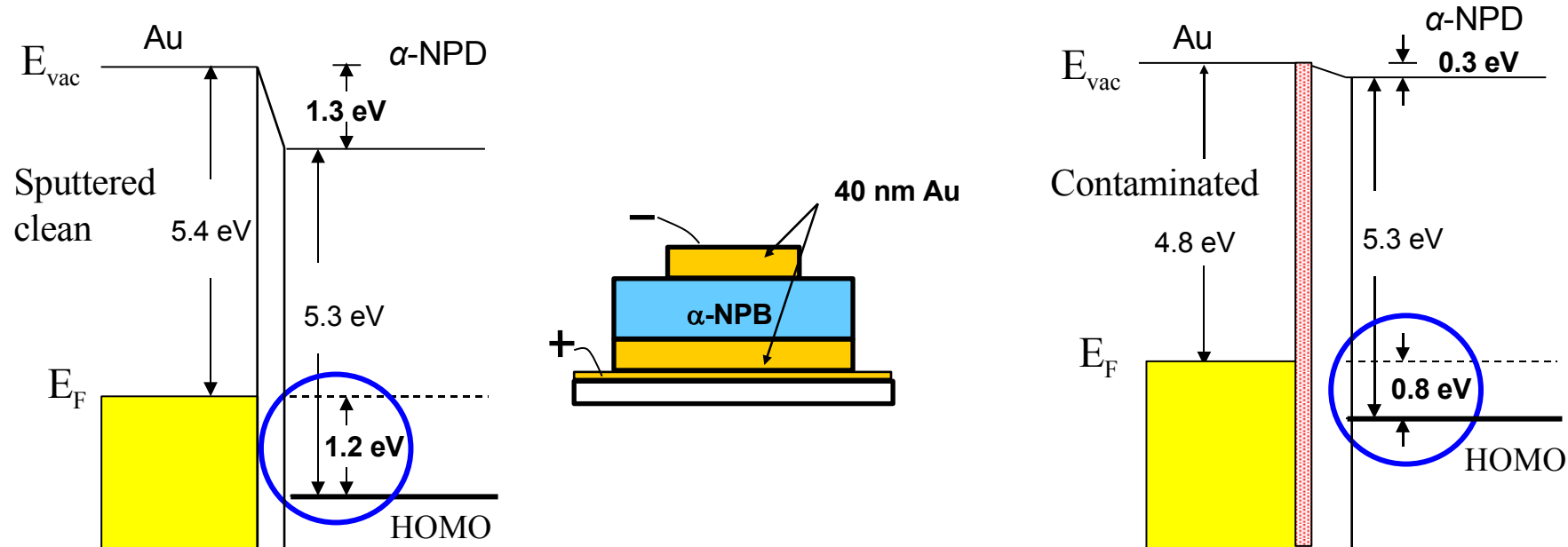
Use of metals with low work function (Ca, Mg...)

But such metals are very sensitive to oxidation

Use alloys such as Mg/Ag or Al in combination with alkali metals like Li, Cs, K, Na...



Barrier, dipole vs injection



Metal-organic interfaces are varied and complex

Interface chemistry and interdiffusion can play key roles

- change with interface processing (deposition sequence)
- affect interface barriers (gap states, doping effects, dipoles)

Source: A. Kahn, Summer school, Aussois, 2005

External quantum efficiency

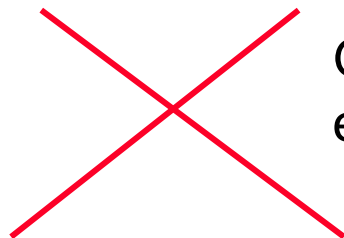
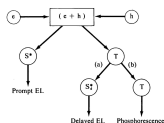
$$\eta_{q \text{ ext}} = \frac{\text{Number of emitted photons}}{\text{Number of injected electrons}} = \eta_r \cdot \chi \cdot \Phi_{\text{PL}} \cdot \eta_{\text{ext}} \quad (\%)$$

η_r : probability that charges recombine to excitons $\longrightarrow \eta_r \sim 1$

χ : probability of production of emissive species $\longrightarrow \chi = 1/4$

Φ_{PL} : quantum efficiency of luminescence

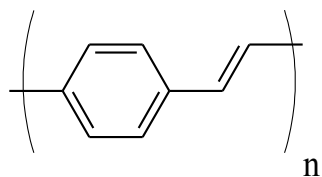
η_{ext} : fraction of generated photons leaving device $\longrightarrow \eta_{\text{ext}} \sim 1/2n^2$



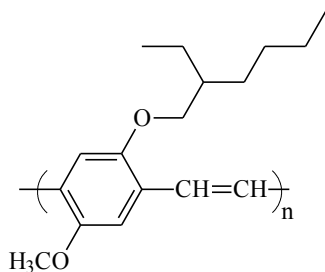
Generally, only singlet excitons are radiative

$\eta_{q \text{ ext}} : \sim 5 \% \text{ max}$

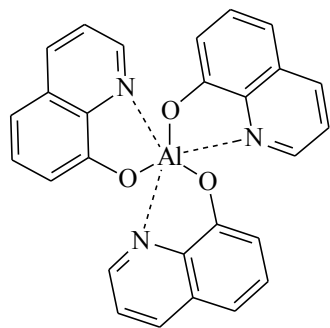
Fluorescence efficiency in solide state



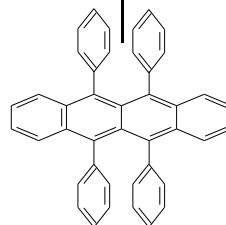
PPV



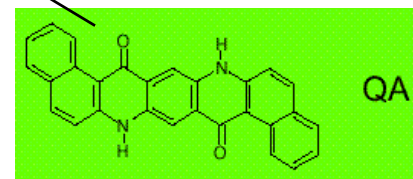
H₃CO



Materials	Φ_{PL} (%)	$\lambda_{em.}$ (nm)
PPV	27	516
MEH-PPV	15	605
CN-PPV	35	710
Alq ₃	25	520
Almq ₃	42	505
QA doped Alq ₃	75	540
Rub. doped Alq ₃	95	565



RUBRENE



QA

External power efficiency

Power efficiency: light power versus electrical power

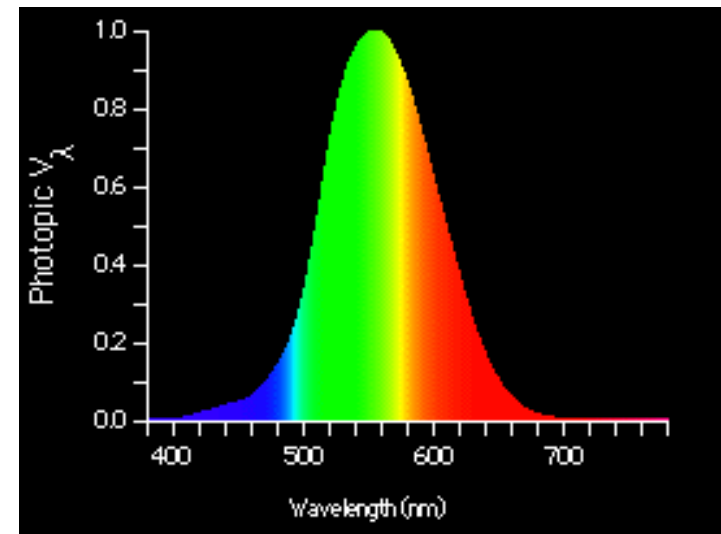
$$\eta_e = \frac{\text{Output light power}}{\text{Input electrical power}} = \frac{n_{\text{ph}} \cdot h\nu}{q \cdot V} = \eta_q \text{ext.} \cdot \frac{h\nu}{e \cdot V} \quad W_L/W$$

Luminous efficiency (lm/W)

luminous flux versus electrical power

$$\eta_L = \eta_e \cdot v_\lambda \cdot k_m$$

With $k_m = 683 \text{ lm/W}$



Other useful units

Characterization of device efficiency : cd/A

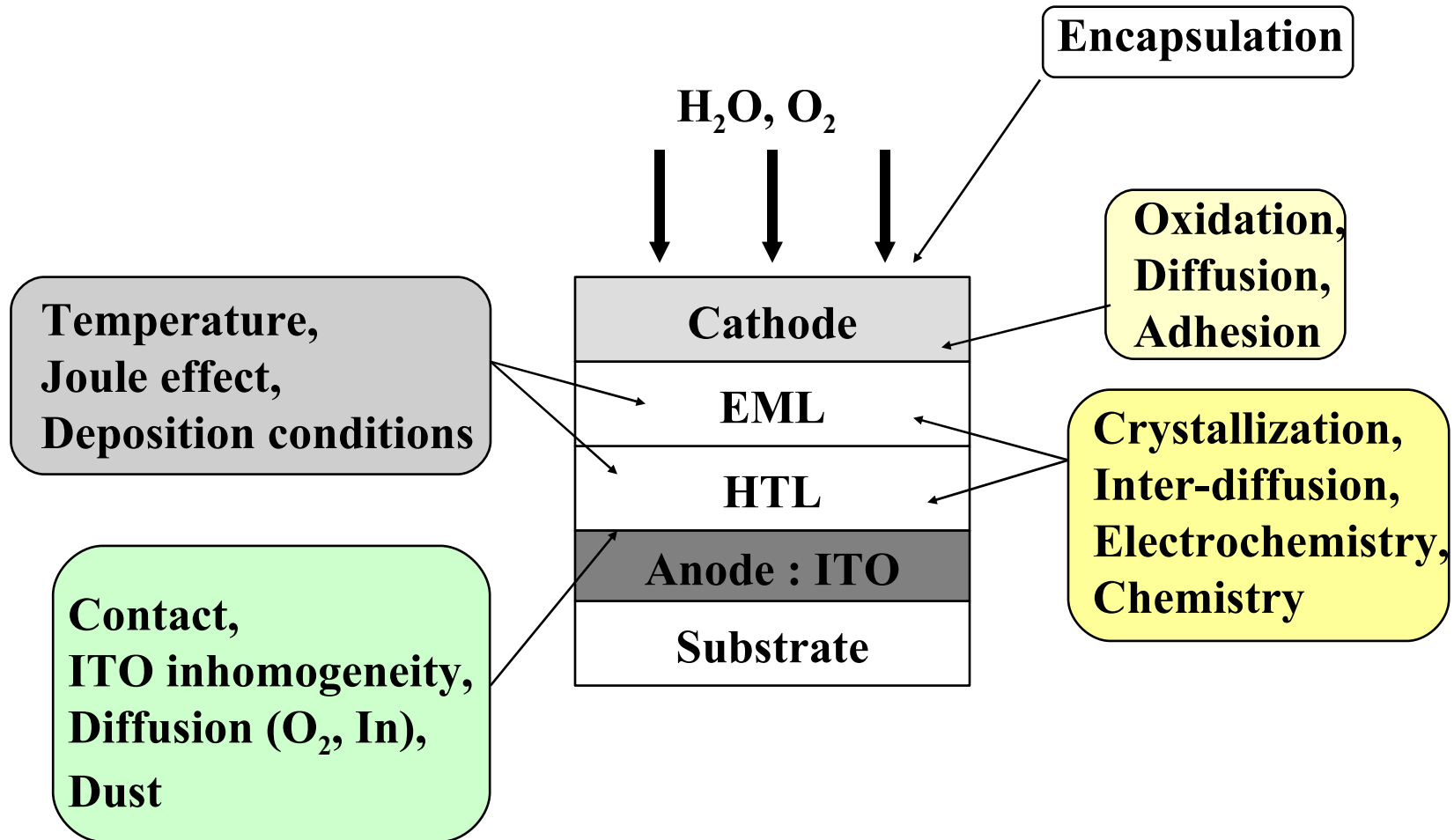
$$cd/A = \frac{L (cd/m^2)}{10 * J (mA/cm^2)}$$

$$lm/W = \frac{cd/A * \pi}{V (V)}$$

Luminance-efficiency vs Applied voltage

<http://www.cdtltd.co.uk/avyellow.gif>

Source : **Covion**

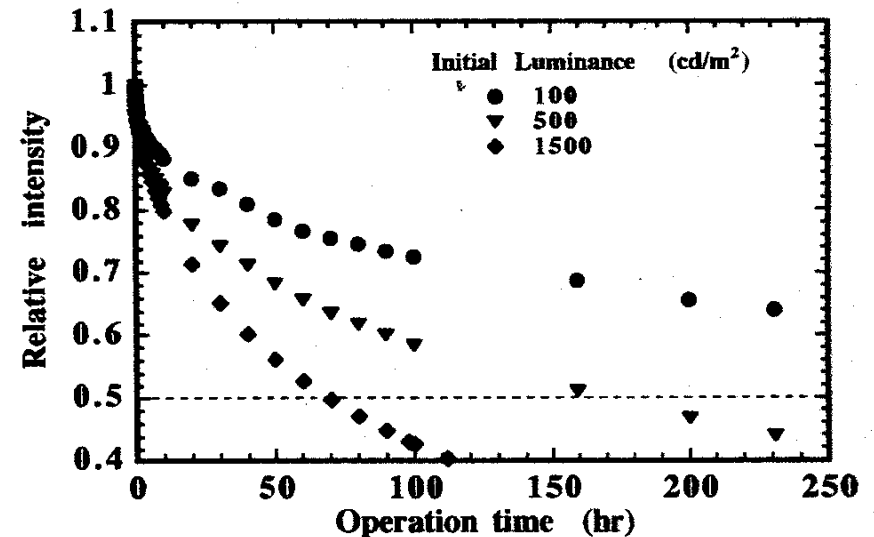
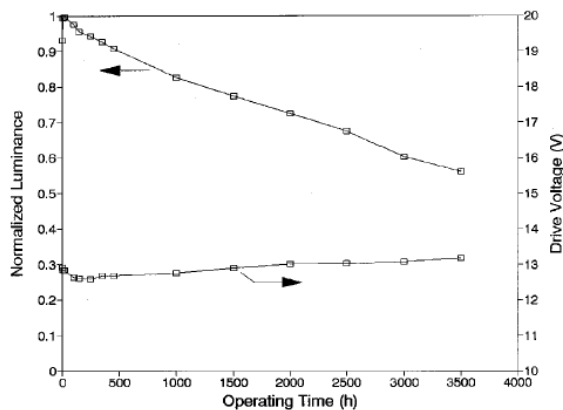


Degradation of OLED devices is one of the main issues. Degradation phenomena occur both under operating condition as well as under storage.

❌ No really standardized measurement method
(DC vs pulsed constant current, brightness level ...)

➤ Device lifetime usually defined as :

Mean time to half-brightness



- Very thin
- Light weight
- Fast response time
- High brightness
- Large viewing angle
- Low power consumption
- RGB, white
- Low DC drive voltage
- Structural flexibility
- Large operating temperature range

Les diodes électroluminescentes organiques

Dispositifs et matériaux électroluminescents

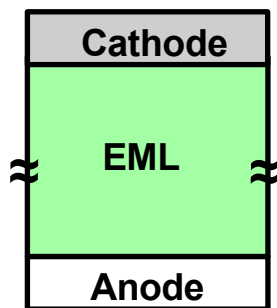
Efficiency & stability



Thick crystals

Pope (1963)
Helflich (1965)

