Les LEDs organiques source de lumière du future ?

ASPROM
OPTEZ POUR L'INNOVATION

27-28 janvier 2010
Paris

Georges Zissis, C. Cioarec, P. Melpignano, D. Buso
M. Ternisien
georges.zissis@laplace.univ-tlse.fr

Historique

Applications

1997 2002 2003 2009 2010

Électroluminescence dans les polymères (Cambridge)

Polymères

1990

Hétérojonctions

1987

Première OLED multi-couches (C.Tang et S. Van Slyke, Eastman Kodak)

Films minces

1977

Découverte de la conduction électronique dans les films de poly-acéthylène

Cristaux

1962 Invention de la LED

1963 Electroluminescence dans l'anthracène

2000

A. Hegger

A. McDiarmid

H. Shirakawa

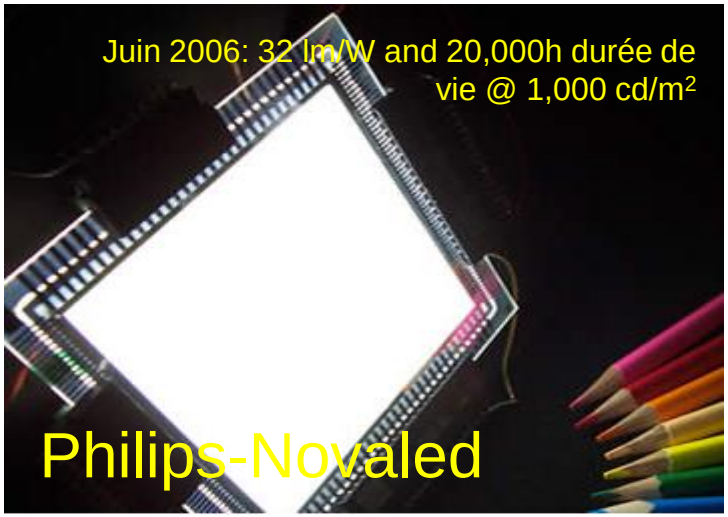
Les progrès des OLEDs blanches

L'efficacité augmente très rapidement

Première annonce par Kodak (1987)

- General Electric: 15 lm/W (Janvier 2005)
- Philips-Novaled: 32 lm/W (Juin 2006)
- Osram: 40 lm/W (Septembre 2006)
- Univ. Displ. Co: 63 lm/W (Octobre 2006)
- Univ. Displ. Co: 102 lm/W (Juillet 2008)

Affaire à suivre…



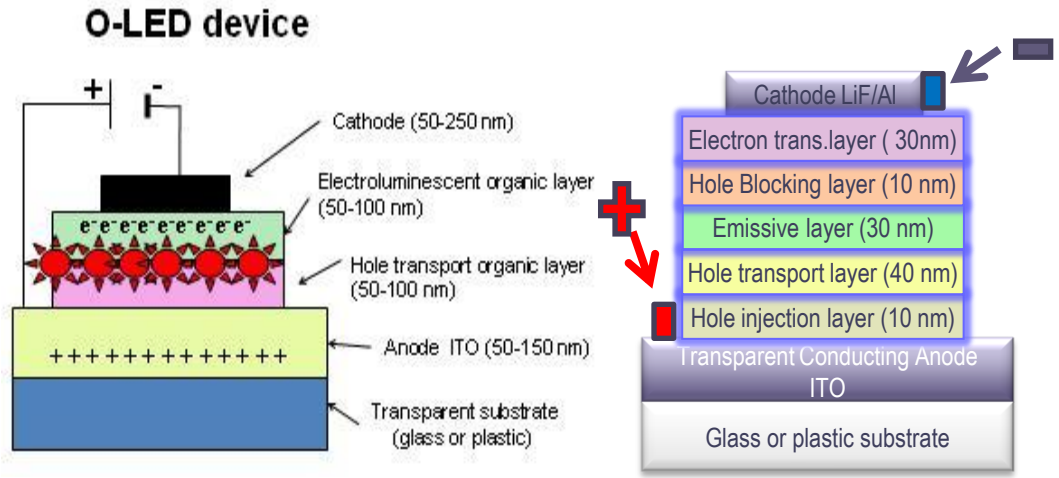
Qu'est-ce une OLED ?

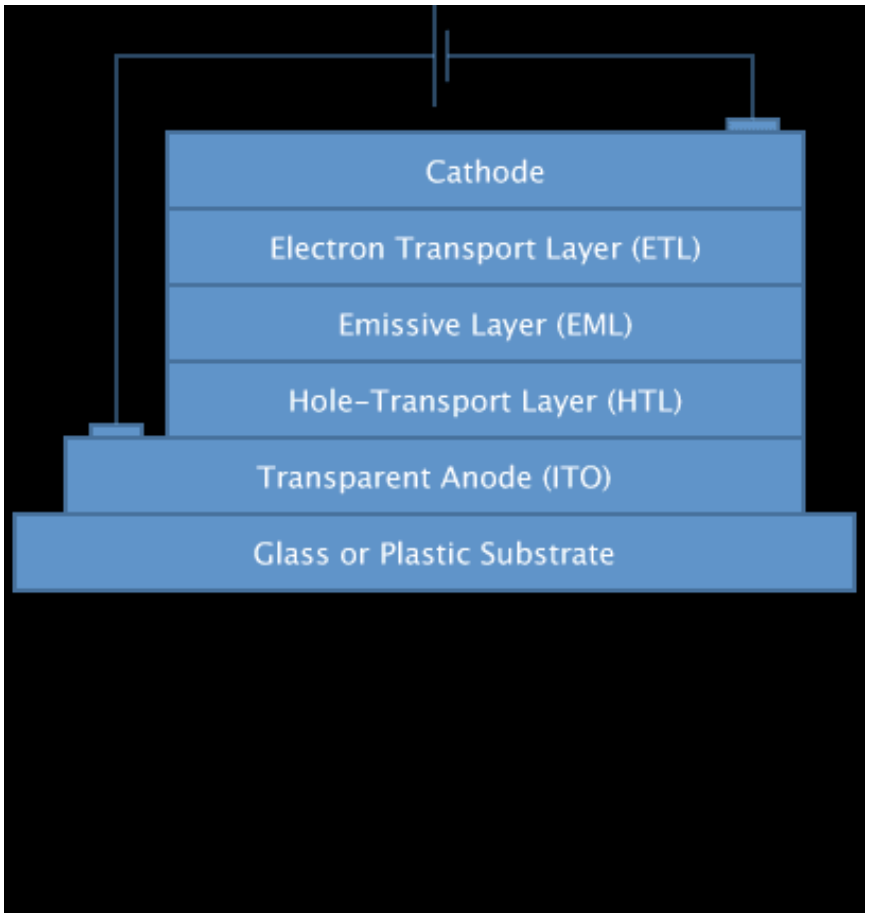
Une OLED est une diode électroluminescente utilisant un empilement de matériaux semi-conducteurs organiques