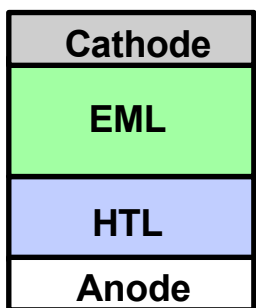
Monolayer



1965

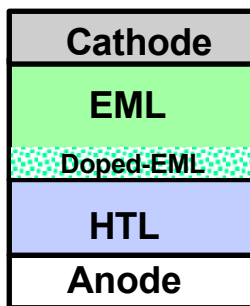
2-layers

EK US patent
#4539507

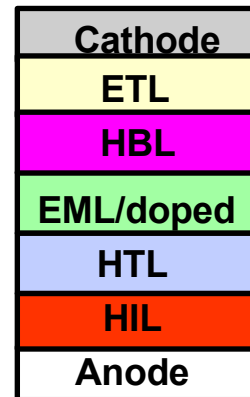


PLED 1985

EK US patent
#4769292

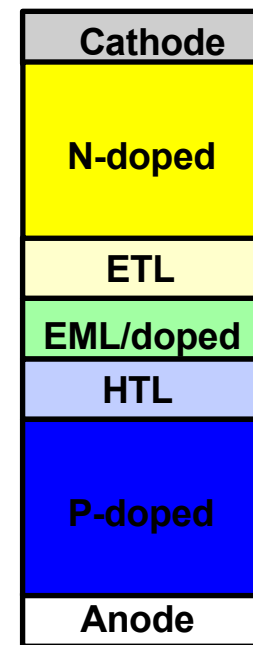


Multilayers



HBL
Hole Blocking layer:
Exciton confinement

PIN

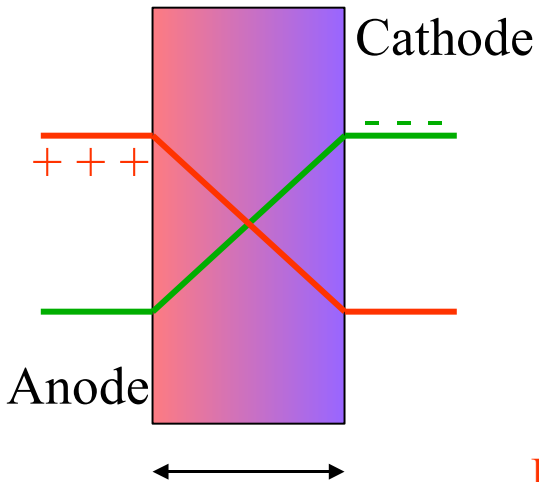


Doped transport layers
K. Leo, U. Dresden

2002

Single layer device : recombination zone

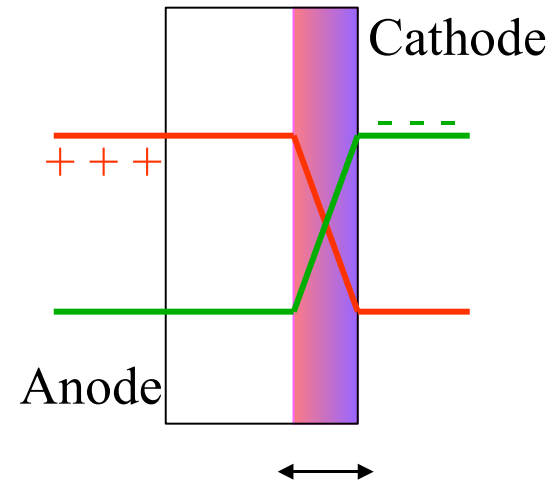
Balanced charge
transport



Recombination zone

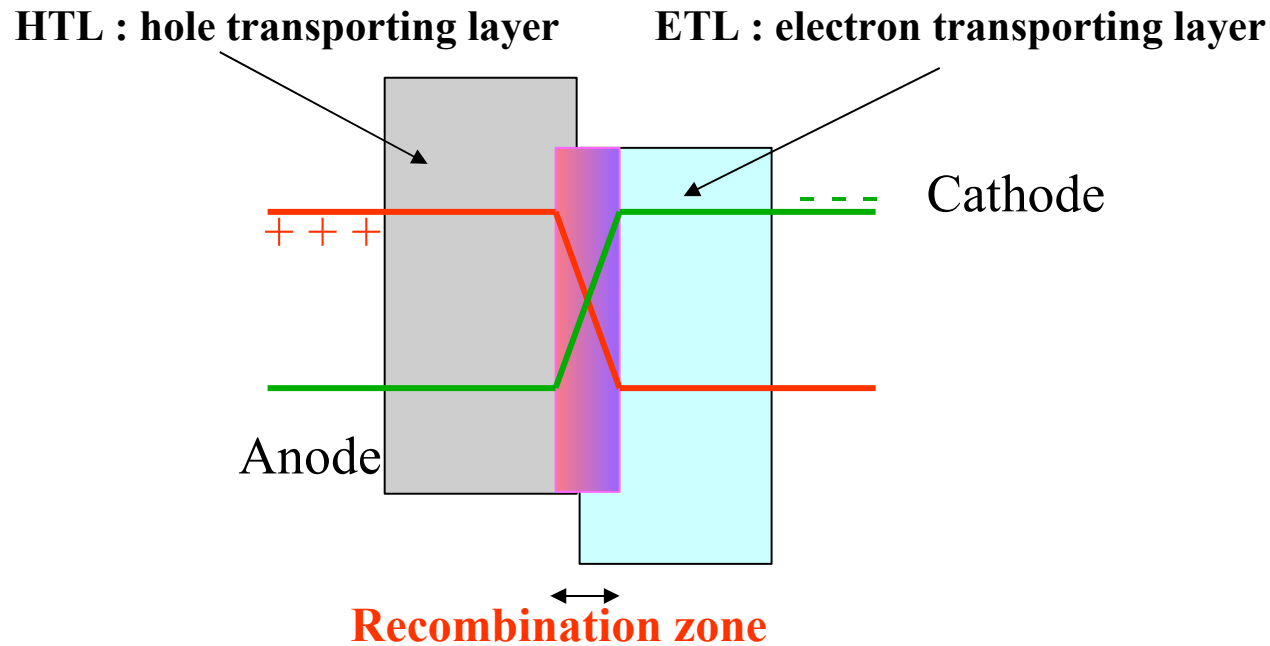
- e^-/h^+ recombination occurs in the organic material bulk.
- Not many organic materials have electron and hole mobilities that are in the same order of magnitude

Imbalanced charge
transport

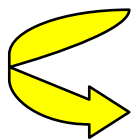


- e^-/h^+ recombination occurs near an electrode.
- Reduction device efficiency due to quenching of luminescence by the electrode (cathode).

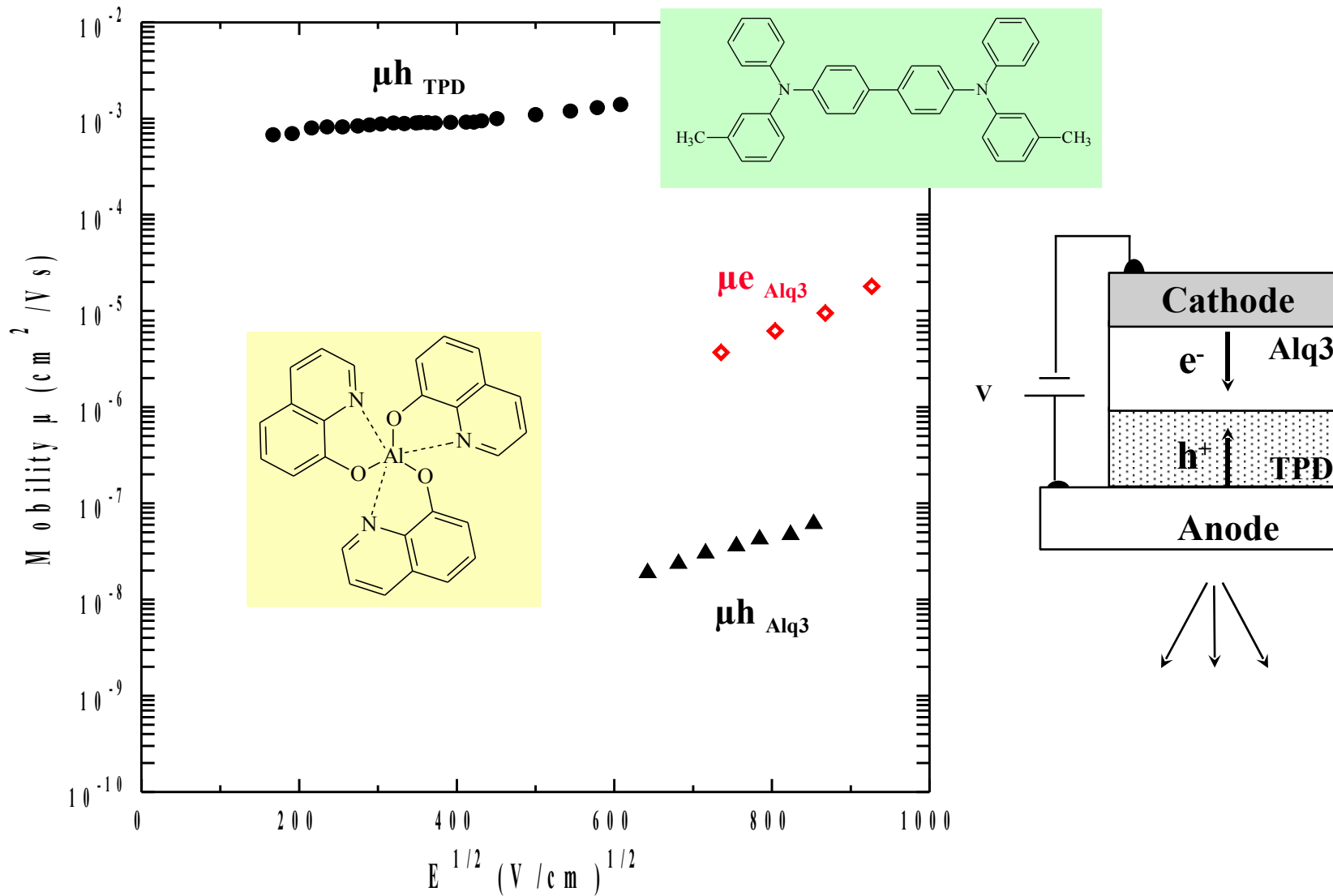
Bilayered device : recombination zone



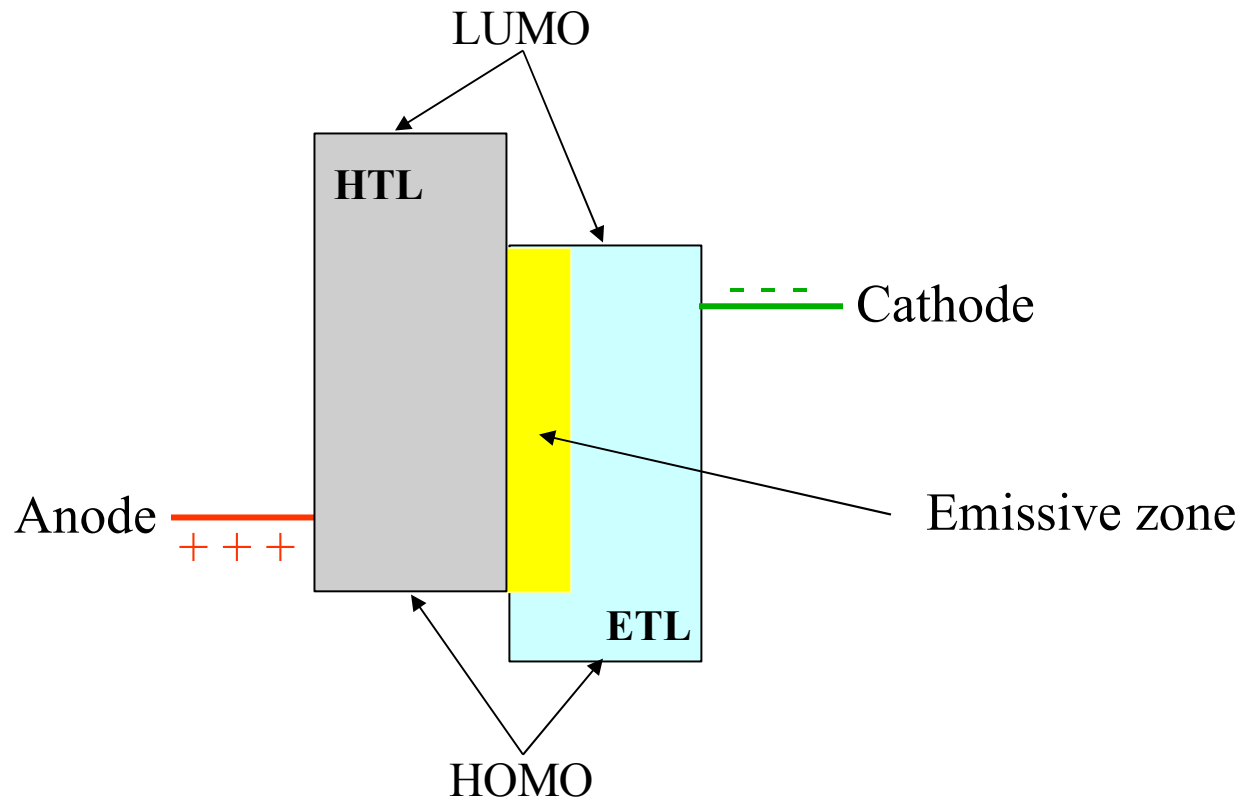
- e^-/h^+ recombination occurs away from the device electrodes.
- Broadens the number of useful organic materials (only single carrier type per layer).
- Allows reduction of the barrier for charge injection.



More efficient device

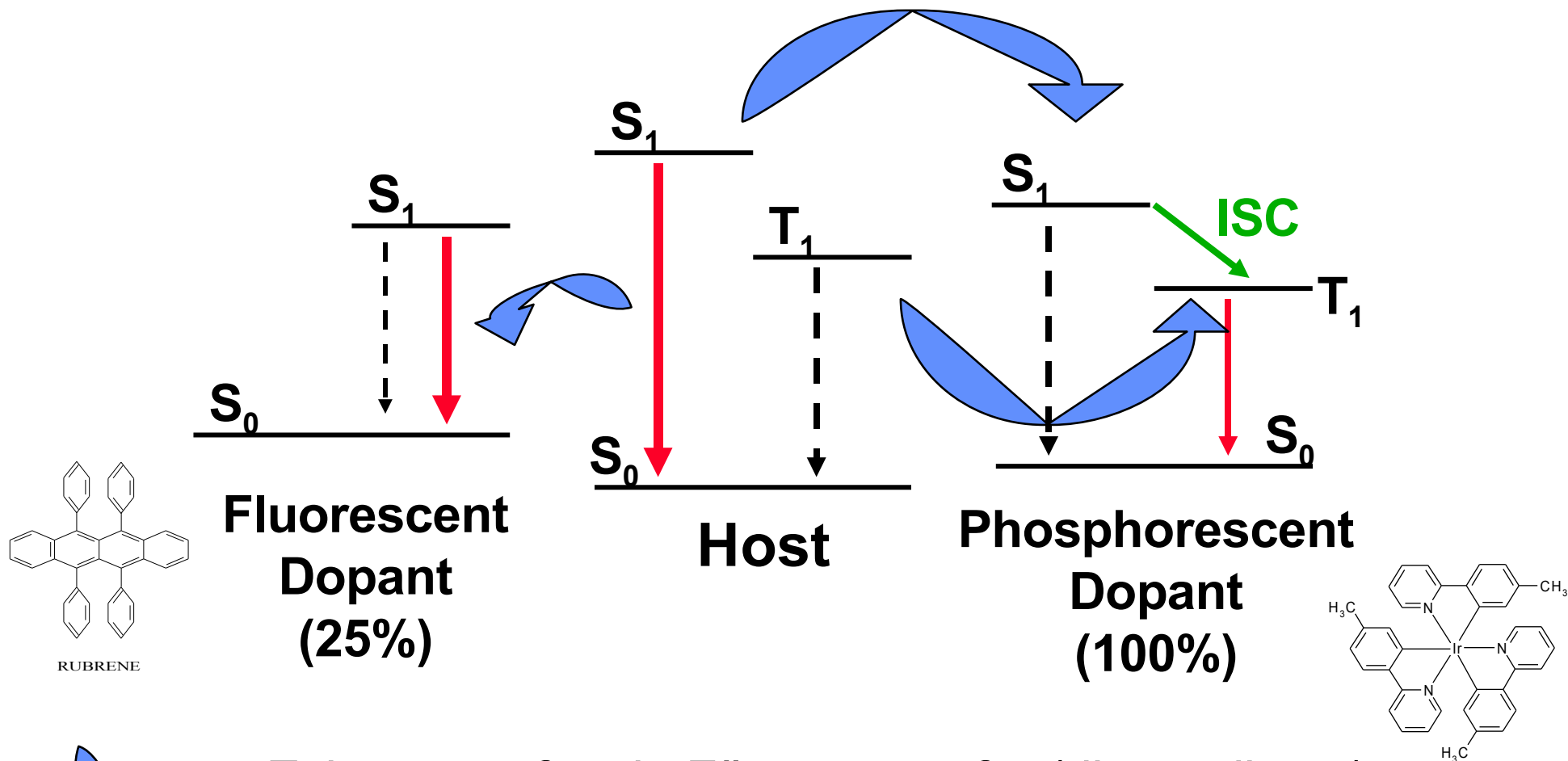


Bilayered device : emissive zone



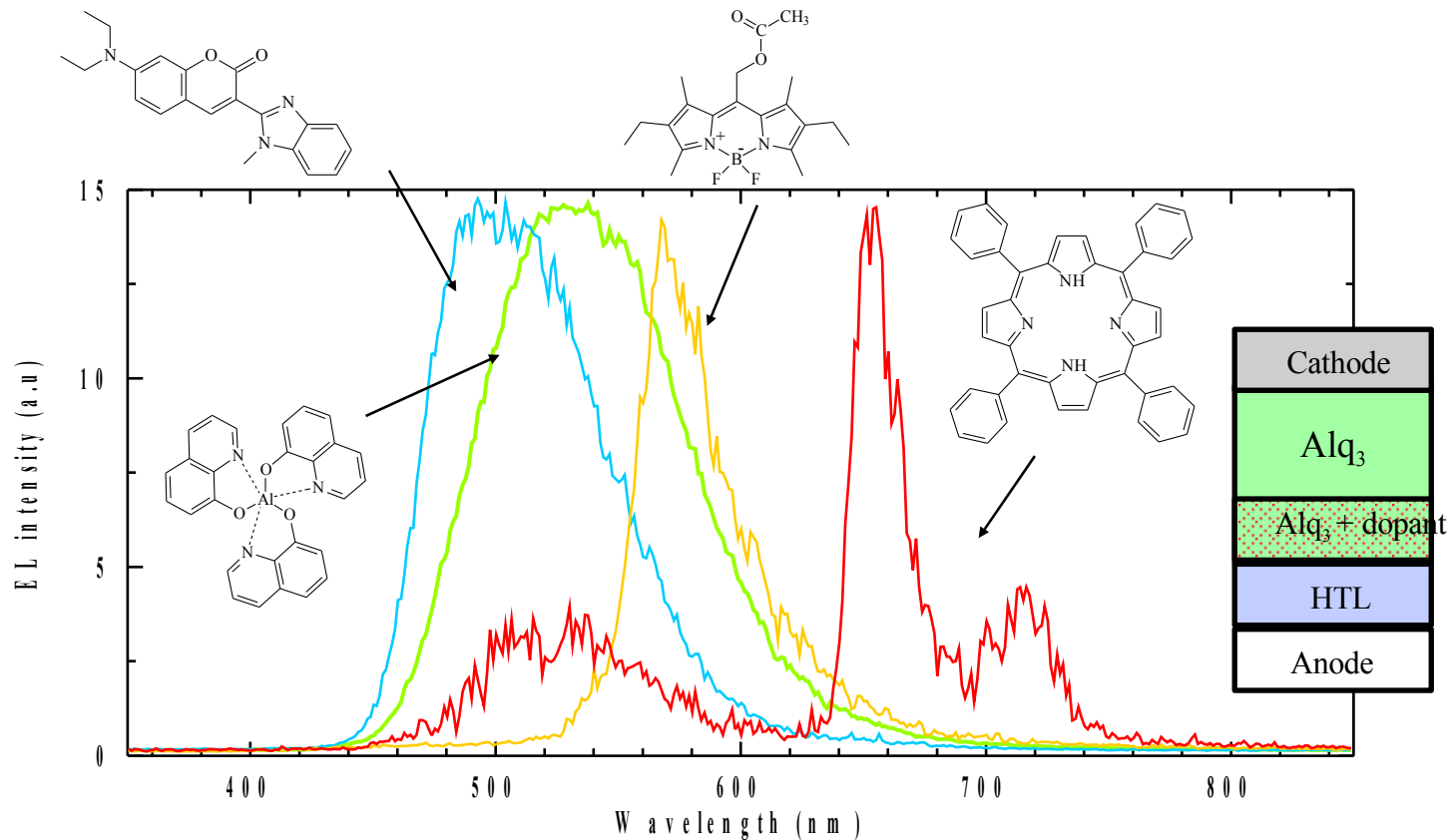
- The emissive zone is confined to a small section of the device and usually near the HTL/ETL heterojunction.
- Color tuning and luminance efficiency can be improved by doping the emissive zone with a highly luminescent molecule.