Deux Technologies

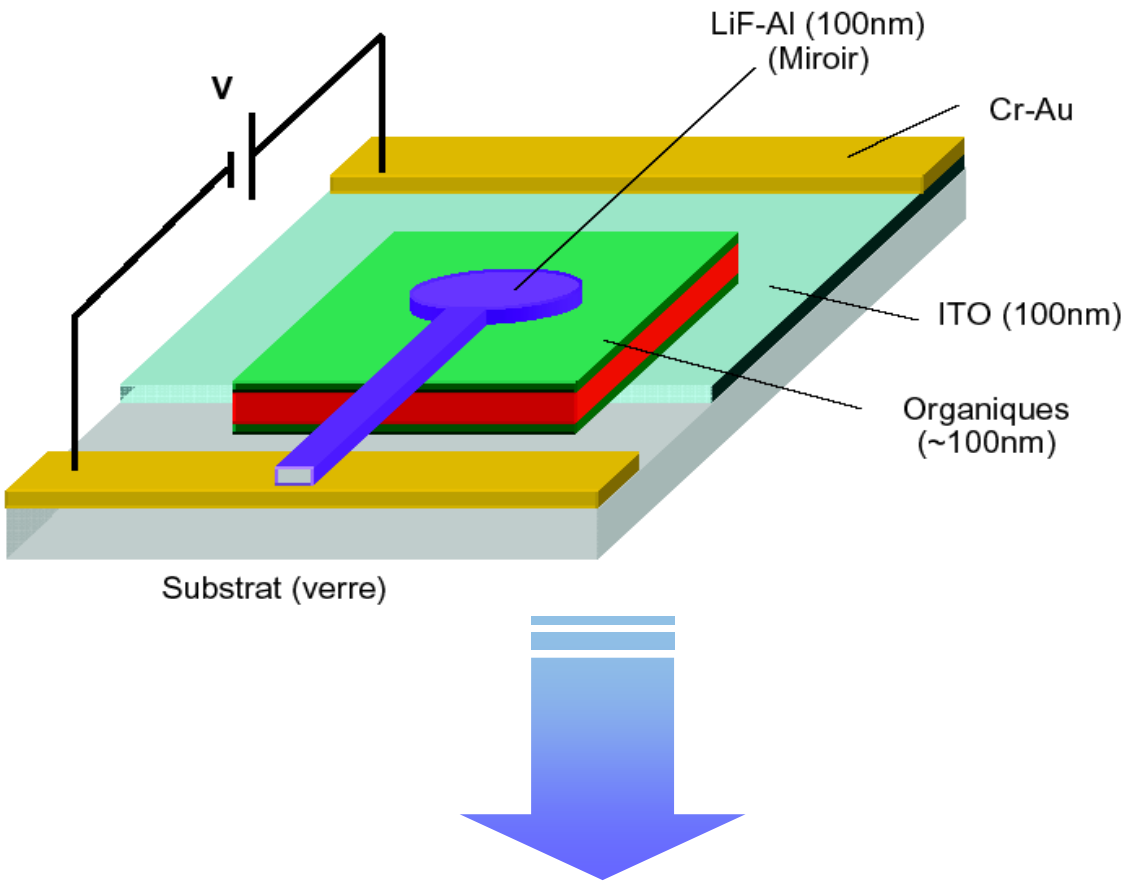
Polymères

Petites molécules





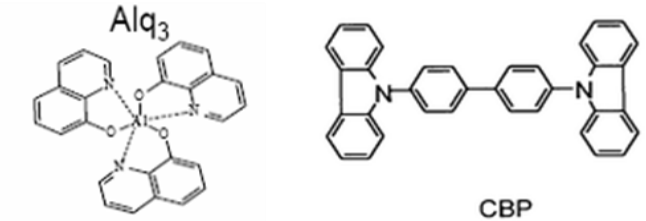
L'architecture



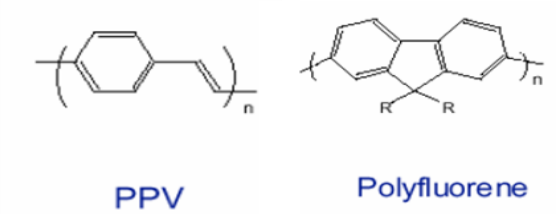
- Injection d'électrons: Al, Au, Ag…

- Transport des électrons et trous et recombinaison

"petites molécules"



Polymères



- Injection des trous: ITO, ZnO…

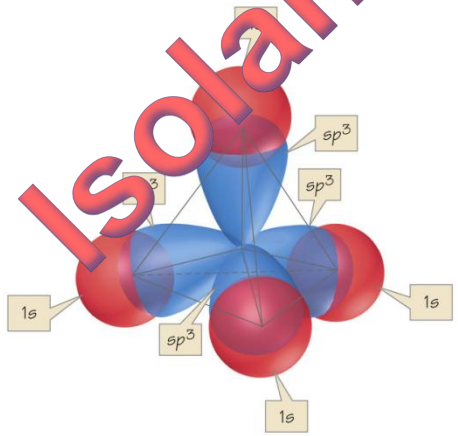
Le principe de fonctionnement

- ✓ Le plastique est isolant sauf que dans les semi-conducteurs organiques, il y a possibilité de conduction …

CH_4

4 électrons de valence et 4 atomes voisins :

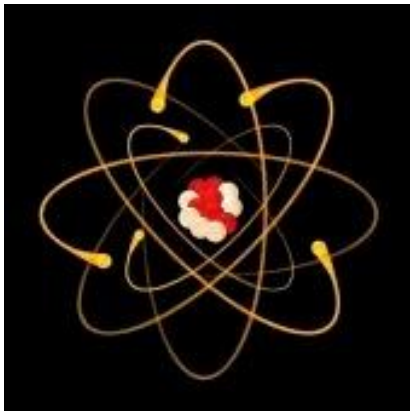
Hybridation sp^3



Isolant

C : $1s^2\ 2s^1 2p_x 2p_y 2p_z$

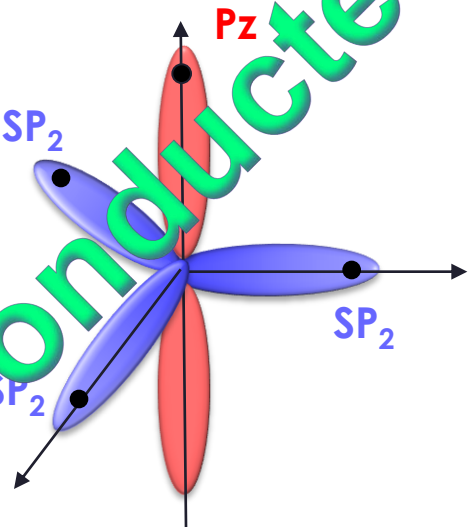
4 e^- de valence



Radical CH_3

4 électrons de valence et 3 atomes voisins :