Exciton transfer through doping



Exciton transfer via Förster transfer (dipole-dipole) or Dexter transfer (charge transfer)

ISC : Intersystem crossing (via spin orbit coupling)



Efficiency improvement

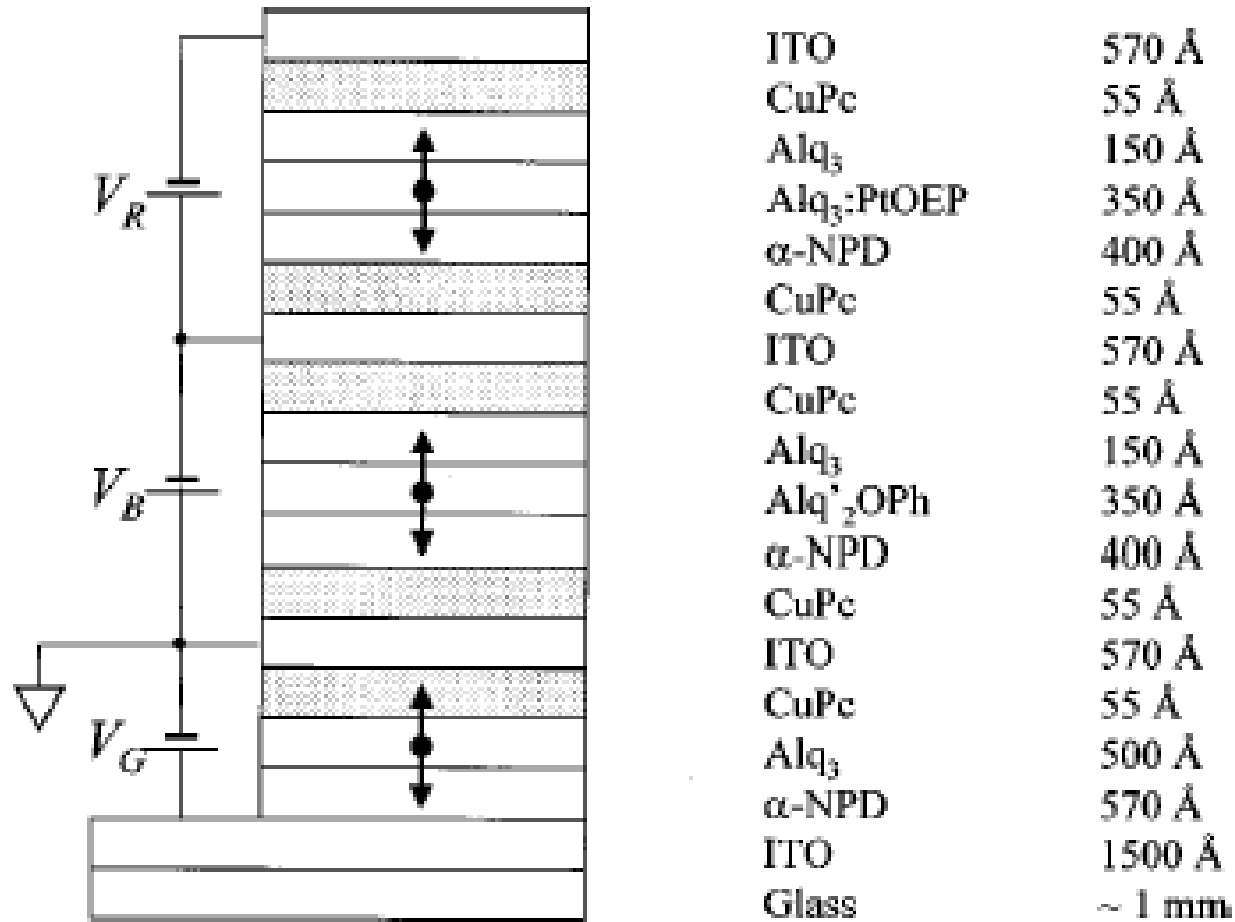


PL ~ 1 (avoid quenching/low concentration)

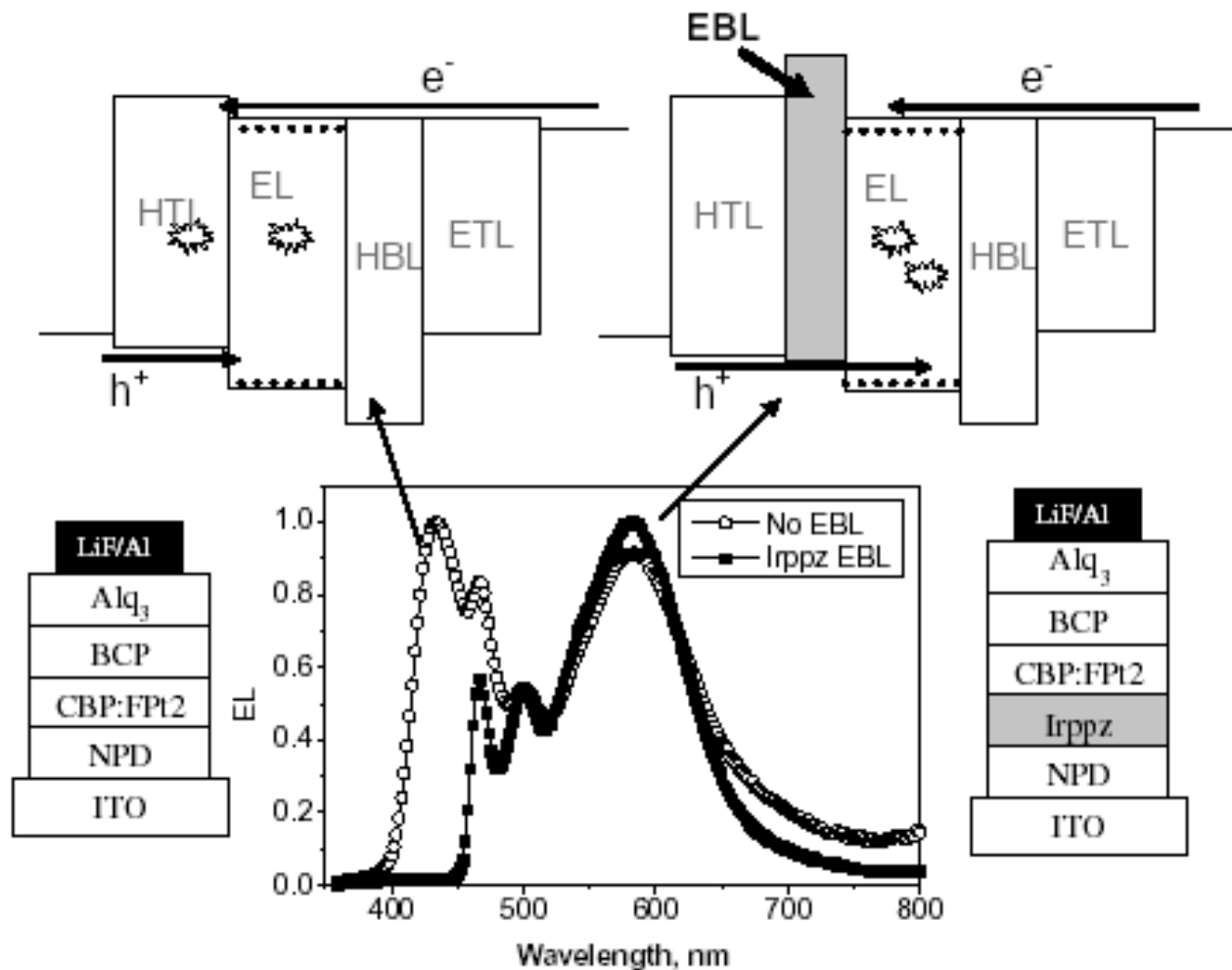
Color tuning (energy transfer)

Lifetime improvement

Device engineering: RGB stack OLED



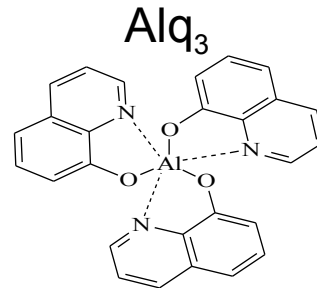
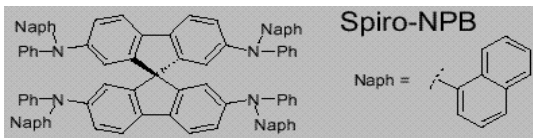
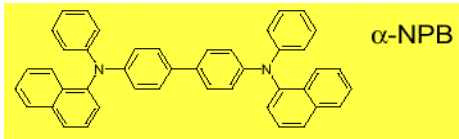
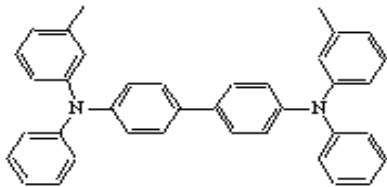
G. Gu et al., Appl. Phys. Lett., Vol. 74, 305 (1999)



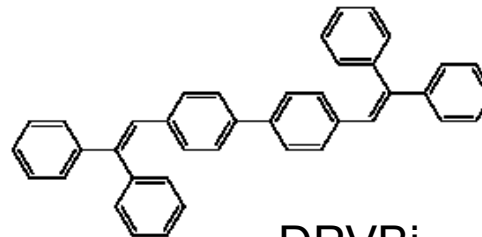
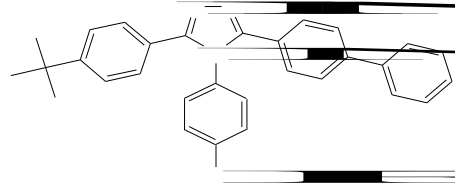
V.I. Adamovich et al., Organic Electronics 4 (2003) 77–87

Matériaux transport electrons ou matrice

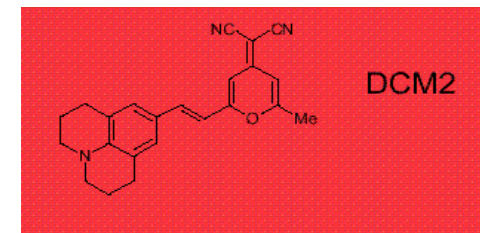
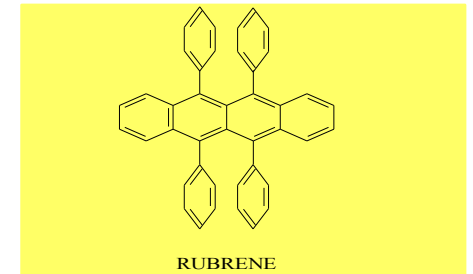
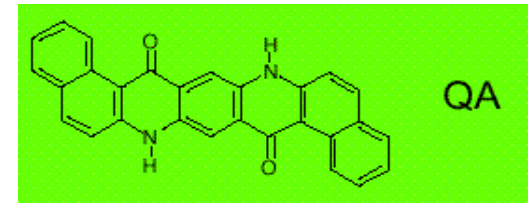
Matériaux transport de trous



Dérivé oxadiazole

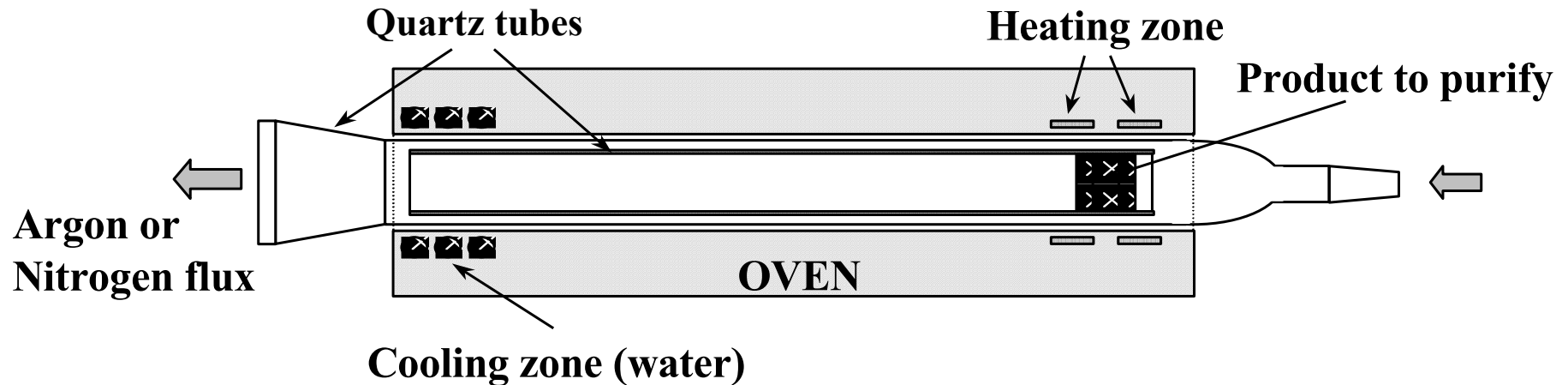


Dopants

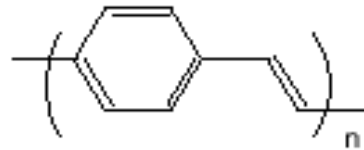


Un point clé : la pureté des matériaux

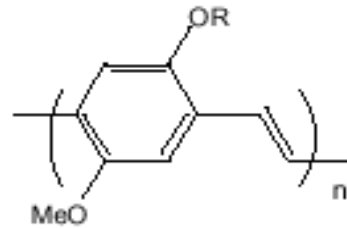
The purity of the material is a main issue Purification by train sublimation



Alq_3	Φ_{PL}
As received	13%
Purified	25%

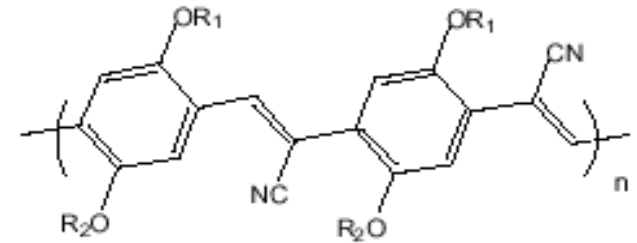


PPV

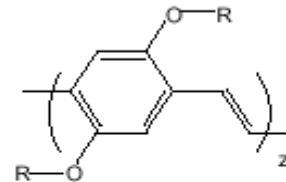
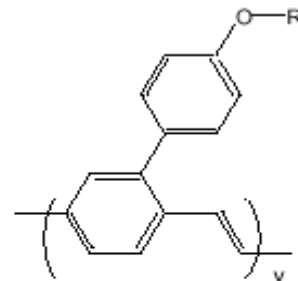
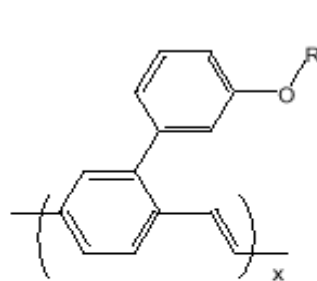


MEH-PPV $R = \text{CH}_2\text{CH}(\text{Et})\text{Bu}$
 "OC₁C₁₀" PPV $R = (\text{CH}_2)_3\text{CH}(\text{Me})(\text{CH}_2)_2\text{CHMe}_2$