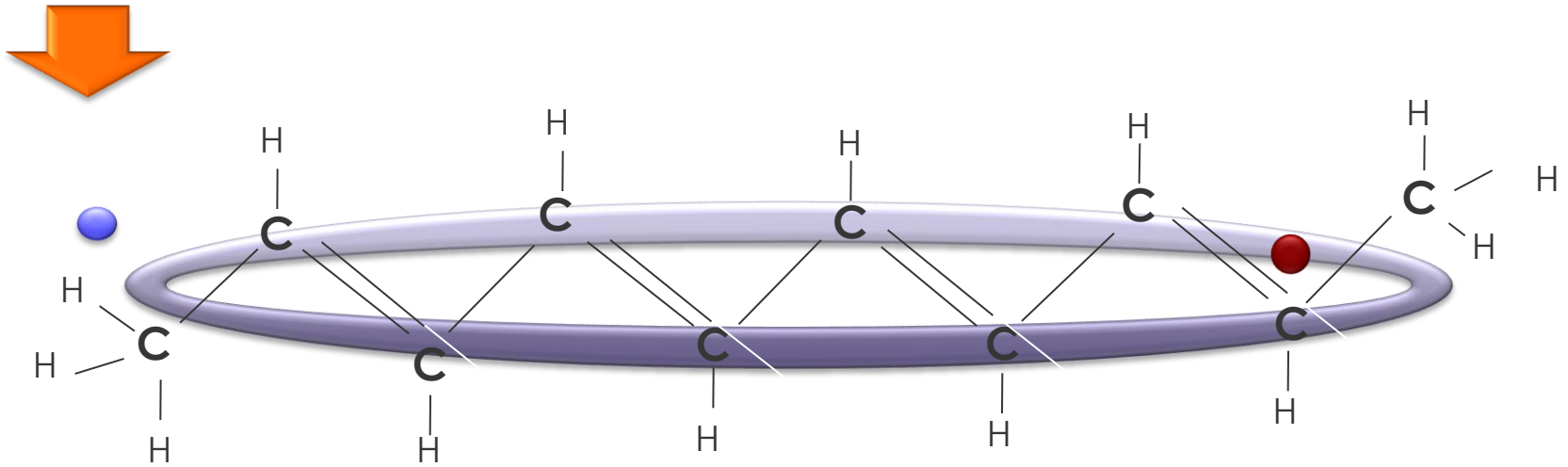
Hybridation sp^2



Conducteur

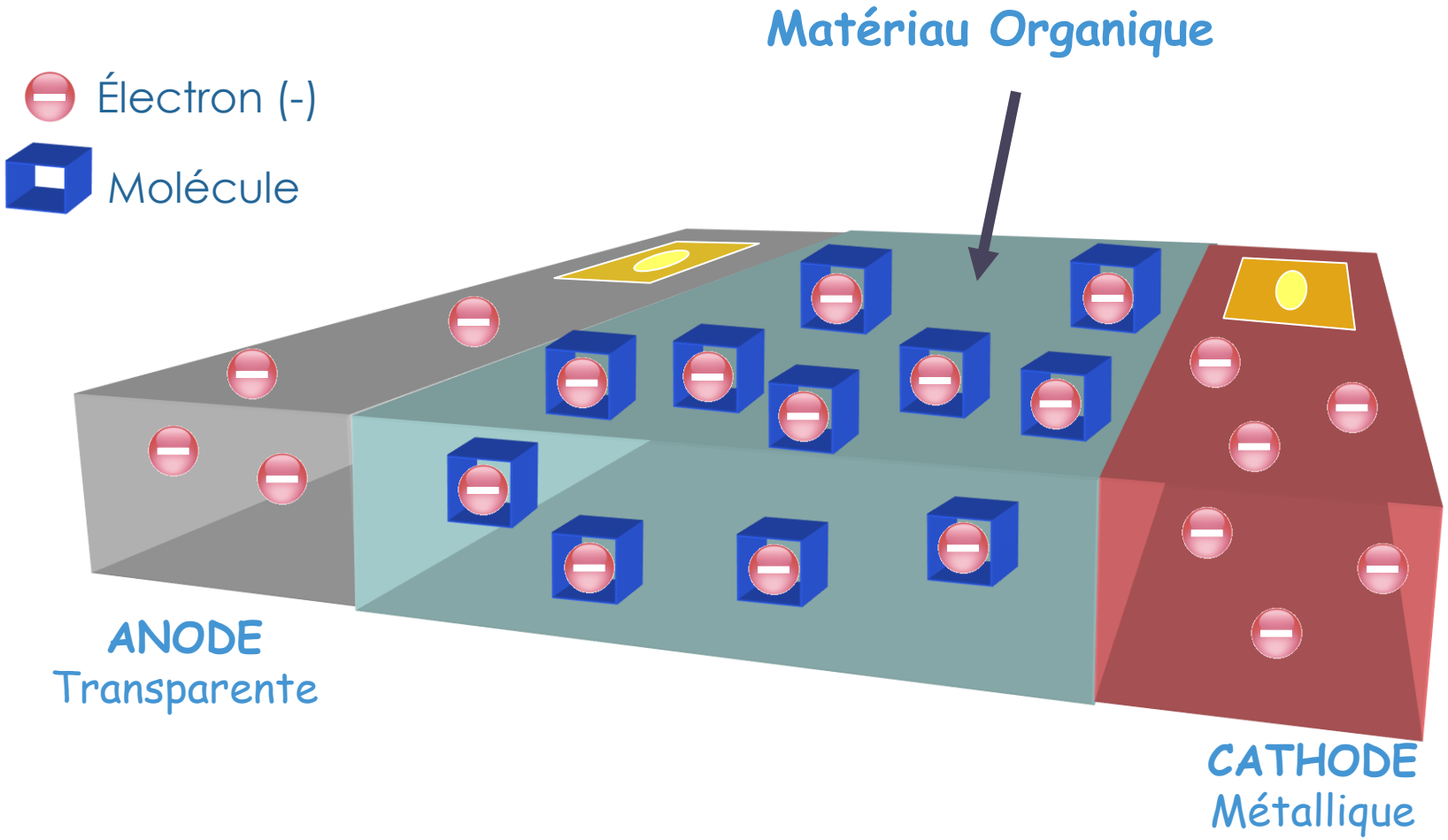
Un exemple plus complèxe

Capture d'un e^- sur la molécule



Délocalisation et naissance d'un polaron

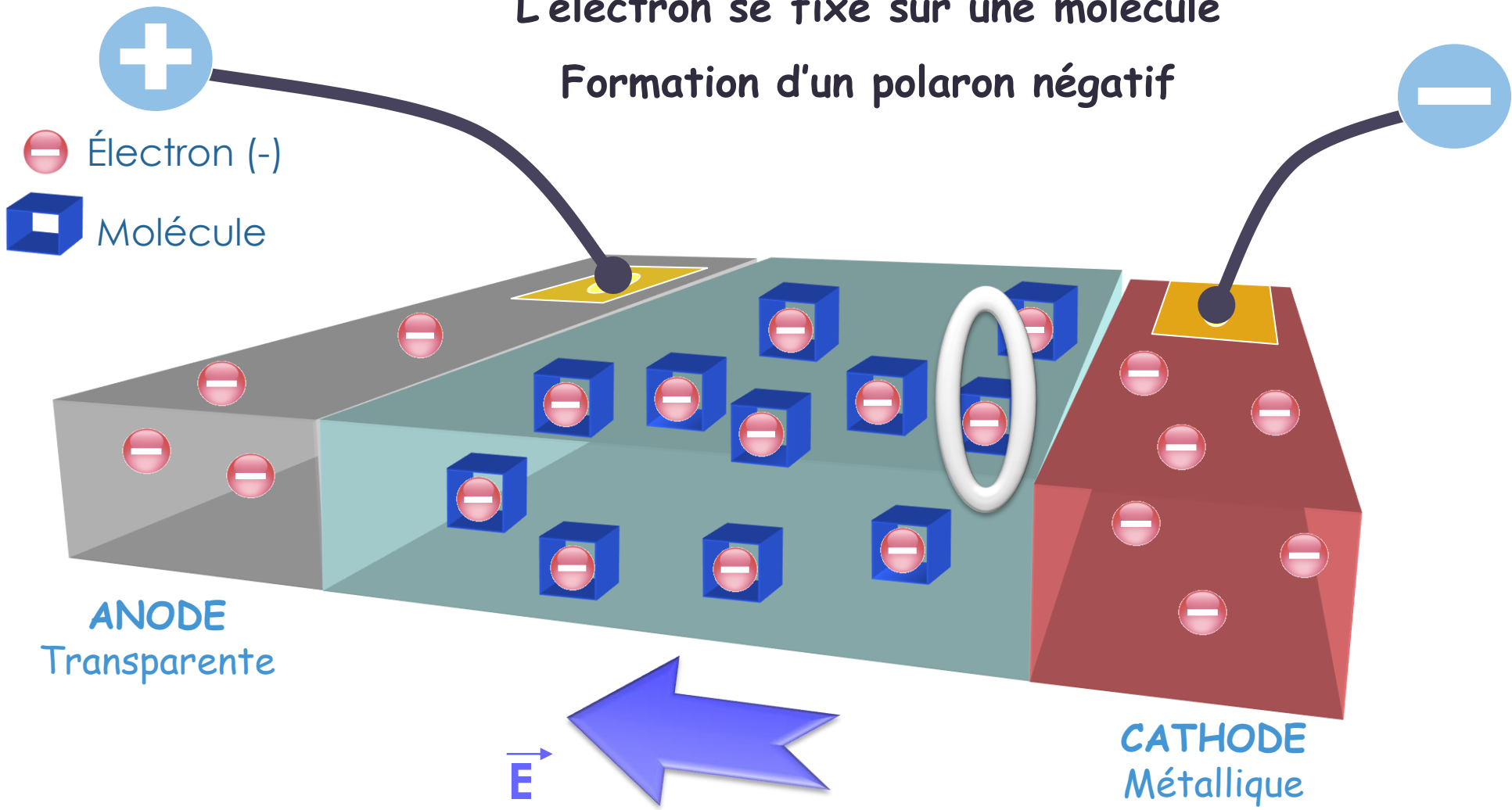
Du polaron à m'exciton et à la lumière



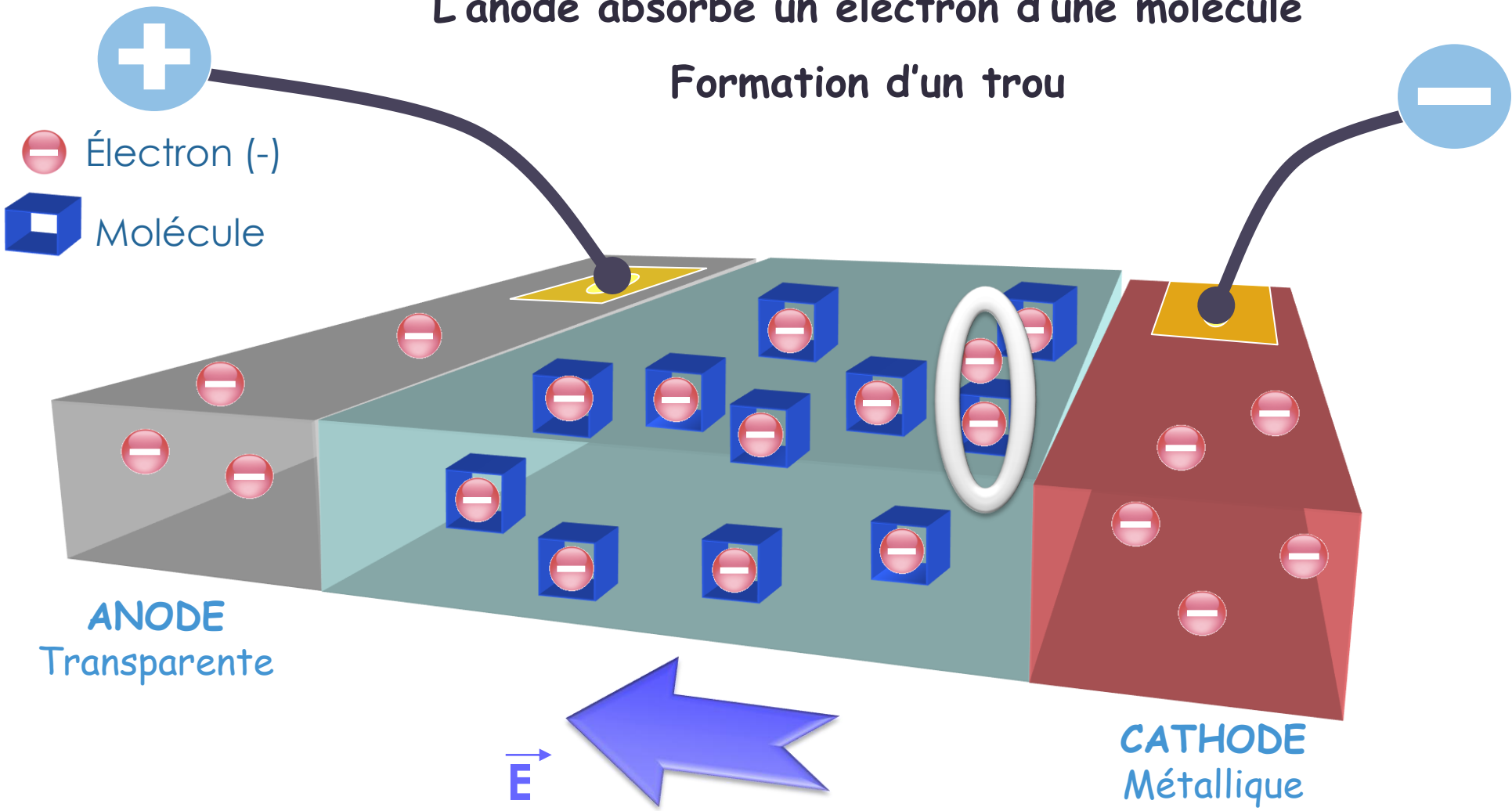