Soluble PPV's

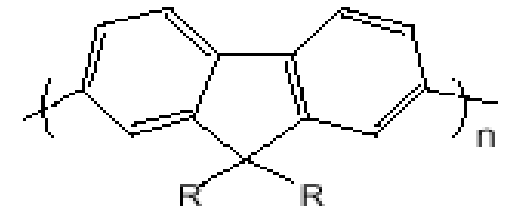


Cyano-PPV

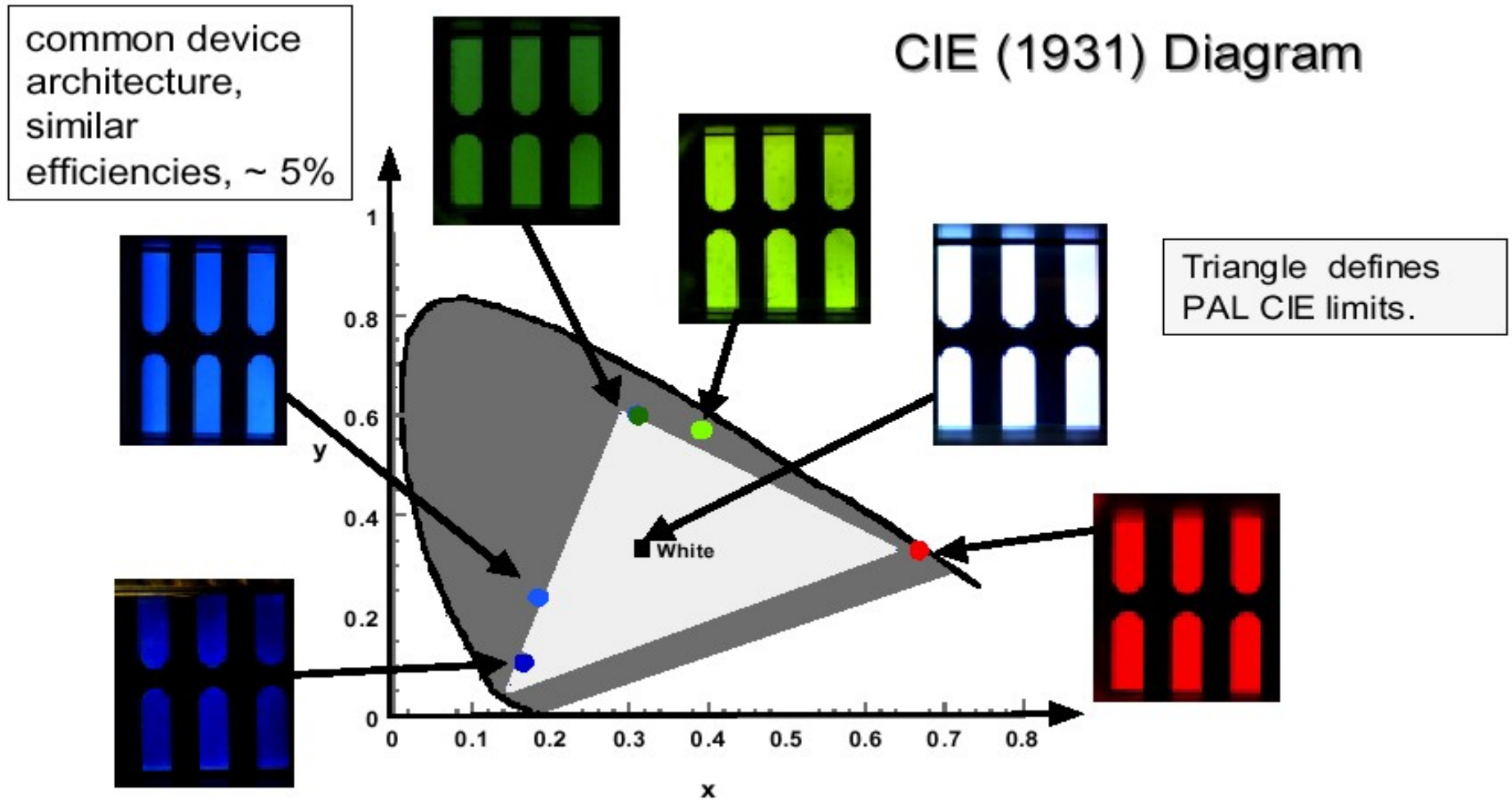


$R = (\text{CH}_2)_3\text{CH}(\text{Me})(\text{CH}_2)_2\text{CHMe}_2$

Covion PPV co-polymers



Polyfluorene



- High luminescence efficiency (PL, EL)
- Adequate conductivity (p or n type)
- Good temperature stability (high T_g)
- Good radical cation/anion stability
- Good oxidative stability (water, oxygen)
- Good coatability (thin, uniform films with no pinhole defects or impurities)
 - PLED : Good film formation from solution
No side reactions with solvents
 - OLED : Does not degrade during evaporation
No catastrophic film crystallization
- Color saturation and purity (narrow spectra and correct CIE coordinates)

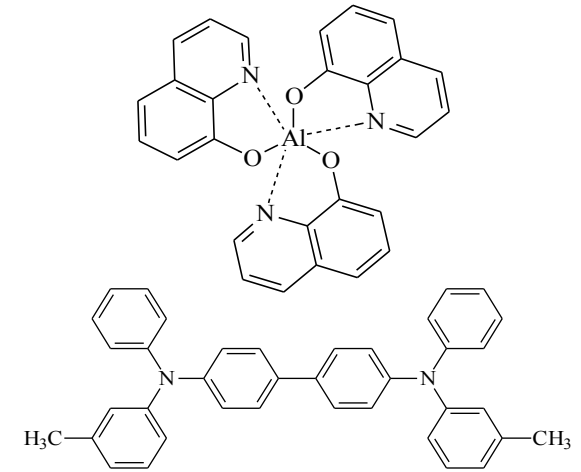
Films minces de matériaux organiques π -conjugués

2 classes de matériaux :

➔ **1987** : diodes efficaces à base de
OLED 'petites molécules'

C.W. Tang, S.A. Vanslyke, Appl. Phys. Lett. 51
(1987) 913

Films préparés par évaporation sous vide

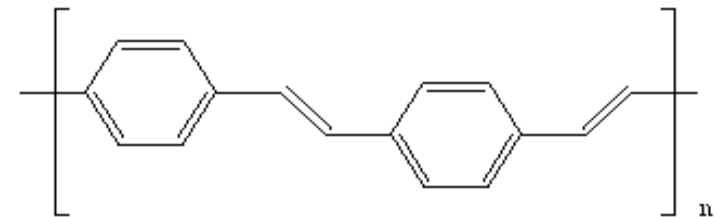


➔ **1990** : Electroluminescence dans les polymères

PLED

J.H. Burroughes et al.,
Nature 347 (1990) 539

Films préparés par spincoating



Poly(p-Phenylene-Vinylene)

Utilisation de matériaux phosphorescents pour augmenter l'efficacité

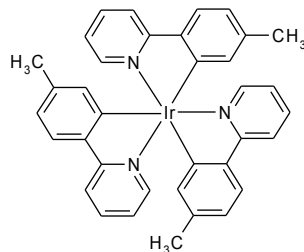
➔ Première réalisation:

M.A. Baldo, M.E. Thompson, S.R. Forrest et al., Nature 395 (1998) 152

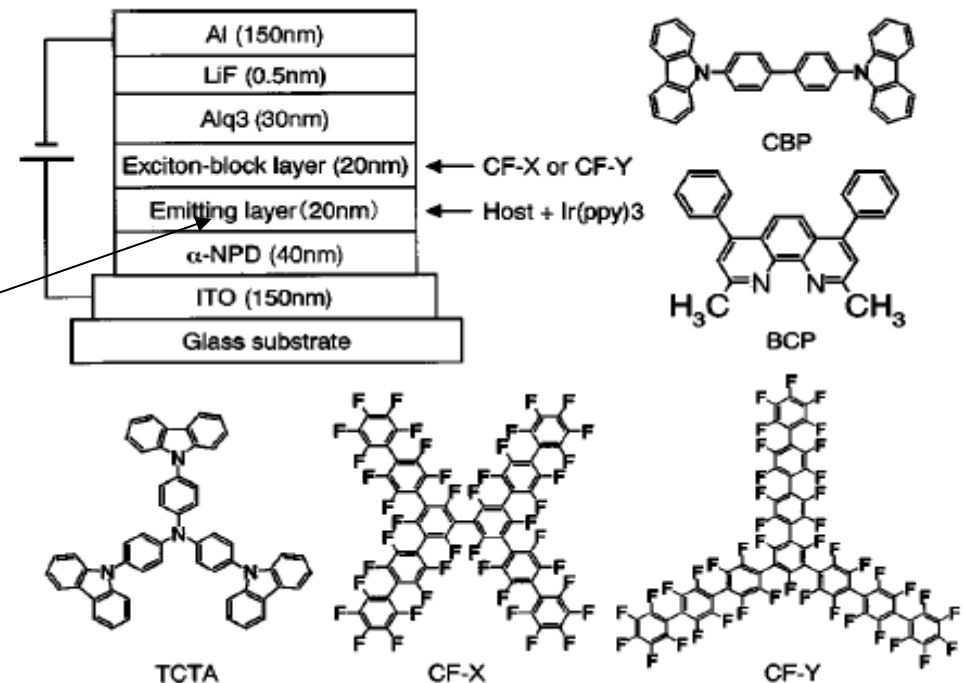
➔ Efficacité record:

M. Ikai et al., APL 79 (2001) 156

70 lm/W @ 65 cd/A, $\eta_{\text{ext}} = 19\%$

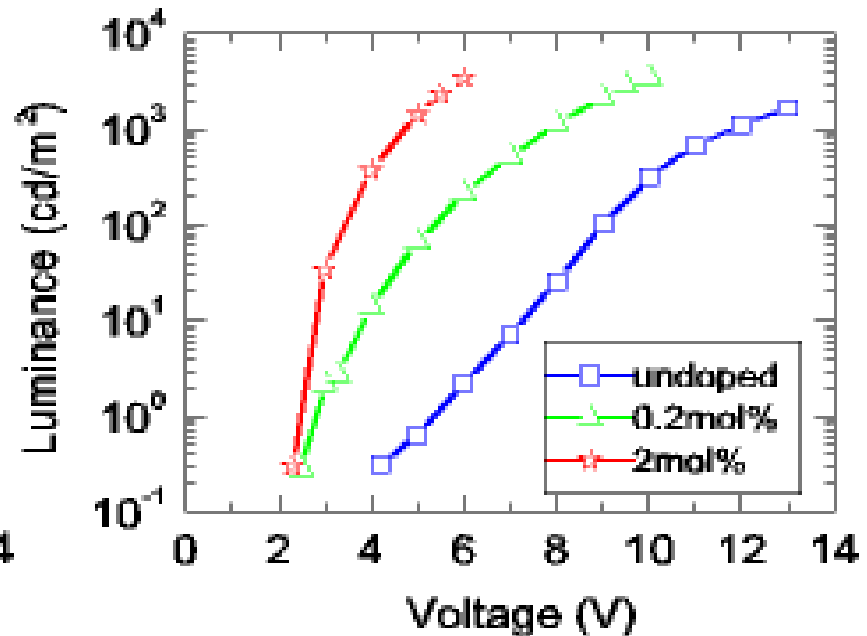
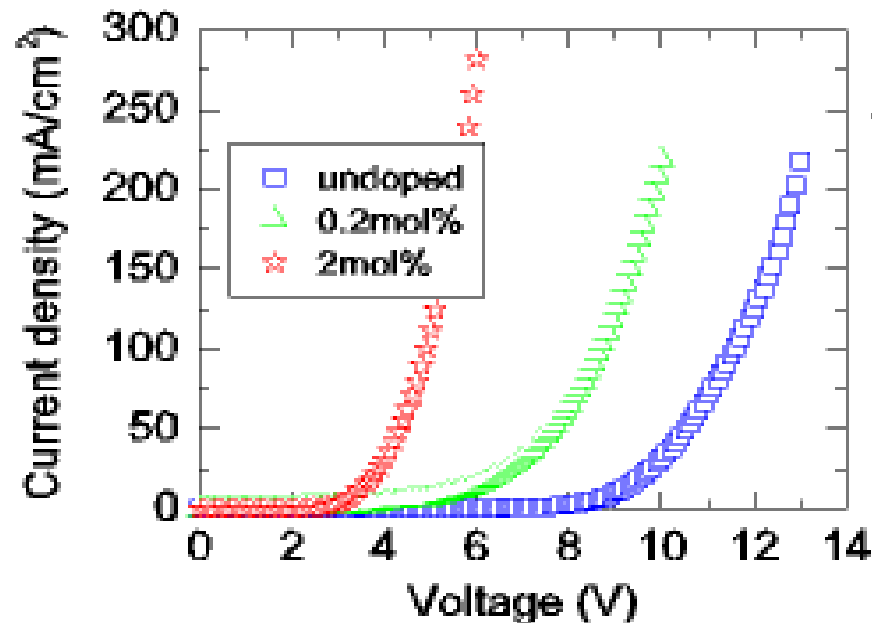


Ir(ppy)₃ in TCTA



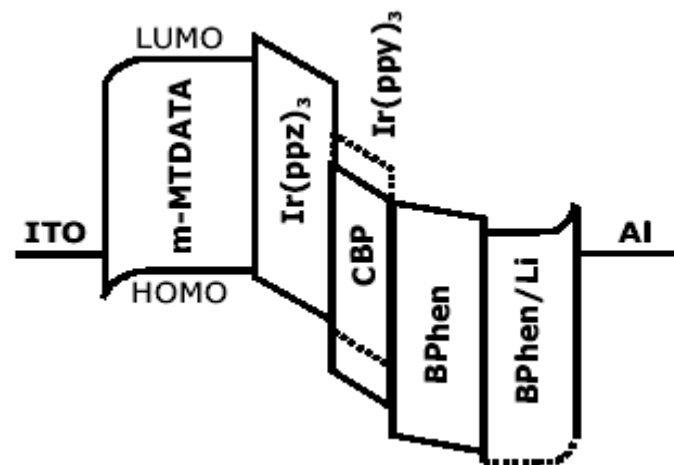
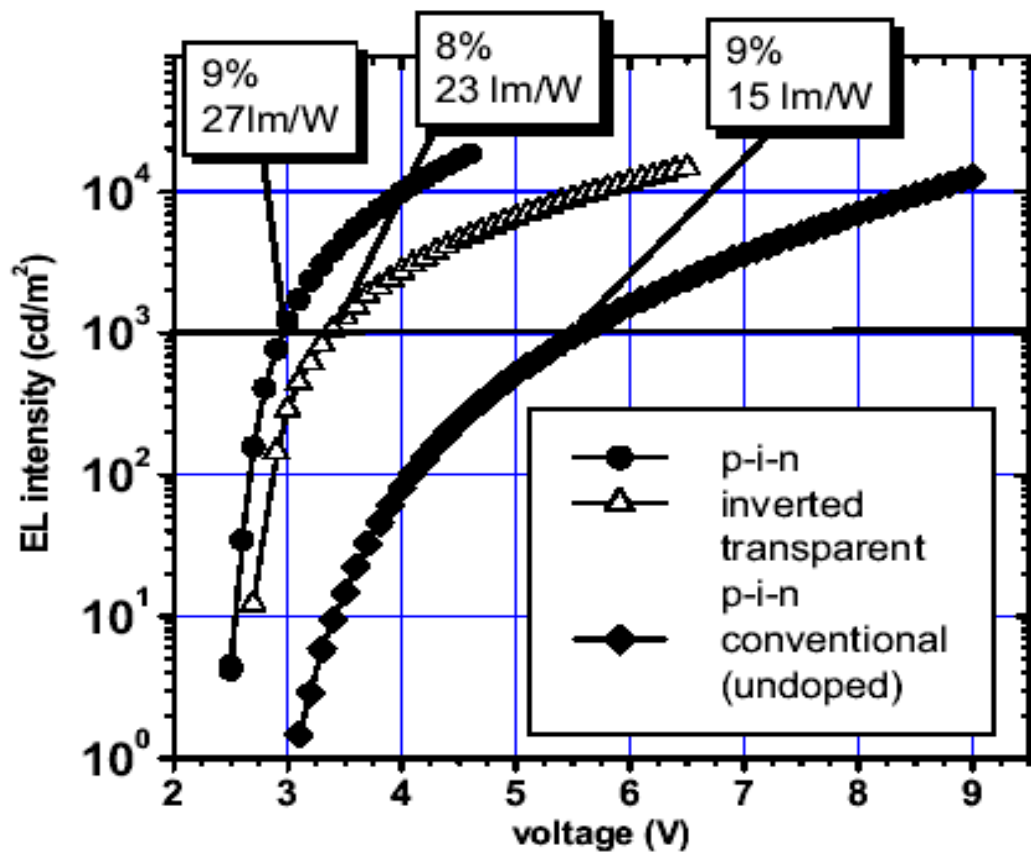
ITO /p-TDATA (100nm, doped F₄-TCNQ) / TPD (5nm) / Alq₃ (65nm) / LiF (1nm) / Al

I-V and electroluminescence characteristics of doped OLEDs



Improved OLEDs using doped hole transport layers

Ref.: K. Leo et al., Univ. Dresden



Ref. : M. Pfeiffer et al., Adv. Mater. 14 (2002) 1633

Small molecules : fluorescent materials

Colour	Red	Green	Blue
L (cd/m ²) @ 20 mA/cm ²	400	1500	600
Cd/A @ 20 mA/cm ²	3	7	3
T ½ (h) @ 100 cd/m ² , 20°C	30 000	100 000	25 000

Ref. Eastman Kodak, 2002

Small molecules : phosphorescent materials

		UDC PHOLED materials	CIE (x, y)	Luminous Efficiency (cd/A)	Lifetime (hrs)	at luminance cd/m ²	
développement	Commercial	Red: RD15	(0.67, 0.33)	12	100 000	500	
		Red: RD07	(0.65, 0.35)	18	40 000	500	
		Green: GD29	(0.30, 0.63)	24	10 000	600	
		Green: GD33	(0.31, 0.64)	40	20 000	1000	
		Green: GD48	(0.32, 0.63)	37	25 000	1000	
	Recherche		RD61	(0.62, 0.38)	30	40 000	500
			GD107	(0.35, 0.60)	40	25 000	1000
			YD85	(0.41, 0.58)	65	under test	1000
			New green	(0.32, 0.63)	80	15 000	1000
			New green	(0.32, 0.63)	57	40 000	1000
	New blue	(0.16, 0.37)	22	15 000	200		
	New blue	(0.14, 0.13)	9	under development	200		
	new blue	(0.16, 0.10)	3	under development	200		

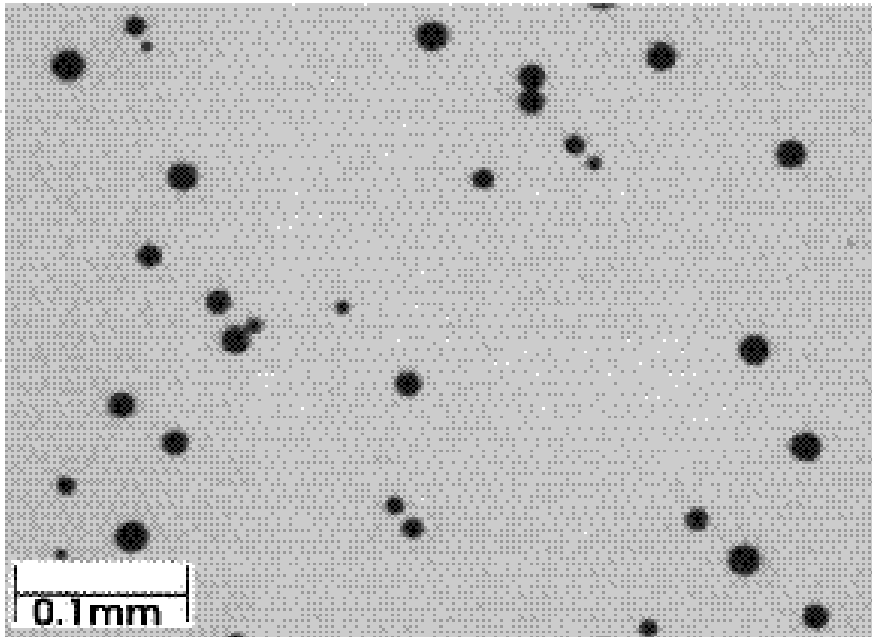
Source: M.S. Weaver et al., Proceeding Eurodisplay 2005, 188 (2005)