Du polaron à m'exciton et à la lumière

L'électron se fixe sur une molécule

Formation d'un polaron négatif



Du polaron à m'exciton et à la lumière

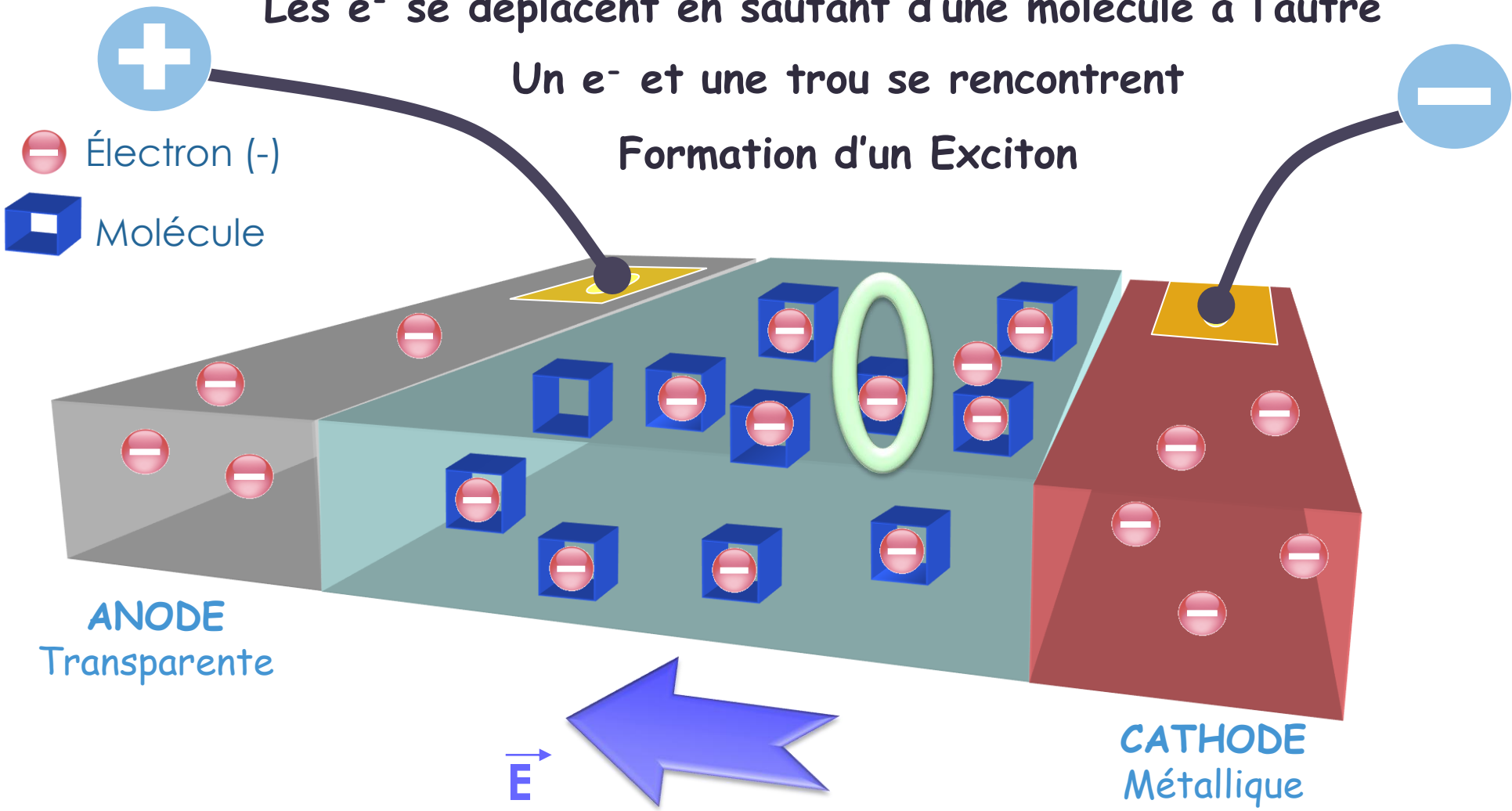


Du polaron à m'exciton et à la lumière

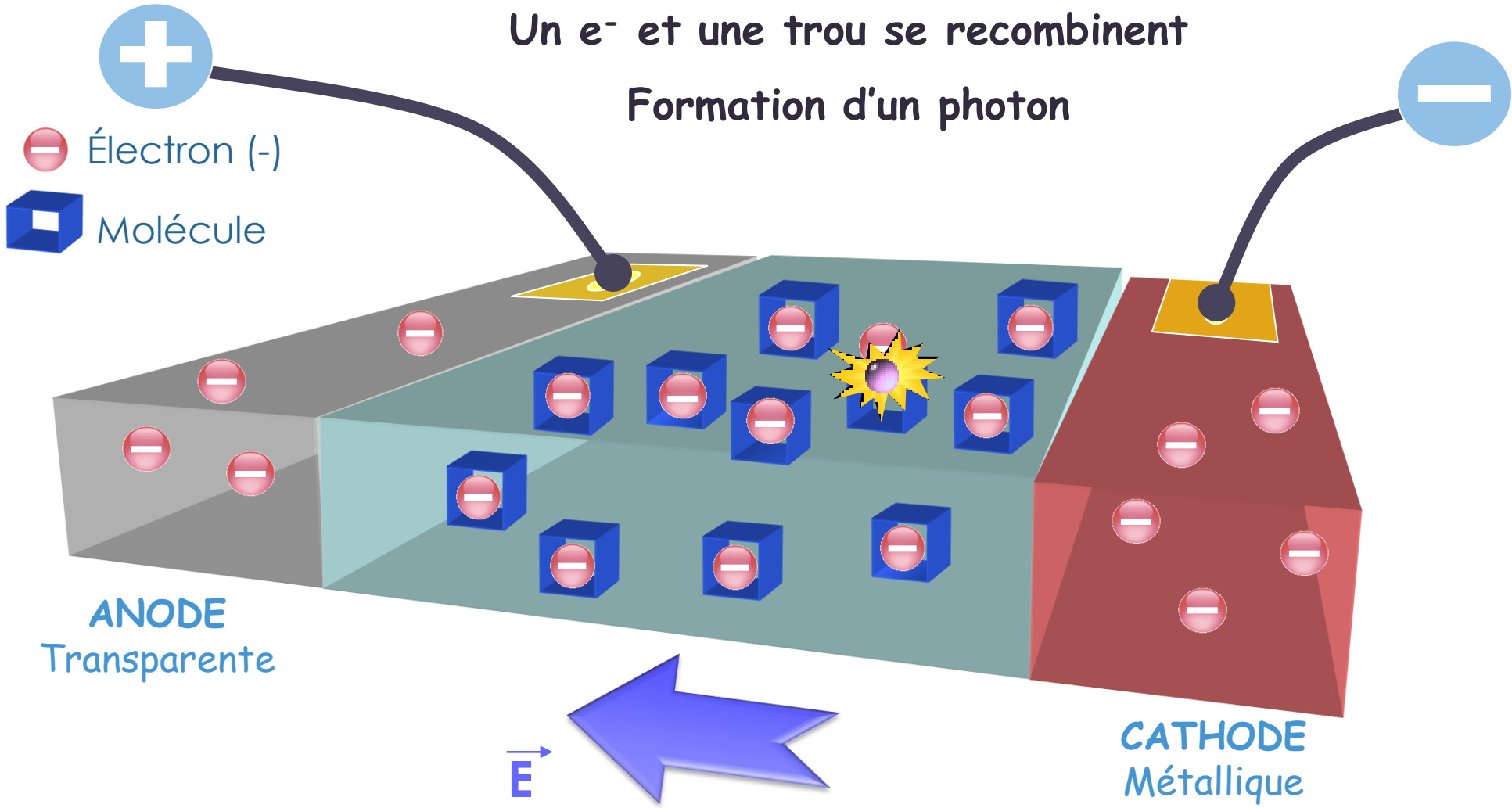
Les e⁻ se déplacent en sautant d'une molécule à l'autre