Polymer performances

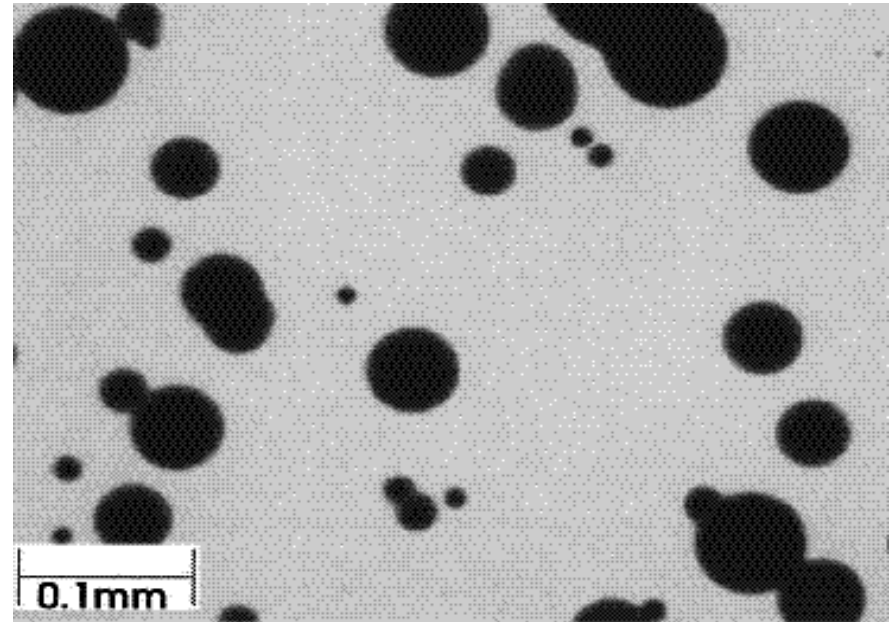
Color	At 100 cd/m ²		Lifetime at RT (hrs)	
	CIE (x, y)	Luminous efficiency (cd/A)	measured at L (cd/m ²)	extrapolated ^a at 100 cd/m ²
Red	(0.68, 0.32)	1.7	1790 2000	~210 000
Green	(0.43, 0.55)	7.7	2867 2000	~255 000
Blue	(0.16, 0.20)	4.8	510 1425	~100 000
Yellow	(0.50, 0.49)	2.1	2420 4000	~290 000
Orange	(0.58, 0.42)	0.9	8138 1000	~320 000
White	(0.30, 0.36)	5.1	290 1600	~40 000

^a assuming that lifetime is proportional to $1/(\text{luminance})^n$ with $1.3 < n < 2$

Source: N. Patel, CDT Workshop Notes, Eurodisplay 2005

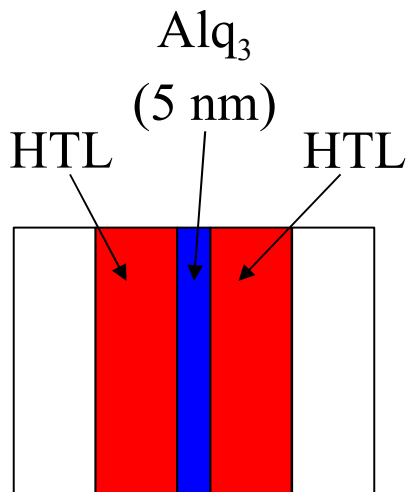


T₀



After storing for 24 in ambient conditions

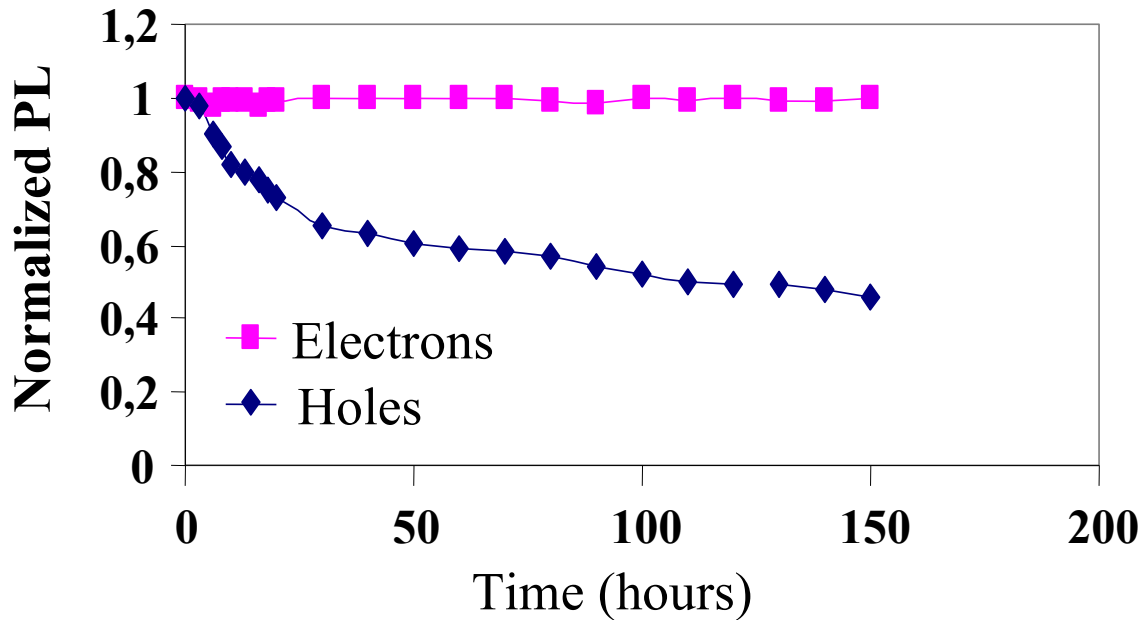
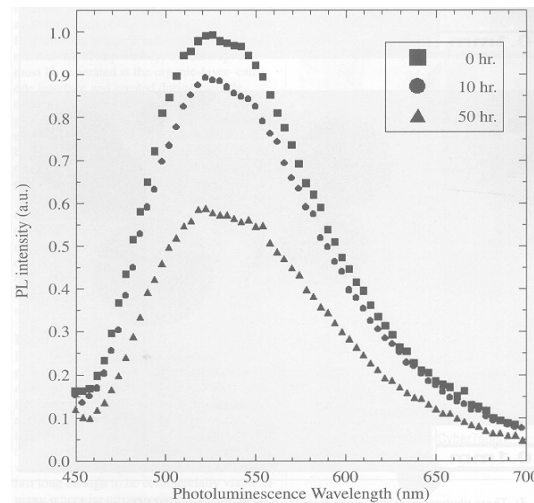
Ref.: Liew et al., Appl. Phys. Lett., Vol. 77, N° 17, 23 October 2000



Hole-only device



Eviter formation
espèces cationiques
Alq₃⁺

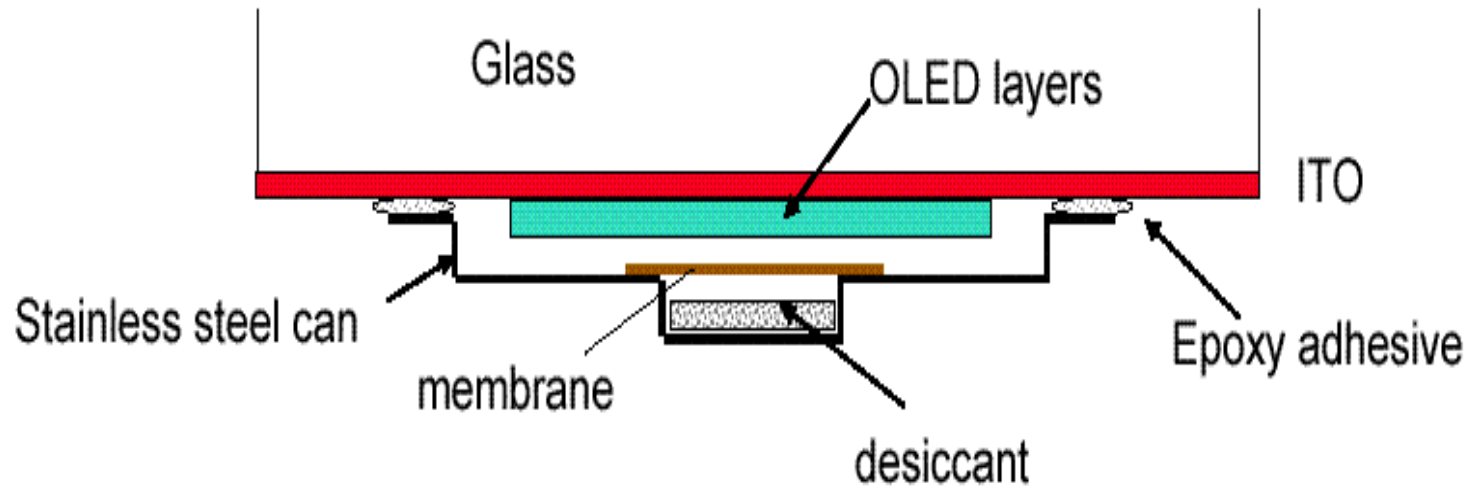


Principaux effets de la dégradation

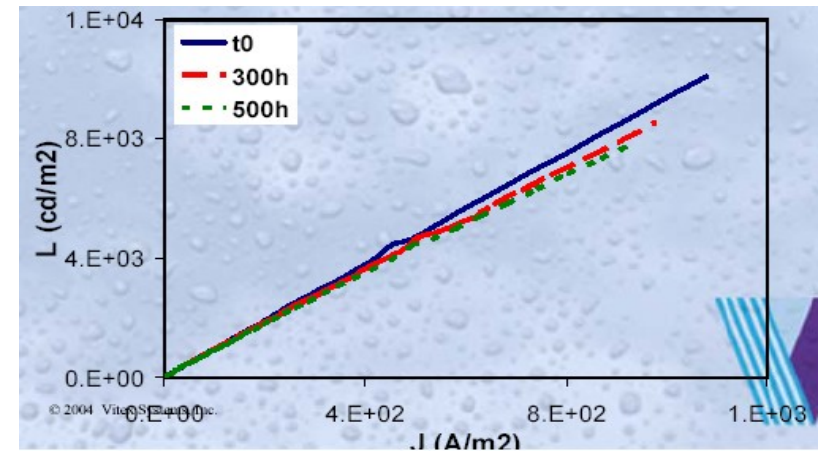
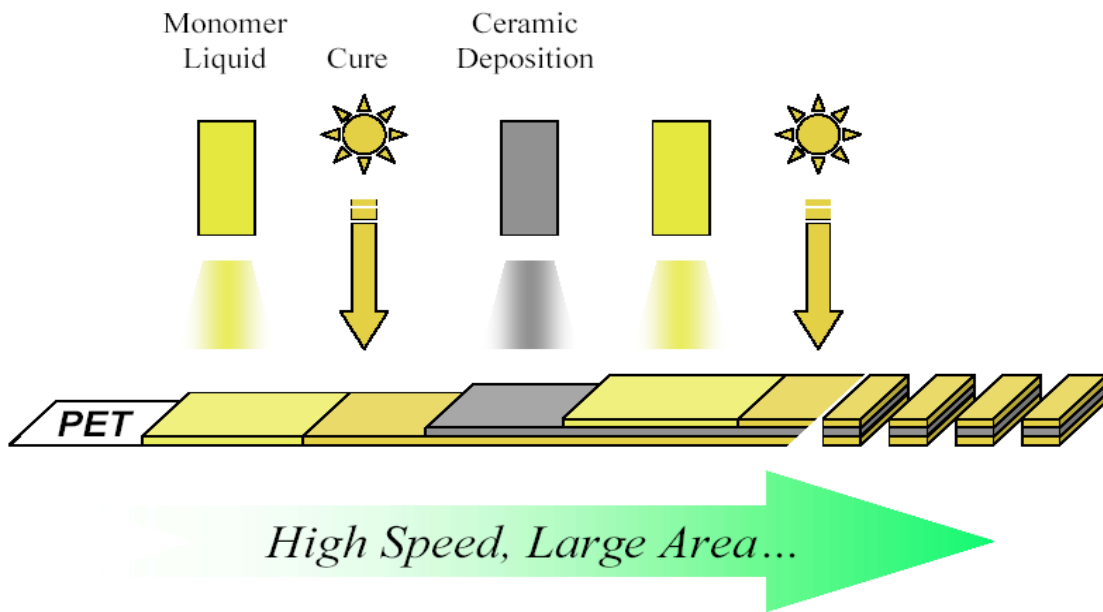
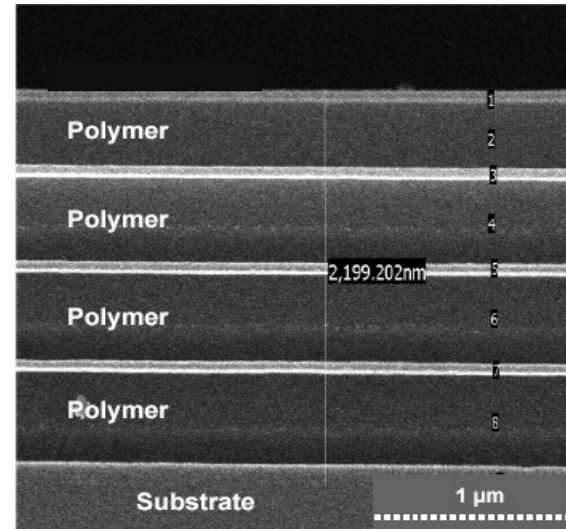
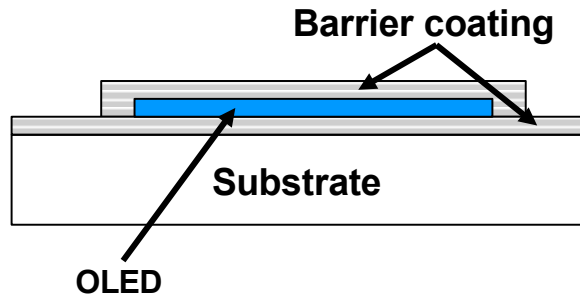
- ➔ **Diminution de la luminance**
 - vieillissement des matériaux
 - vieillissement différentiel (RGB)

- ➔ **Augmentation de la tension de fonctionnement**
 - barrière injection (électrodes, interfaces)

- ➔ **Apparition et croissance de ‘points noirs’**
 - électrodes, environnement



Pioneer Patent EP 0 776 147 A1



Source : Vitex



PLED Dupont Plastic Substrate



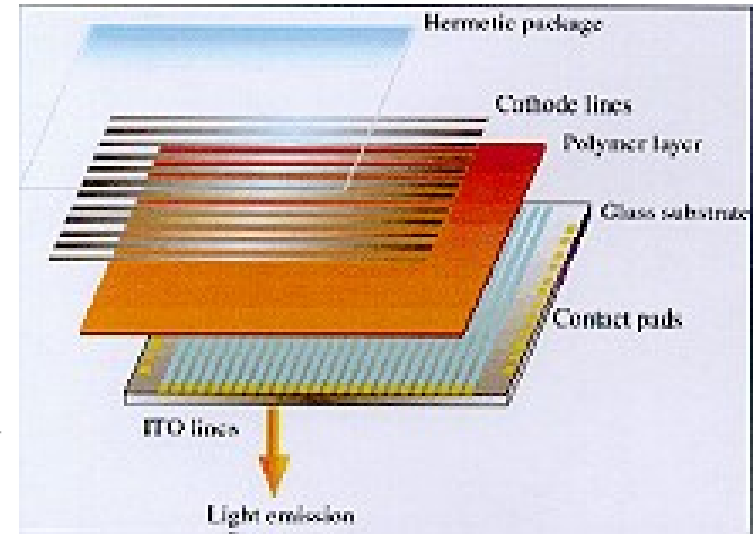
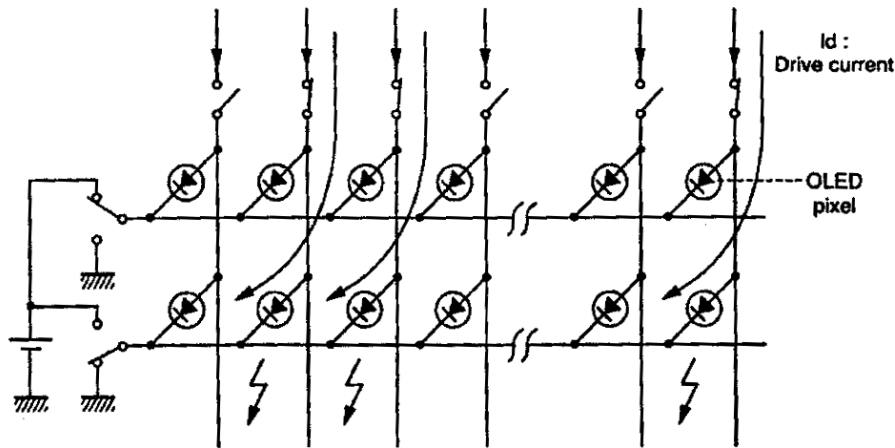
Universal Display Corporation

$L=200 \text{ cd/m}^2$, $e= 175 \mu\text{m}$

Pixels : $400 \mu\text{m} \times 500 \mu\text{m}$

Les diodes électroluminescentes organiques

Adressage des écrans OLEDs



Pour chaque ligne : $L_{\text{crête}} = N_{\text{ligne}} * L_{\text{moy.}}$

soit écran VGA :

si $L_{\text{moy.}} = 300 \text{ cd/m}^2$ d'où $L_{\text{crête}} = 72000 \text{ cd/m}^2$

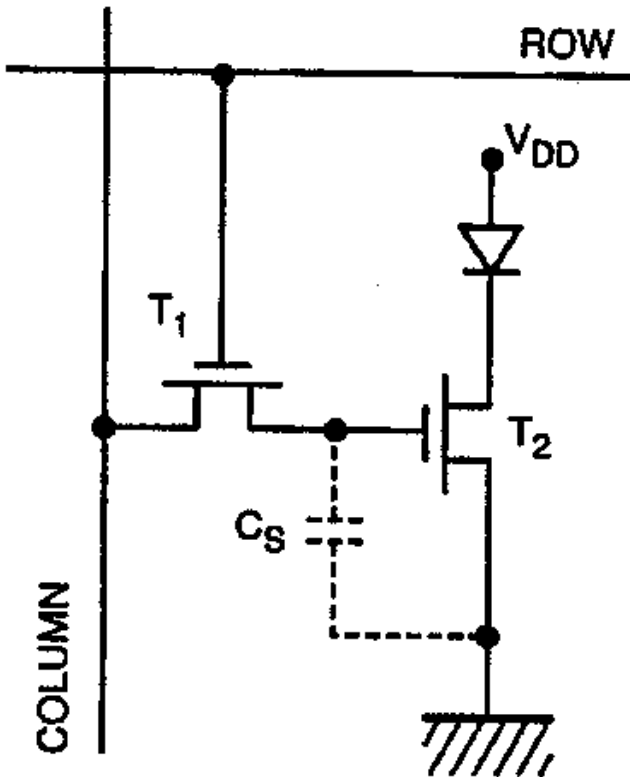
Avantages :

- Bien adapté aux OLEDs
- Simple / bas coût

Inconvénients :

- ☠ Nécessite forte brillance crête

Limitation : ~100 – 150 lignes max (résolution limitée)



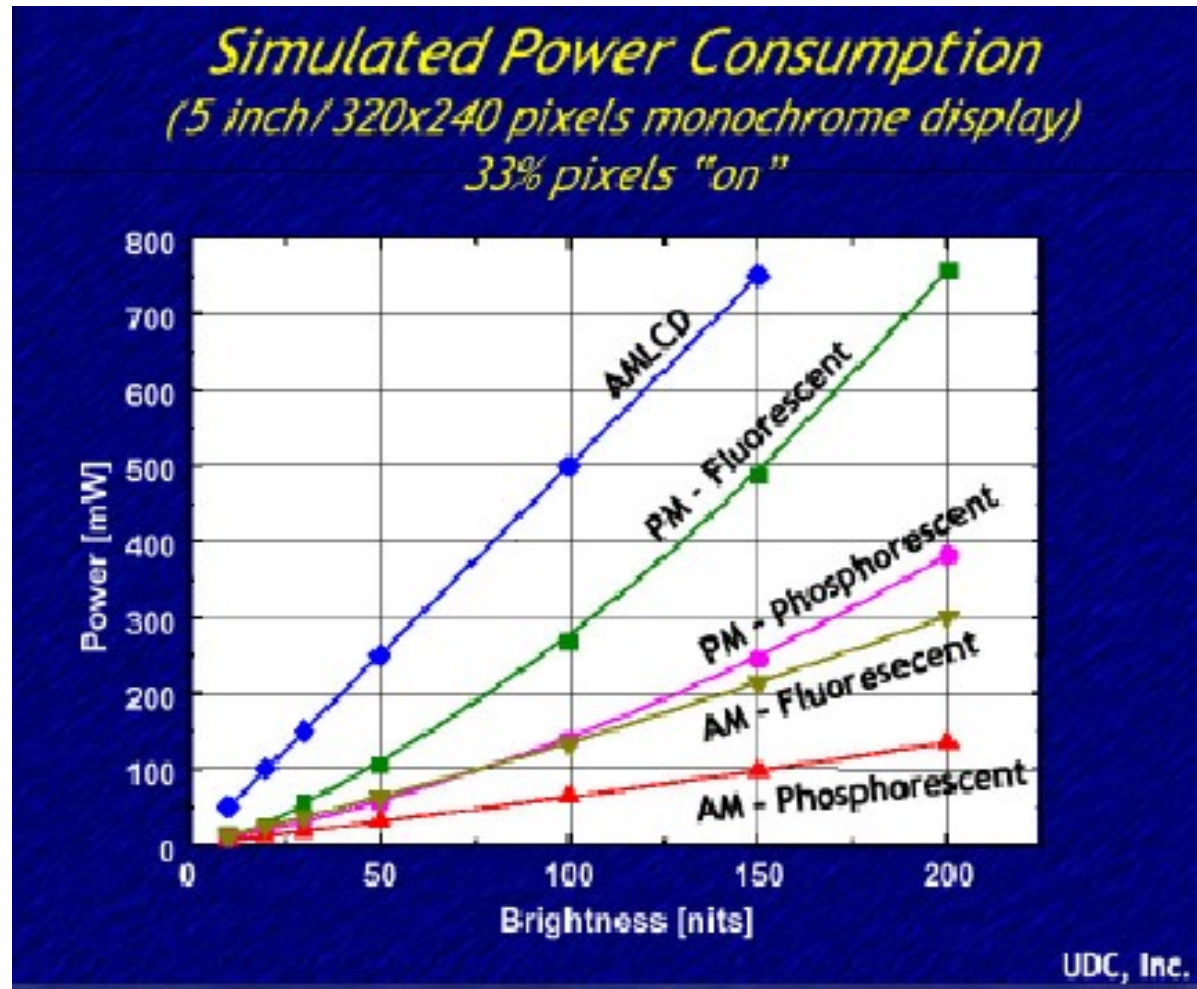
Avantages :

- Découplage adressage / excitation
- Courant plus faible
- Tension compatible TFTs

Inconvénients :

- ☠ Silicium polycristallin
- ☠ Nécessite transistor type p
- ☠ Faible taux ouverture (4 TFTs/pixel)

Fluorescence vs Phosphorescence

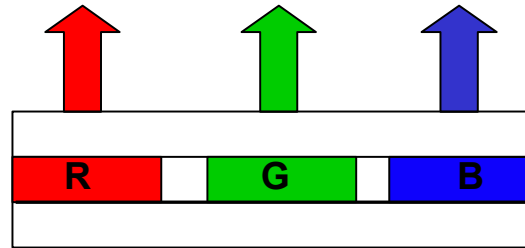


Réf: ELIATECH Co., Ltd., OLED ASIA 2004

Les diodes électroluminescentes organiques

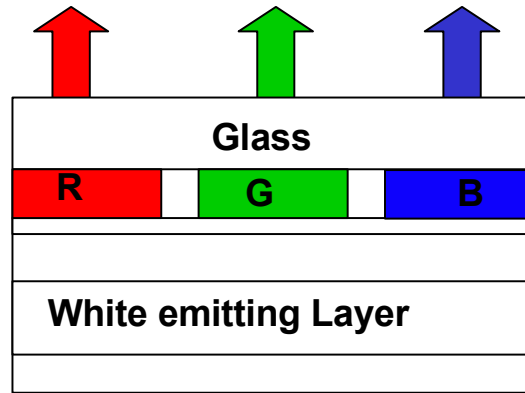
Réalisation de dispositifs couleurs

Side-by-side pattern



OLED with
Blue, Green and Red
emissive sub-pixels

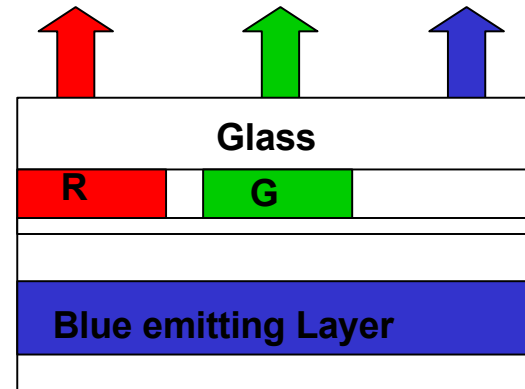
Colour filter



← Red, Green and Blue Filters

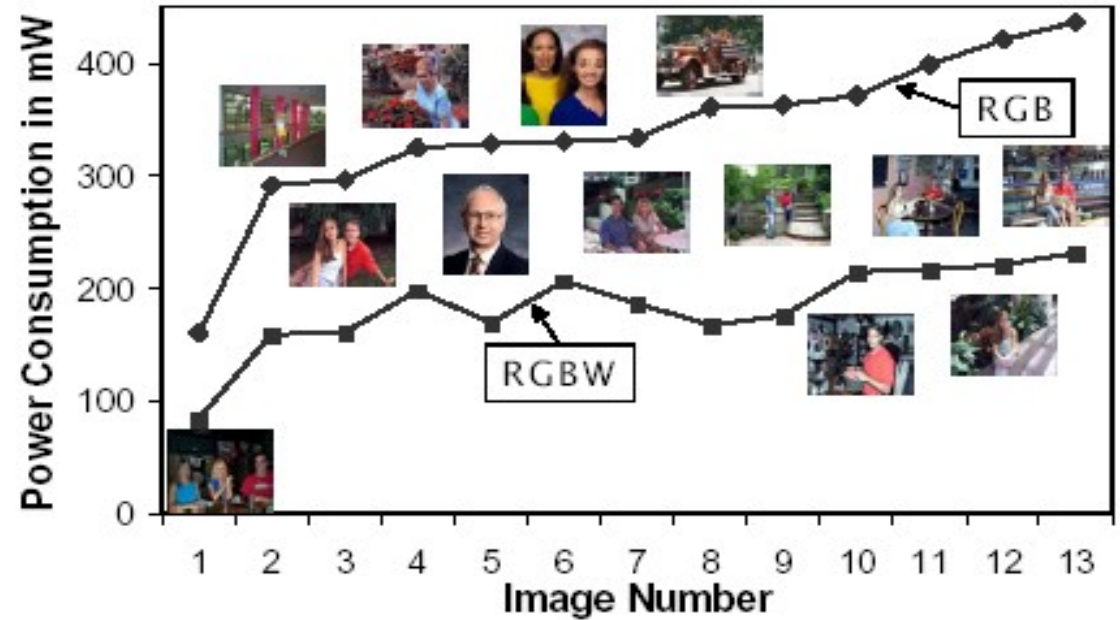
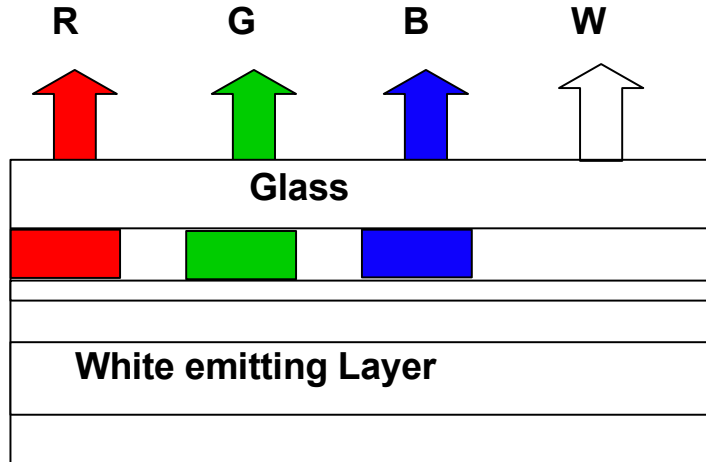
White OLED

Colour Conversion



← Red and Green
Converters

Blue OLED



Source: ASIA Display IMID'04



Blue OLED

- Multilayer structure based on evaporated small molecules

Converting Layers Composition

- Host Photopatternable Polymer (transparent)

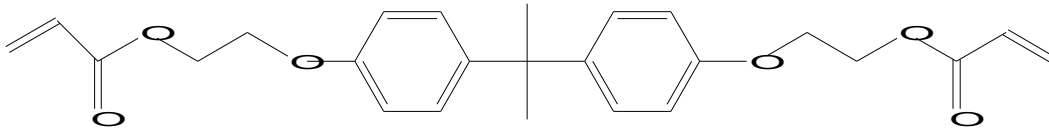
↳ Patterning of Red and Green sub-pixels

- Dye (Green or Red emission)

↳ Good absorption of the blue light from the blue OLED (OD > 2.5)
Efficient emission in green or red (high PL yield and acceptable CIE coordinates)

Photopatternable resin

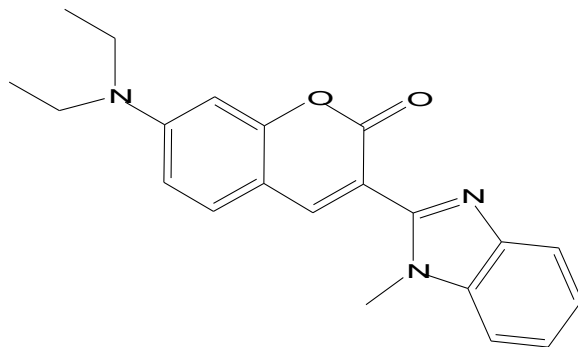
**Bisphenol A ethoxylate diacrylate +
Photoinitiator Irgacure 186 (1% wt / monomer)**



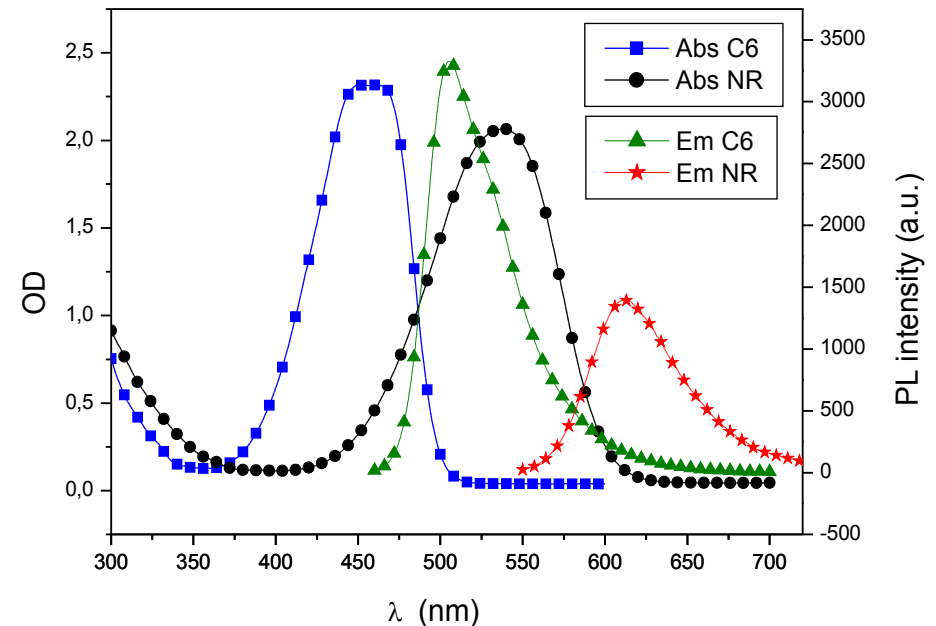
- UV photopatternable resin
- Transparent resin
- Film thickness ~ 5 μm

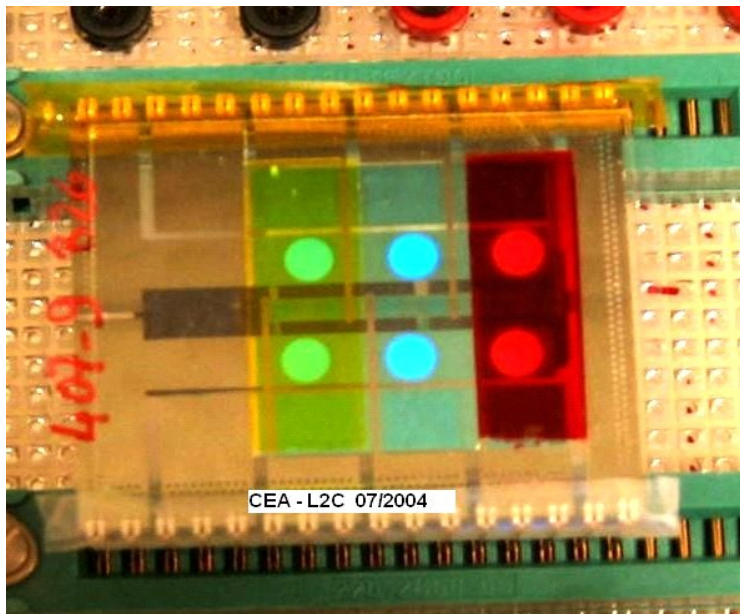
Fluorescent dyes

GREEN: Coumarin 6 (C6)