Un e⁻ et une trou se rencontrent

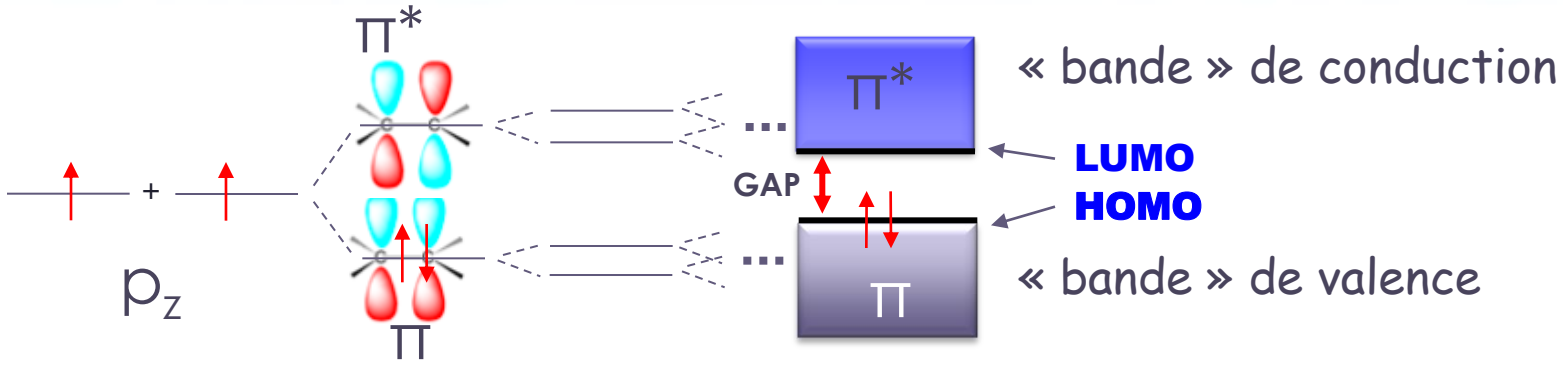
Formation d'un Exciton



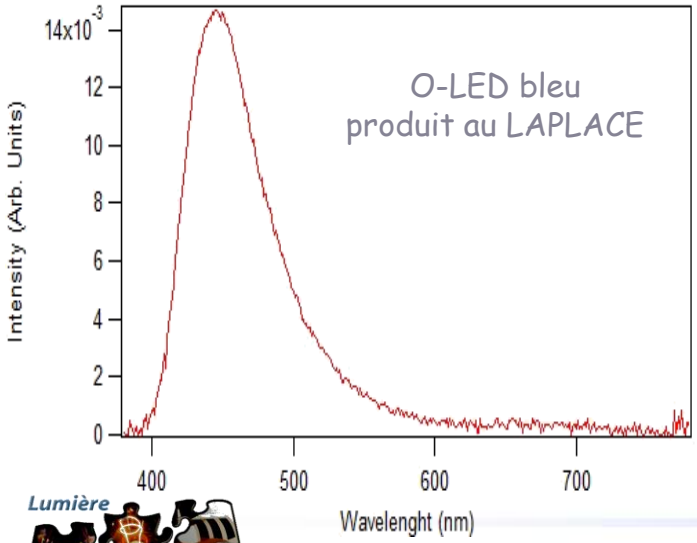
Du polaron à m'exciton et à la lumière



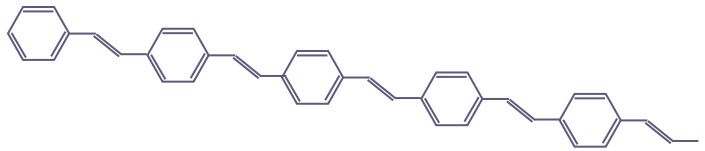
Quelle longueur d'onde ?



On obtient une bande moléculaire unique centrée autour d'une longueur d'onde λ_0



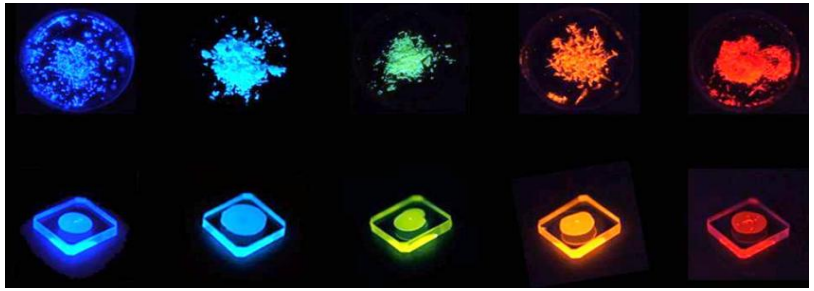
la longueur d'onde centrale est proportionnelle à la longueur de la chaîne moléculaire



LUMO

HOMO

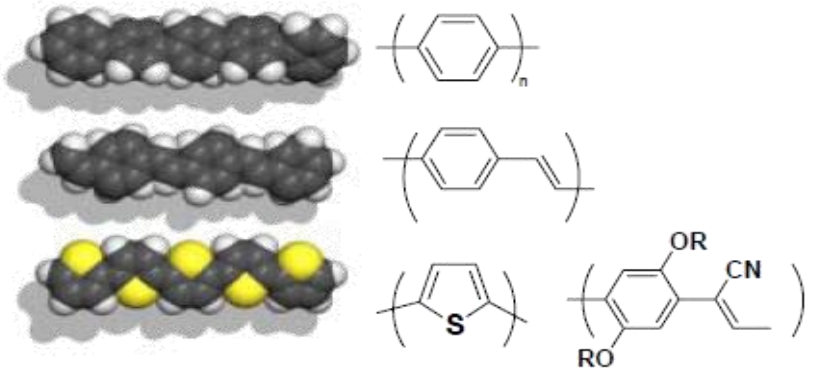
Toutes les couleurs sont possibles !

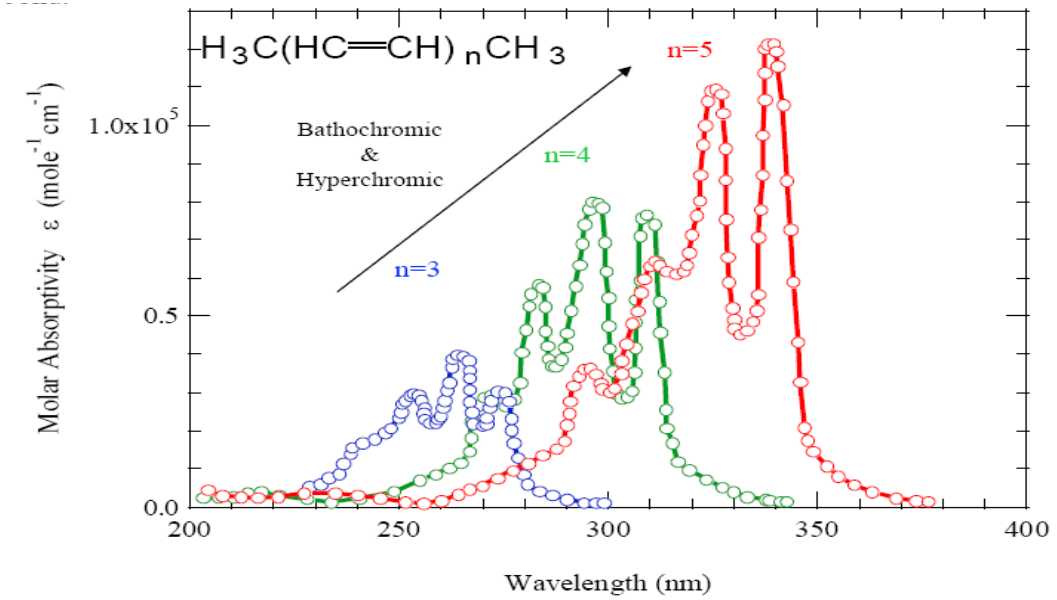


PPP

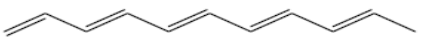
PPV

PT or CN-PPV

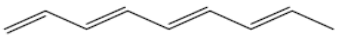




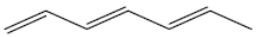
n=5
5 double bonds, 10 π electrons



n=4
4 double bonds, 8 π electrons



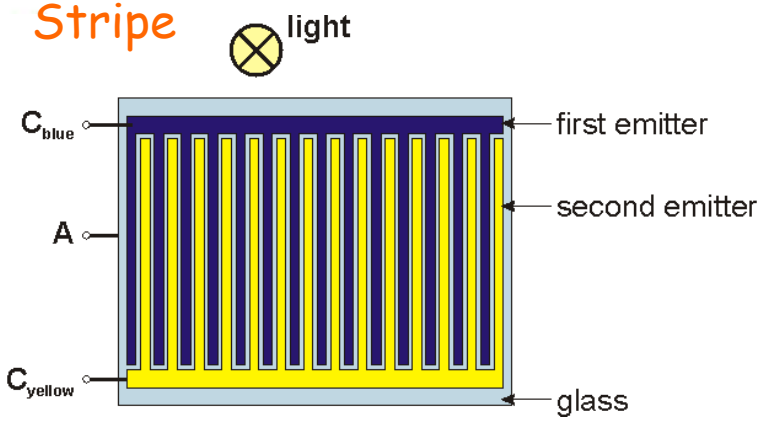
n=3
3 double bonds, 6 π electrons

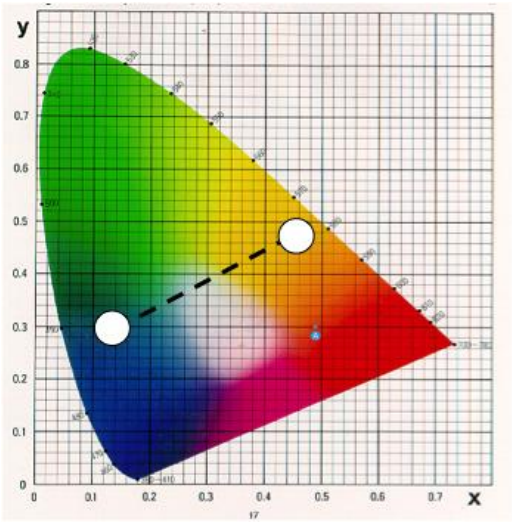


Ref. D. L. Pavia, G. M. Lampman, G. S. Kriz, Introduction to Spectroscopy, 2nd ed. (Saunders College Publishing, 1996), p.289

Comment fait-on une OLED blanche ?