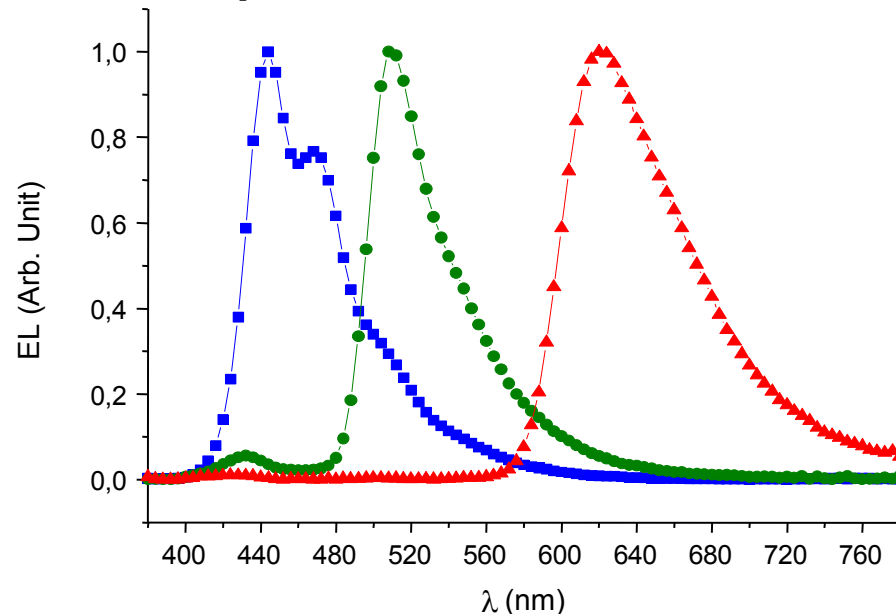


**RED: mixture of green (C6)
and red (Nile Red or NR) dyes**

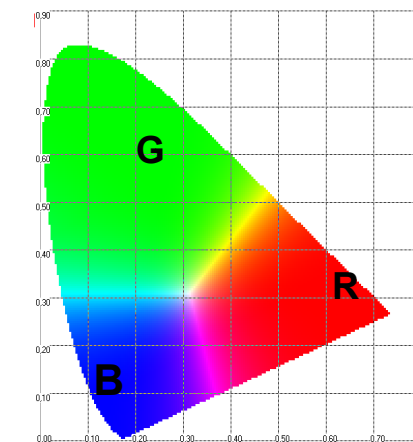




Spectre d'émission

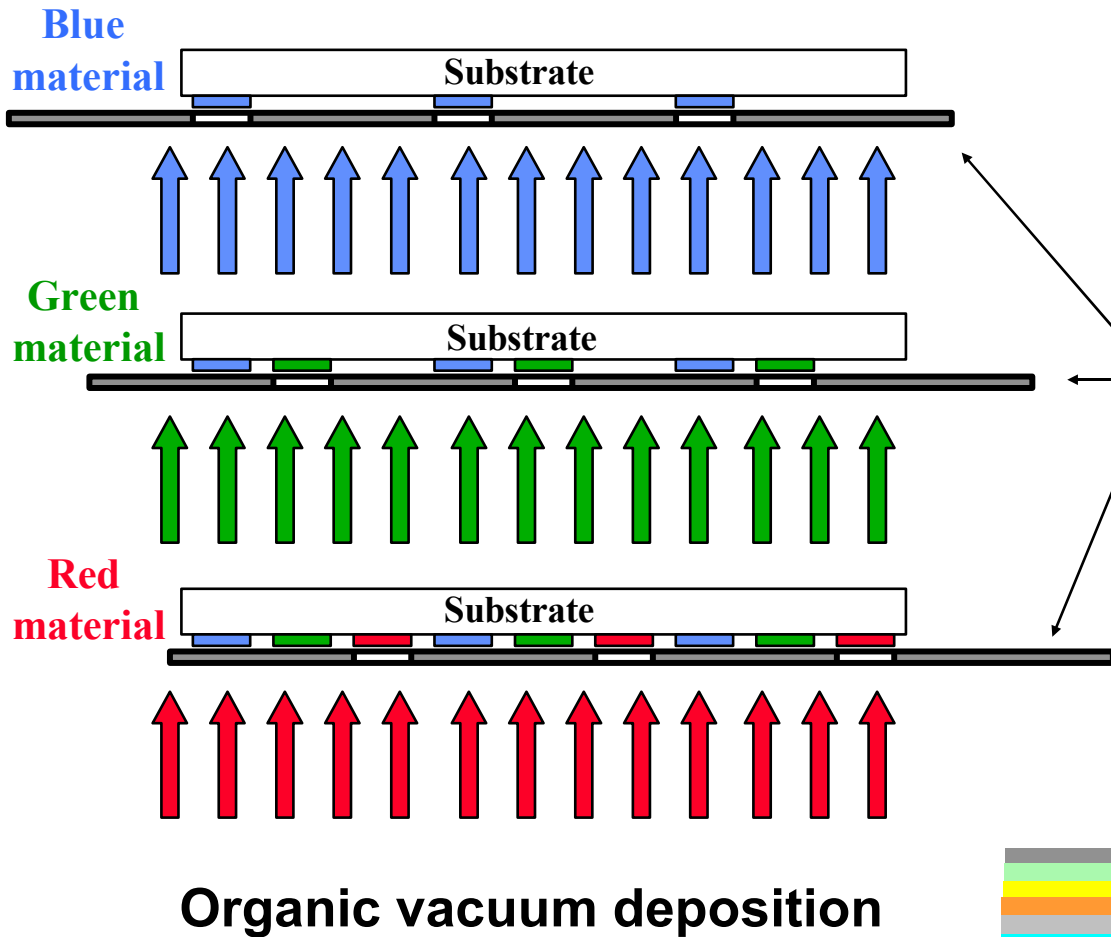


Dispositif	Luminance (cd/m ²) at 10 mA	x	y
B	1779	0.154	0.128
G	1459	0.244	0.609
R	63	0.663	0.329

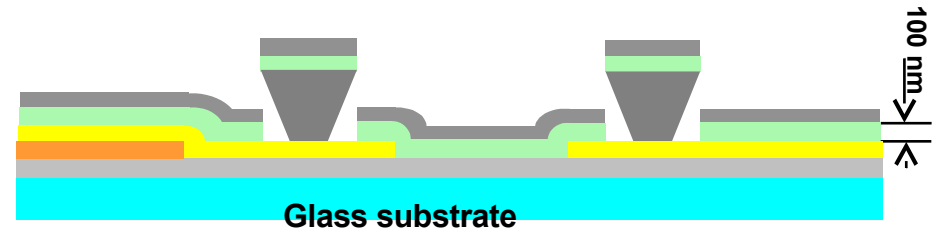
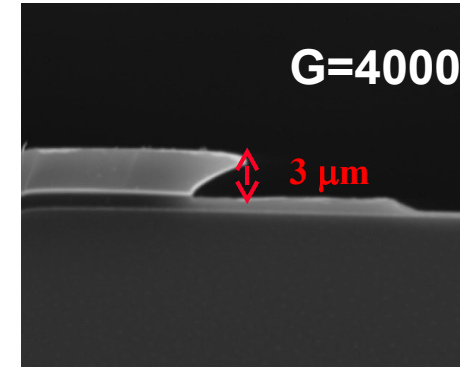
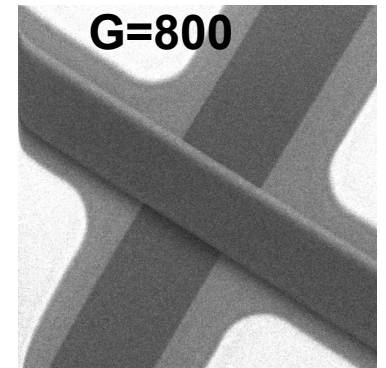


Les diodes électroluminescentes organiques

Techniques de dépôt des matériaux organiques



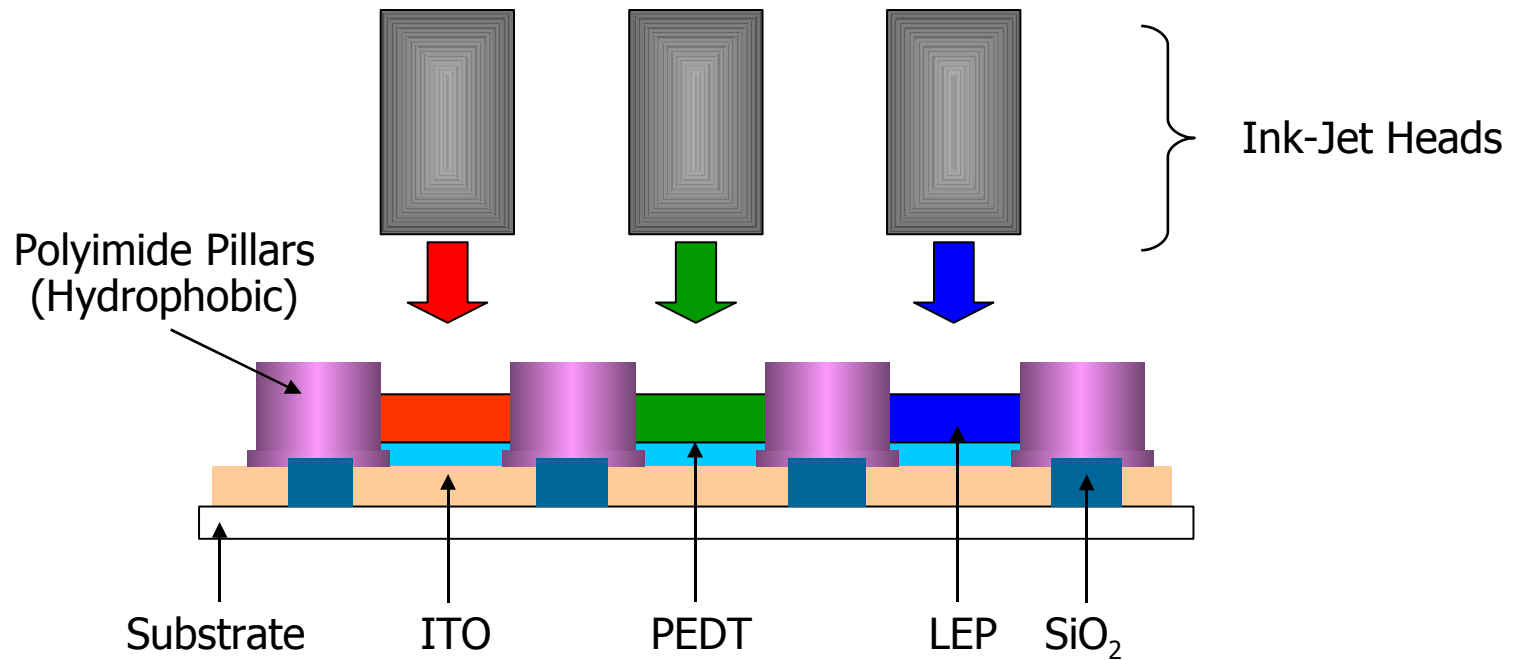
Shadow mask



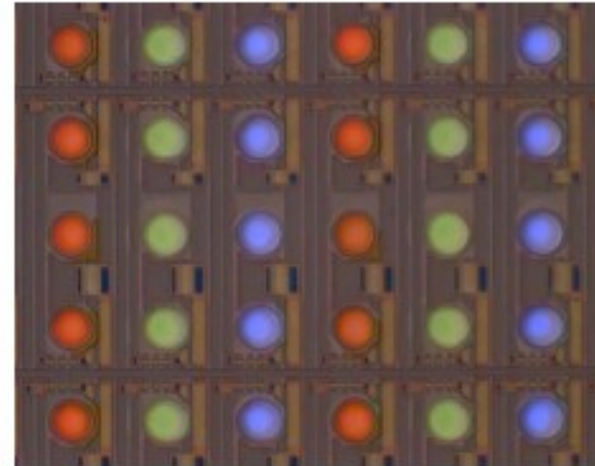
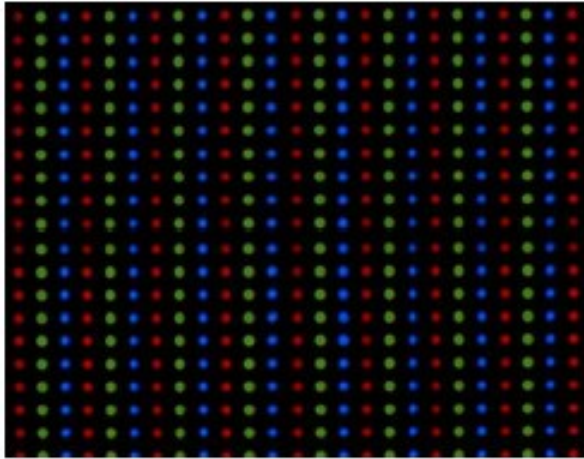


The most common technique for polymer RGB applications is ink-jetting.

Inkjet printing of LEP Colour Displays



Some RGB ink-jetted pixels



CDT/Seiko - Epson

2001

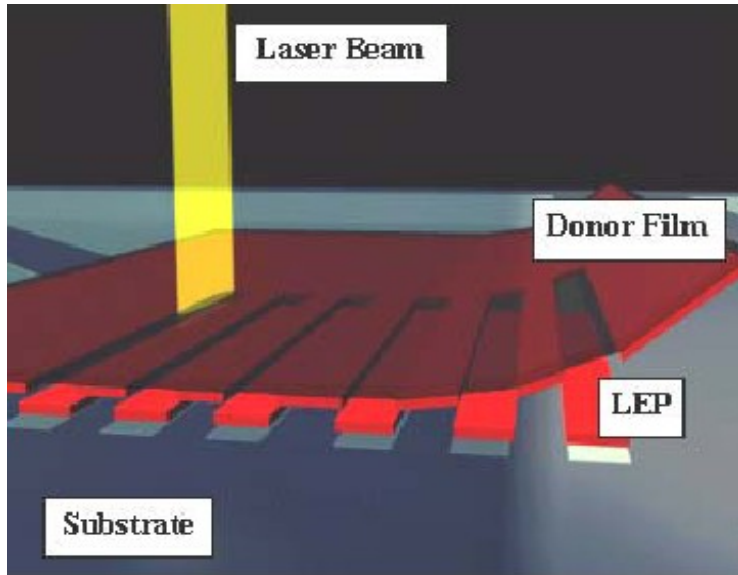
Démonstrateur 2,5'' diag.

200 x 150 pixels (x 9)

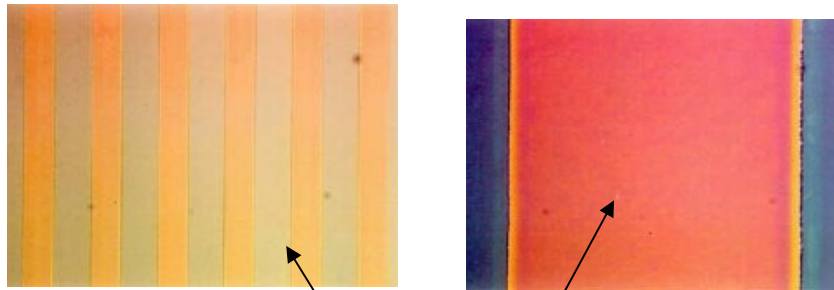
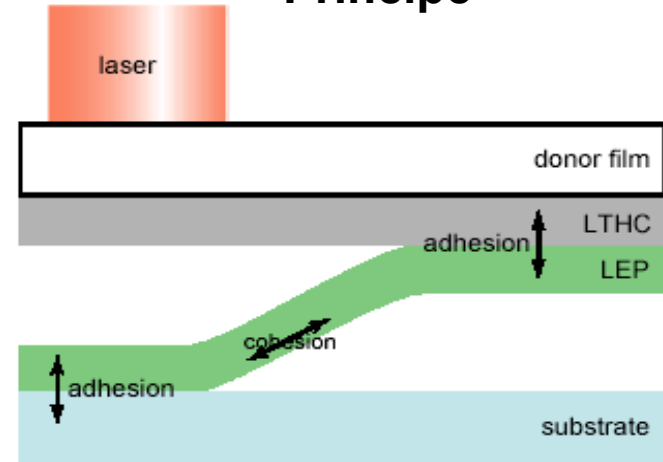
Pixel : 10 μ m x 86 μ m

Pas : 52 x 133 μ m

Laser Induced Thermal Imaging (LITI)