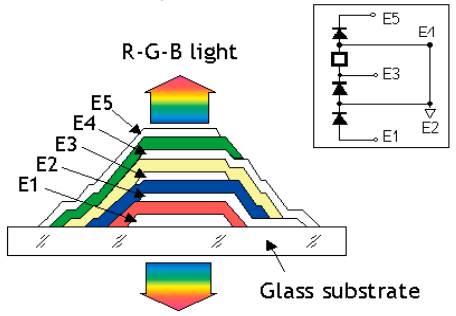
Stripe





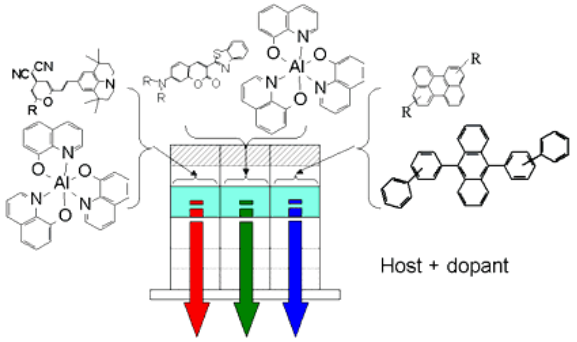
J. Jacobs et al., IEEE IAS (2007)

Sandwich



G. Gu et al., J. Appl. Phys. 86,4076 (1999)

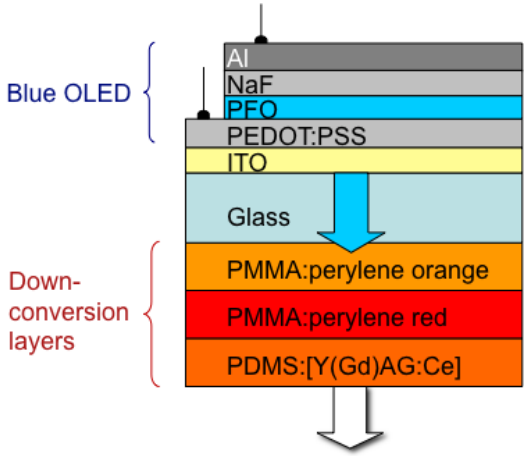
Flat dot/stripe



Mélange RVB

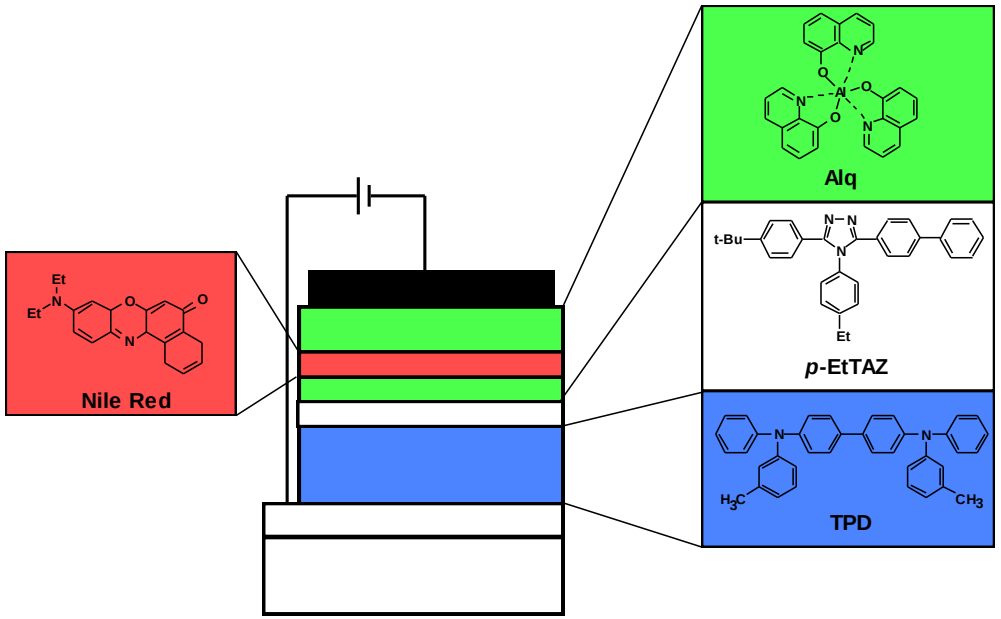
Mélange BJ

Conversion & mélange de longueurs d'onde

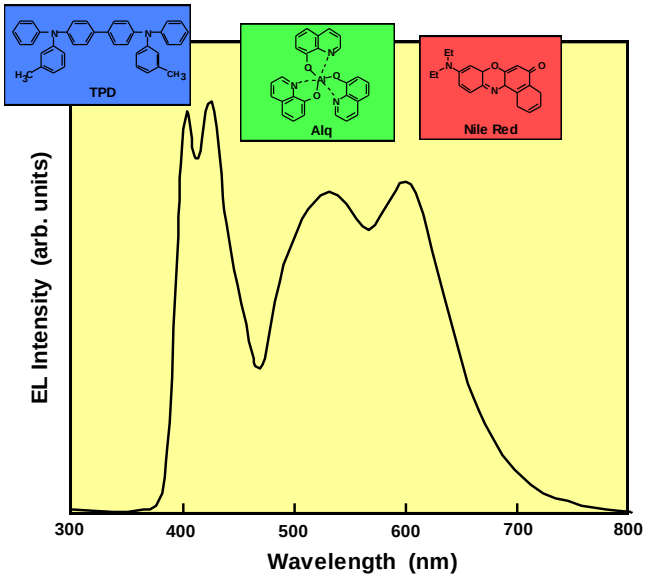


A.R. Duggal et al., Appl. Phys. Lett. 80,3470 (2002)

Les pioniers

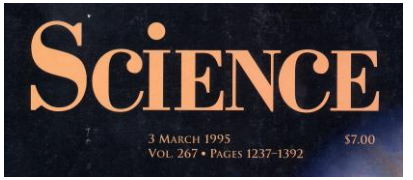


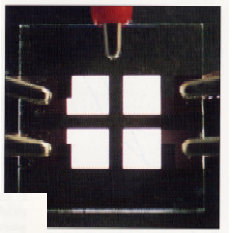
Kido et al., *Science*, **267**, 1332 (1995)



ITO / TPD (400Å) / *p*-EtTAZ (30Å) / Alq (50Å) / Nile Red (1mol%) Doped Alq (50Å) / Alq (400Å) / Mg:Ag

- ✓EQE = ~1%
- ✓Efficacité lumineuse < 1 lm/W
- ✓Durée de vie < 1 jour





photograph of a working white light-
L device. The device is an ITO/TPD (400)
Z (30 Å)/Alq (50 Å)/Nile Red–doped (1
lq (50 Å)/Alq (400 Å)/Mg:Ag cell. The

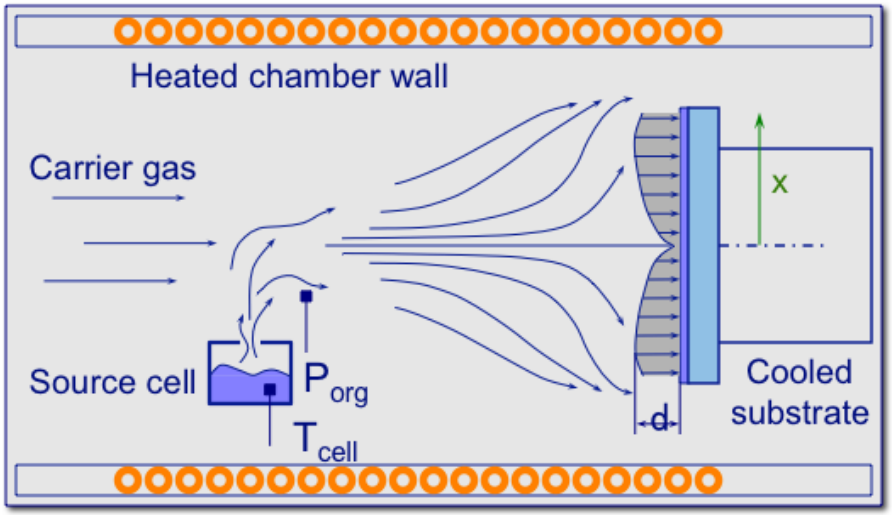
Multilayer White Light–Emitting Organic Electroluminescent Device

Junji Kido, Masato Kimura, Katsutoshi Nagai

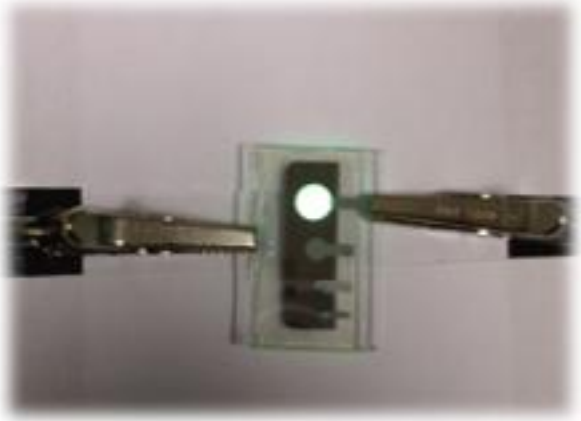
Organic electroluminescent devices are light-emitting diodes in which the active materials consist entirely of organic materials. Here, the fabrication of a white light–emitting organic electroluminescent device made from vacuum-deposited organic thin films is reported. In this device, three emitter layers with different carrier transport properties, each emitting blue, green, or red light, are used to generate white light. Bright white light, over 2000 candelas per square meter, nearly as bright as a fluorescent lamp, was successfully obtained at low drive voltages such as 15 to 16 volts. The applications of such a device include paper-thin light sources, which are particularly useful for places that require lightweight illumination devices, such as in aircraft and space shuttles. Other uses are a backlight for liquid crystal display as well as full color displays, achieved by combining the emitters with micropatterned color filters.