Principe



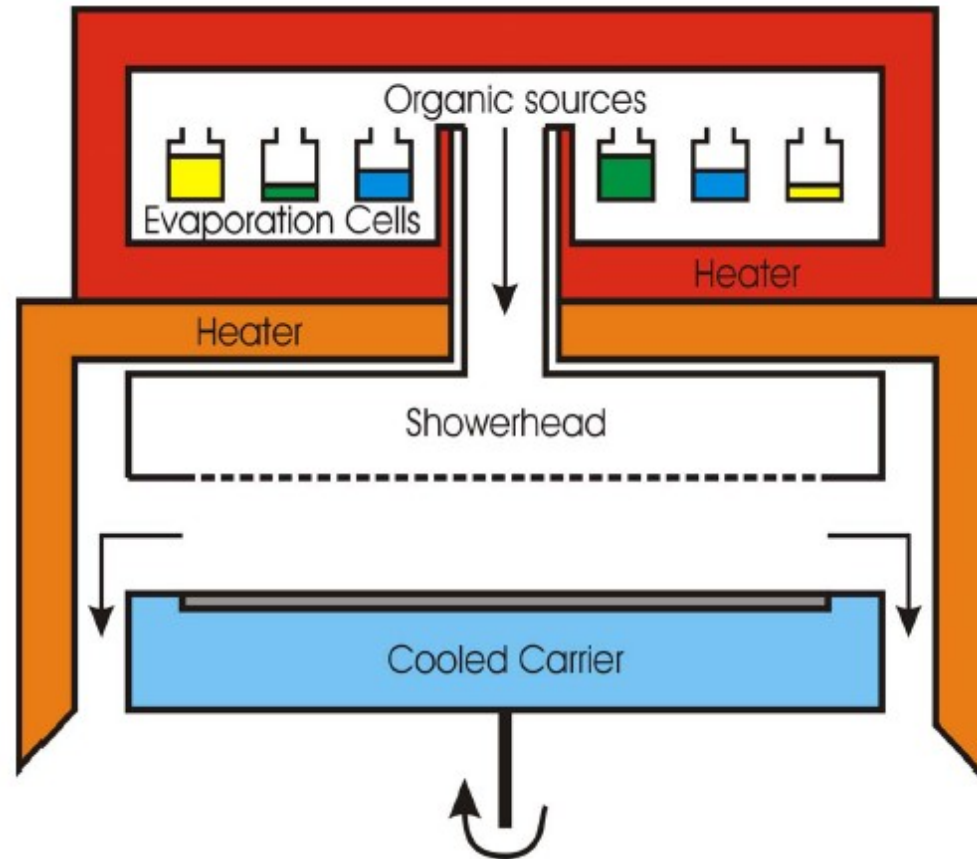
95 μm



3.6" QVGA full color AMOLED
Pixel pitch 80 x 240 μm

Samsung SDI & 3M Display

Organic Vapour Phase Deposition

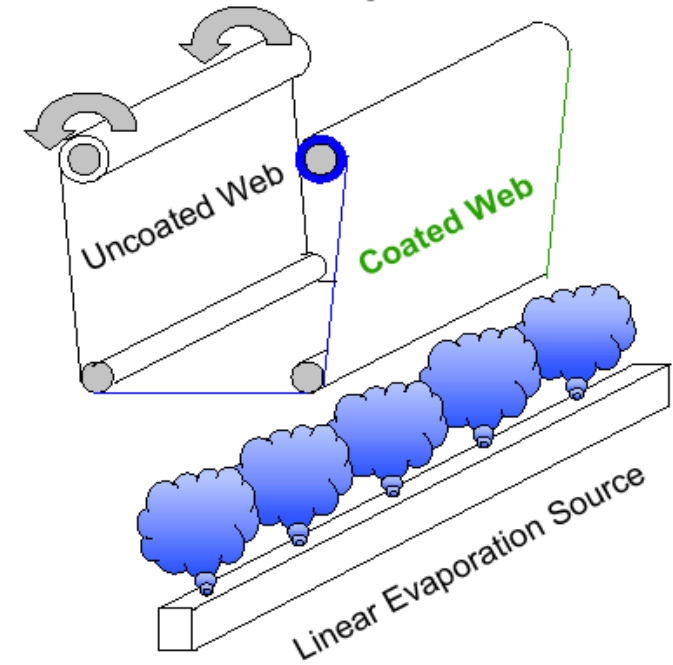


Linear Deposition



Image: Fraunhofer IPMS

Source : Optics.org 24 february 2006



Les diodes électroluminescentes organiques

Démonstrateurs et réalisations industrielles

First OLEDs product on the market

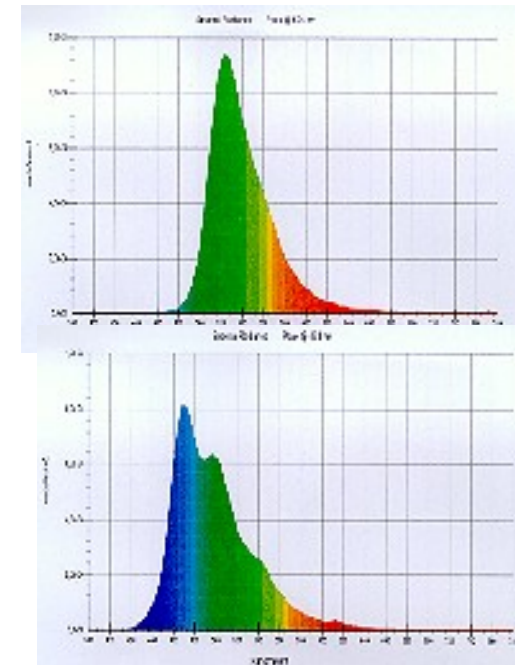


Passive Matrix Display: 256 x 64 Pixel

Display size: 9 cm x 2 cm

Sub-pixel size: 300 μm x 330 μm

Area colour

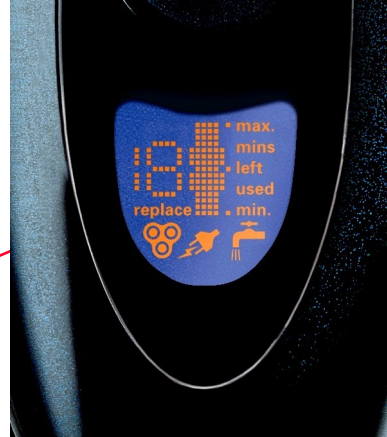


KODAK EasyShare LS633
zoom digital camera
- launched Feb 2003



LPTS poly-Si Active Matrix

Objets commerciaux à afficheur OLED/PLED



MP3 : 40% des écrans sont des OLED

Sanyo-Kodak: Full Colour

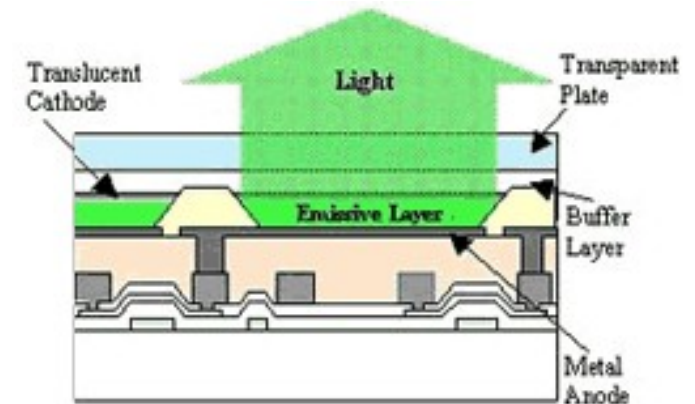


5.5 in. diagonal
320 × 240 pixels
150 cd/m²

Poly-Si active matrix
Sub-pixel size : 116μm x 348μm

**13 in. Diagonal
SVGA 800 x 600 pixels**

**Poly-Si active matrix
Pixel size : 330 μ m x 330 μ m**



Top Emission Structure

Color	Efficiency Cd/A	CIE	
		x	y
Blue	4.5	0.145	0.086
Green	45	0.230	0.667
Red	7	0.703	0.297



'Top emission'

Source: K. Micha et al., IDTech

Prototypes écran OLED

2005

SAMSUNG

1 dalle de 40''



2004

EPSON

4 dalles de 20''

**Table 1: Top Four OLED Manufacturers' Q1'05
Revenue and Growth (US\$ Millions)**

Rank	Manufacturer	Revenue US \$M
1	Samsung SDI	37
2	RITdisplay	28
3	Pioneer	20
4	Univision	14
5	LGE	7
	Others	19
	Total	125

SAMSUNG débute la construction d'une usine d'OLEDs à matrice active

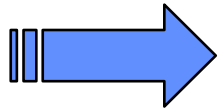
- **Après la production d'afficheurs OLEDs à matrice passive, SAMSUNG vient d'annoncer la construction d'une usine (450 millions de dollars) pour produire des écrans OLEDs à matrice active en silicium polycristallin basse température.**
- **Le marché visé concerne les écrans pour téléphones portables.**
- **La production devrait démarrer début 2007 et produire 20 millions d'écrans sur l'année.**

**Source: Electronique International
novembre 2005**

Les diodes électroluminescentes organiques

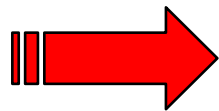
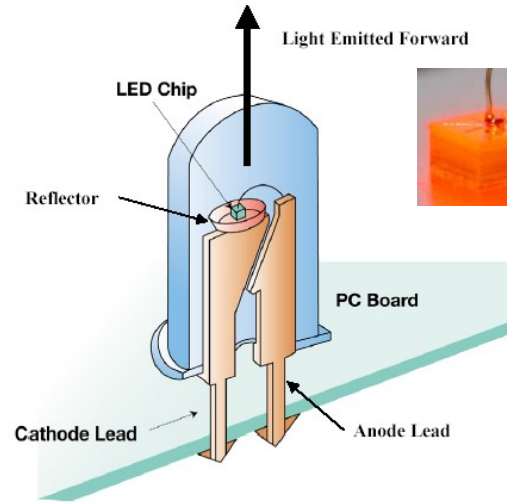
Application à l'éclairage

SSL (Solid State Lighting)



LED
AlGaInN

Source ponctuelle

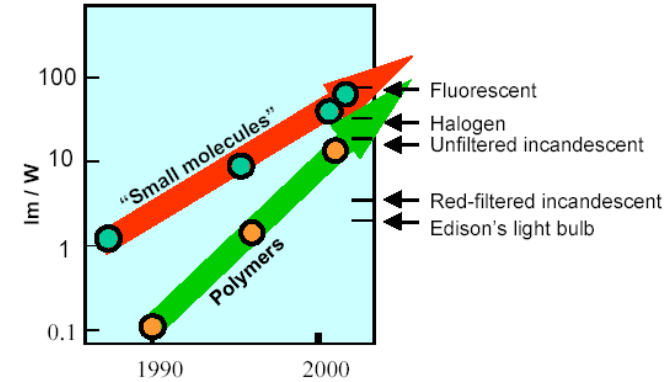
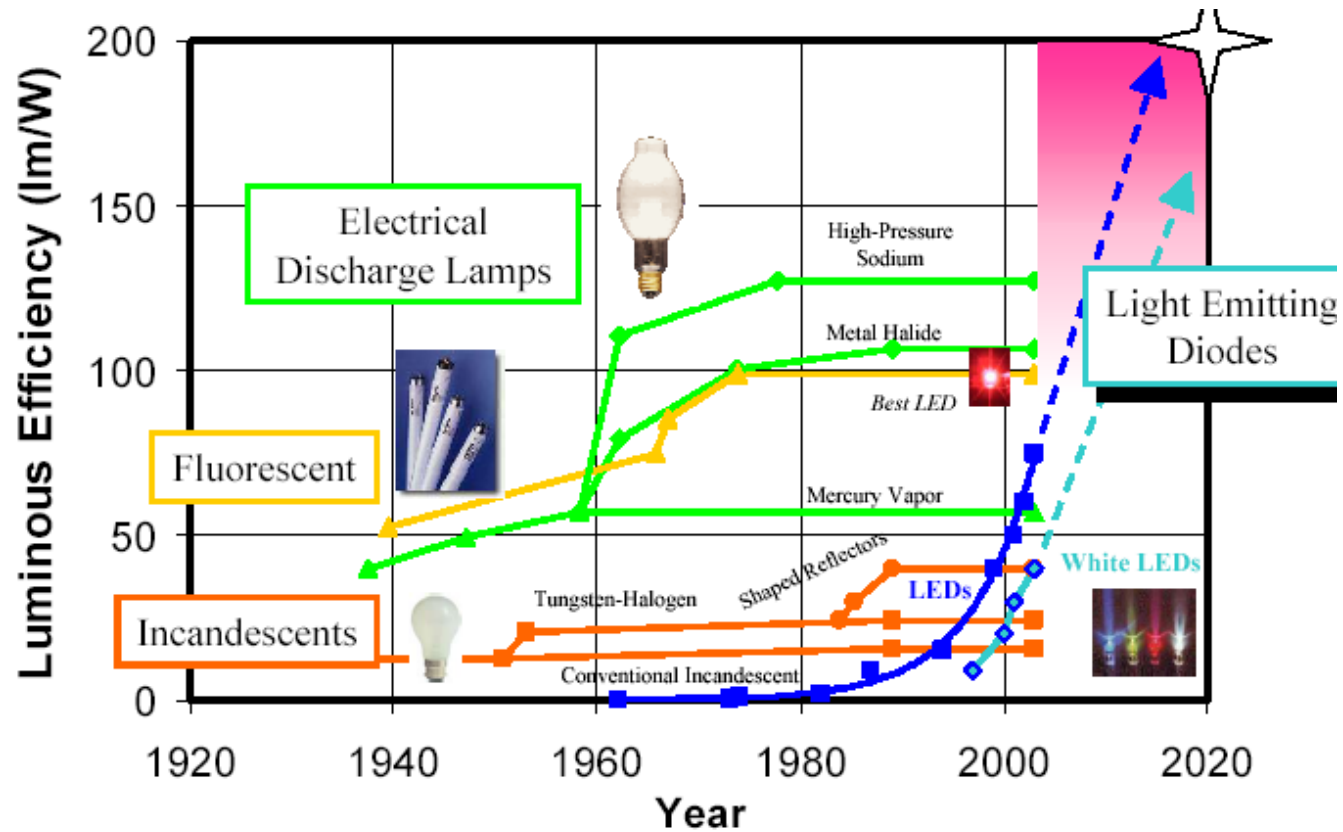


OLED
Petites molécules polymères

Source étendue

Film mince
Ep ~ < 1 mm
Surface conformable





• **Projet OLLA coordonné par Philips (FP6)**

(Organic Light emitting diodes for ICT & Lighting Applications)

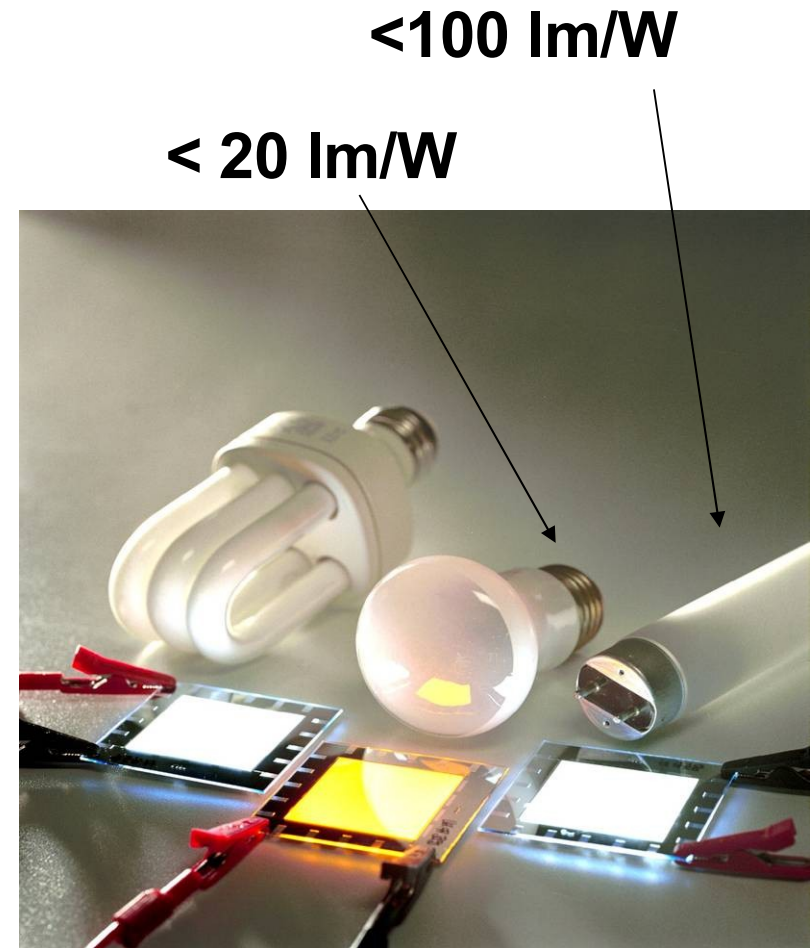
The OLLA Mission

To gather and focus European expertise in OLEDs to jointly accomplish everything necessary for the light sources of the 21st century.

The OLLA target:

1000cd/m ²
50lm/W
10000h
CRI>70
30cm x 30cm

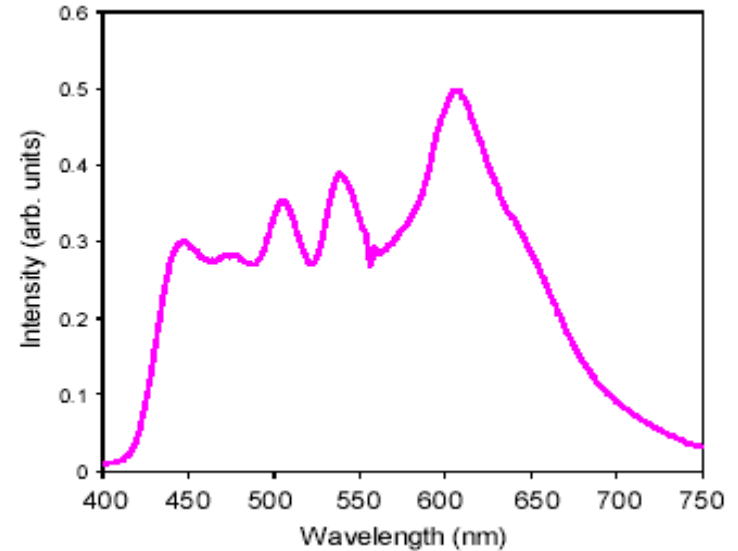
Enabling a leading role for Europe in Solid State Lighting





Equivalent ampoule 80W

Source: General Electrics



Performances à 1000 cd/m²

15 lm/W

CCT: 4400 K

CRI: 88

CIE: $x= 0.36$; $y= 0.36$

NOVALED : record du monde

Développement d'une OLED **verte** pour l'éclairage avec une efficacité de **110 lm/W** at 1000 Cd/m² : c'est 50% de mieux que les LEDs inorganiques

Objectif de NOVALED : dépasser les tubes fluorescents dans le blanc

PRESS RELEASE

Dresden, February 16th 2005





Single colour passive matrix flexible display
Vitex/Universal Display Corp. collaboration

Matériaux organiques (petites molécules et polymères) sont très prometteurs pour une nouvelle technologie d'affichage.

- ✓ Forte croissance prévue dans les 4 prochaines années.
- ✓ Petites molécules permettent de réaliser des structures plus complexes et constituent actuellement la technologie la plus avancée.
- ✓ Les polymères semblent mieux appropriés pour de grandes surfaces.

La 2nde génération de matériaux (phosphorescents) ou de structure (dopage couche de transport) permettent d'atteindre des rendements lumineux très élevés.

Points importants :

- ✓ puissance lumineuse
- ✓ durée de vie
- ✓ CIE (pureté couleur)

Possibilité de fabriquer des dispositifs souples ou conformables.

D'autres secteurs industriels envisageables comme l'éclairage.

Réduction des coûts de production nécessaires pour être compétitif par rapport aux LCDs