Production des OLEDs (1)

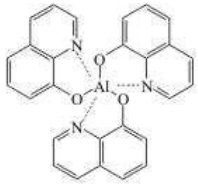
- Pour les petites molécules la méthode de l'évaporation est utilisée:
  - vacuum thermal evaporation (VTE)
  - organic vapor-jet printing (OVJP)
  - low-pressure organic vapor-phase deposition (LP-OVPD)



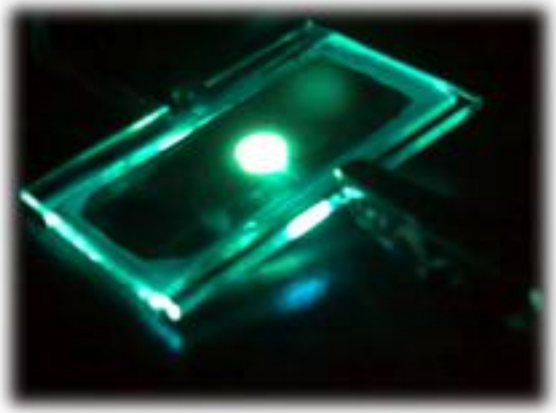
OLEDs produites au LAPLACE



OLED verte
Phosphorescent
TCTA:Ir(ppy)$_3$ (15%)

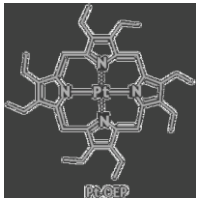


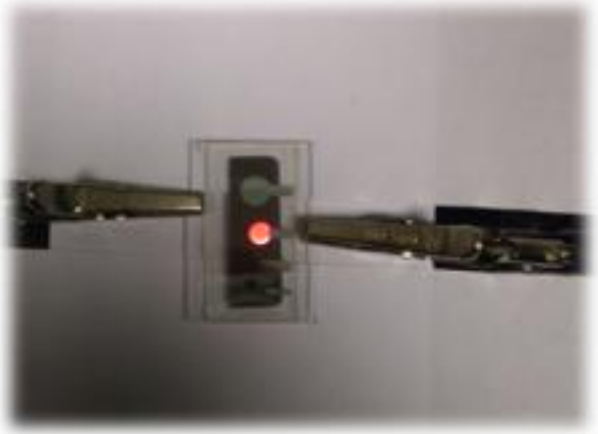
OLED verte
Fluorescent
a-NPB:Alq$_3$



L > 11 000 cd/m²
Durée de vie > 4 000h

OLED rouge
Phosphorescent
CBP:Pt(OEP)$_3$ (10%)

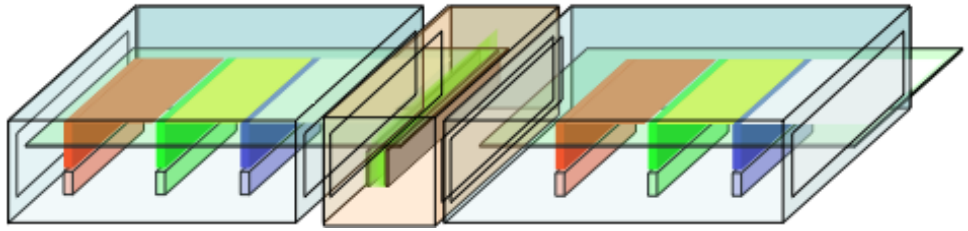


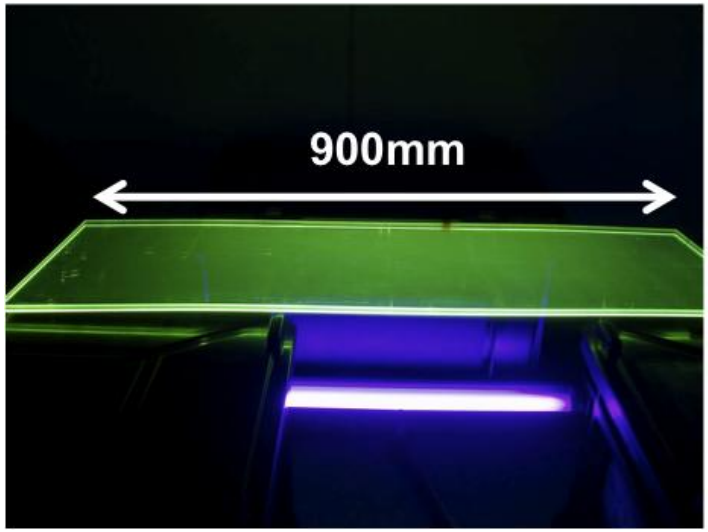


La production à l'échelle industrielle est possible

Objectif: coût de production de l'ordre de 100 € par m^2

In-line deposition for multi-photon OLED

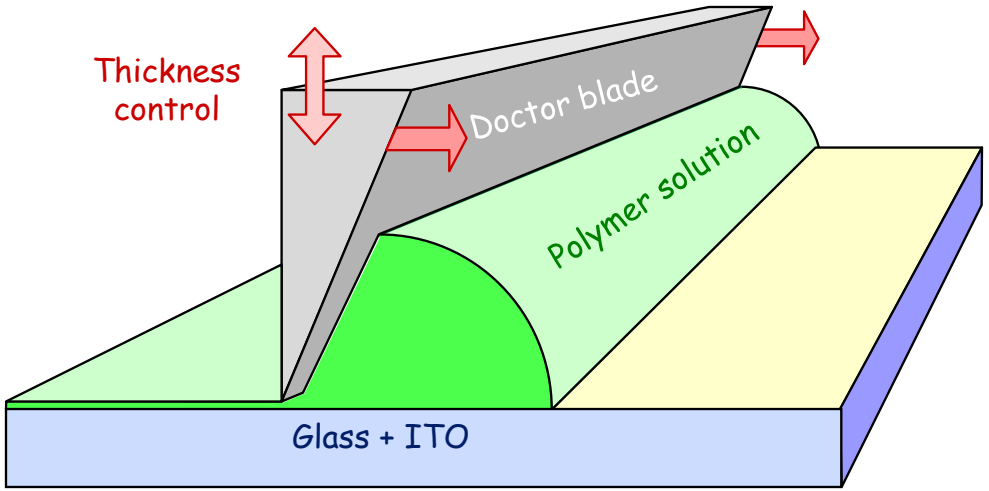




Courtesy J. Kido, 2009

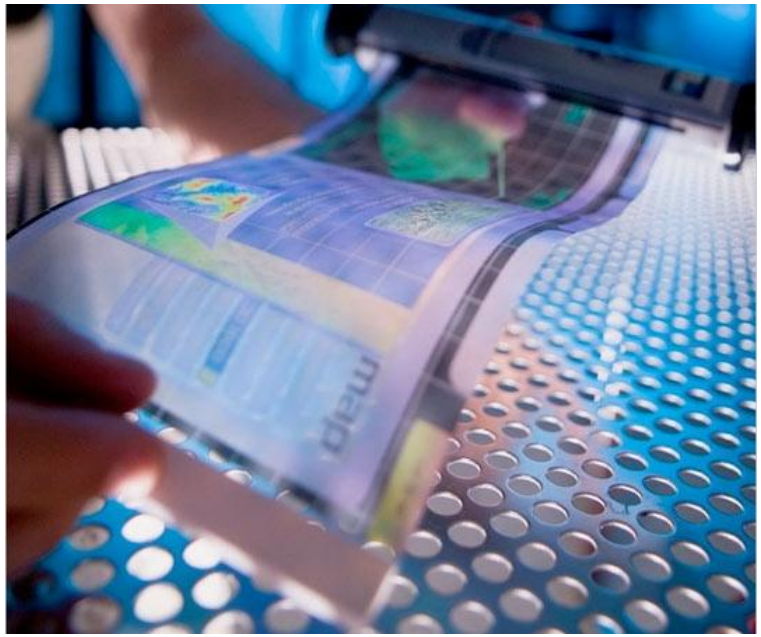
Production des OLEDs (2)

- Pour les polymères d'autre méthodes peuvent être utiilisées
  - spin-coating
  - doctor-blade coating
  - inkjet printing (IJP)

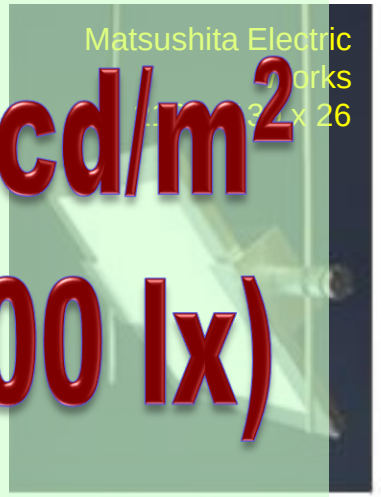


Production des OLEDs (3)

L'objectif à long terme est l'utlisation de la méthode roll-to-roll (R2R)



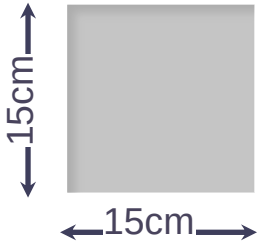
Un luminaire OLED de 1m² avec une luminance 1 500 cd/m² peut éclairer un bureau (400 lx) sans eblouissement



Quelques exemples réels (1)

Yonezawa City (Japon)
OLED Café !

Lighting Fair 2007



RIOE
Research Institute for Organic Electronics

Courtesy J. Kido, 2009

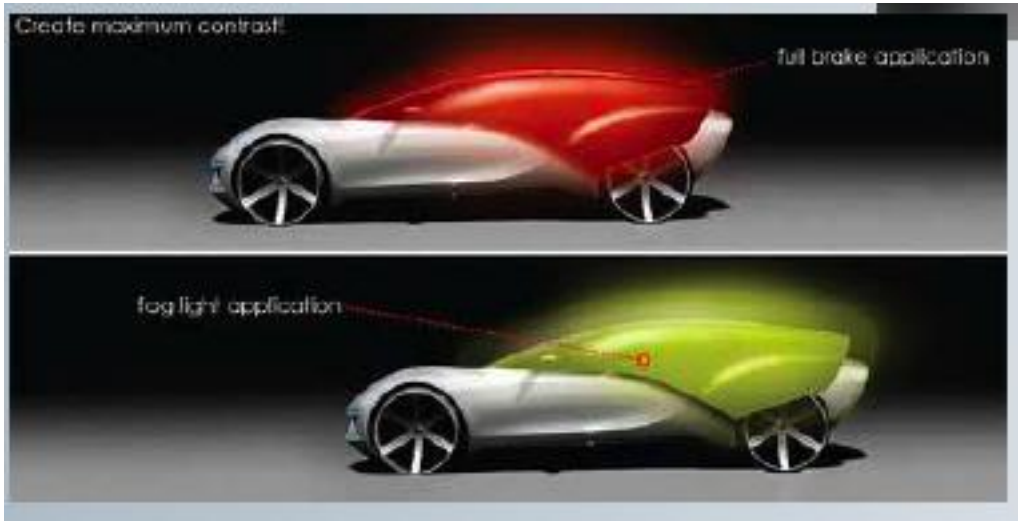
Quelques exemples réels (2)

Lighting Fair 2007

Courtesy J. Kido, 2009

Applications pour l'automobile

novaled



Applications pour les trasports

Trains

Avions

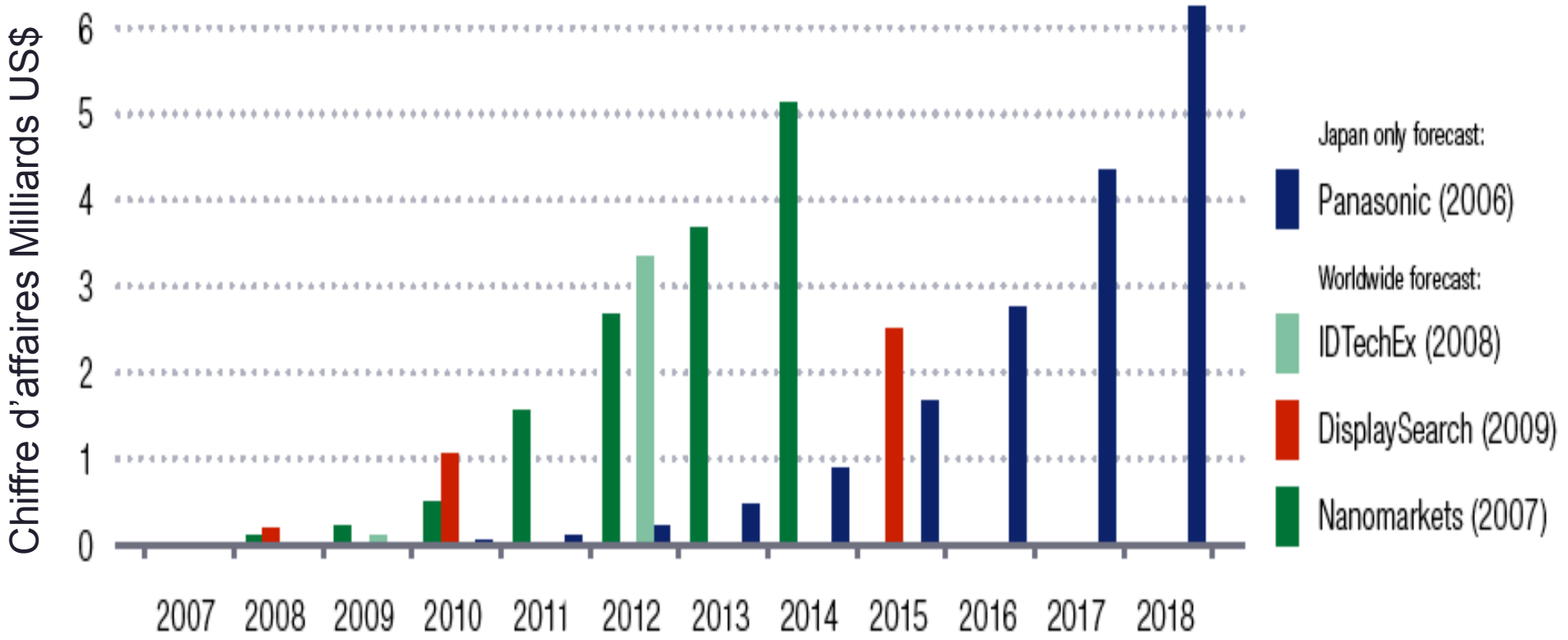
D'autres applications…

Arbre de Noël OLED
(General Electric)

Robe OLED
(Alison Lewis d'e-Textile

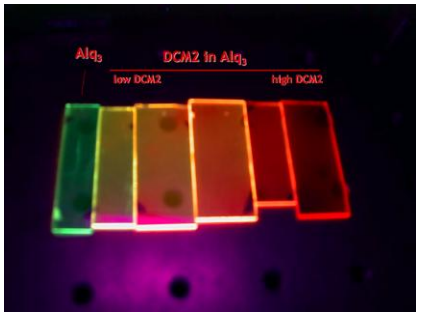
Couette OLED

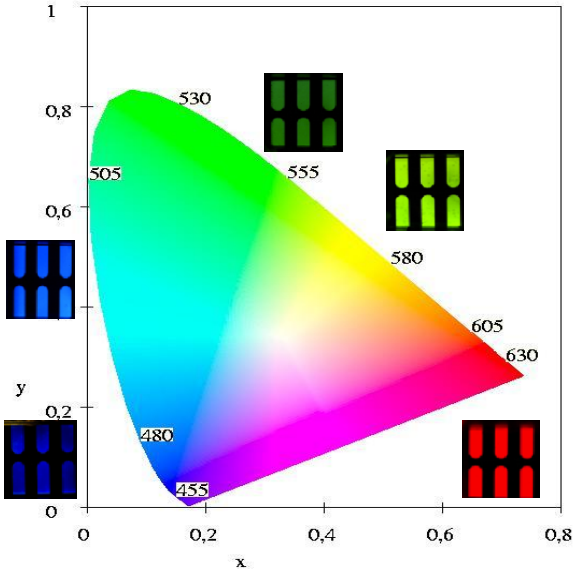
Un marché en pleine croissance

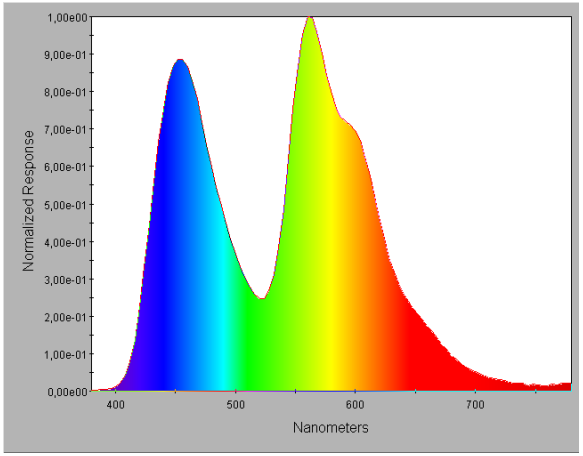


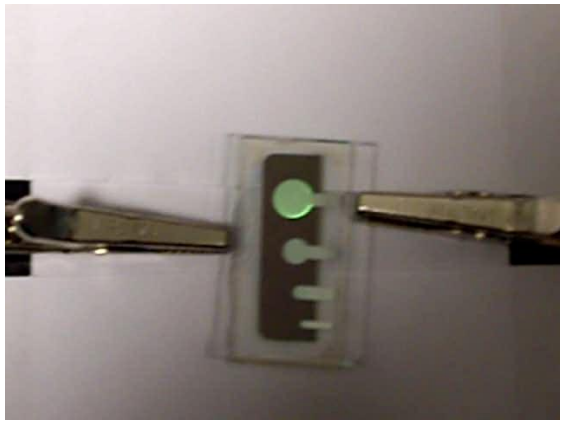
Avantages des OLED

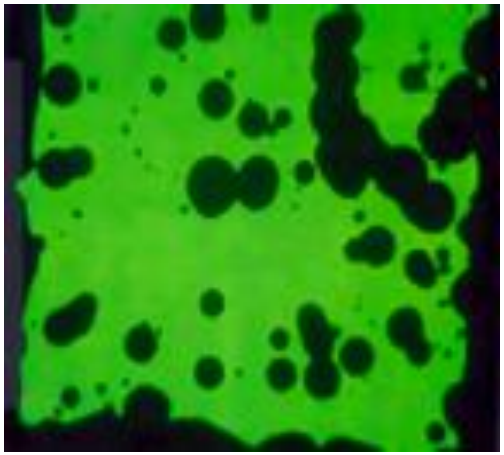
- Toutes les couleurs sont possibles
- Grande qualité de la couleur
- IRC élevé
- Haute efficacité lumineuse
- Source Lambertienne
- Longue durée de vie
- Faible influence de la température
- Excellent comportement mécanique (Flexible, pliable…)
- Extrêmement léger et fin
- Facile à produire à faible coût
- Faible empreinte environnementale
- Gradable

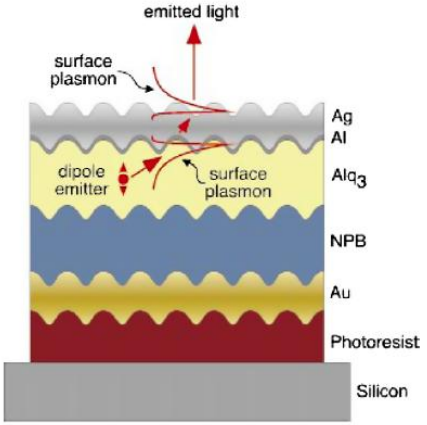




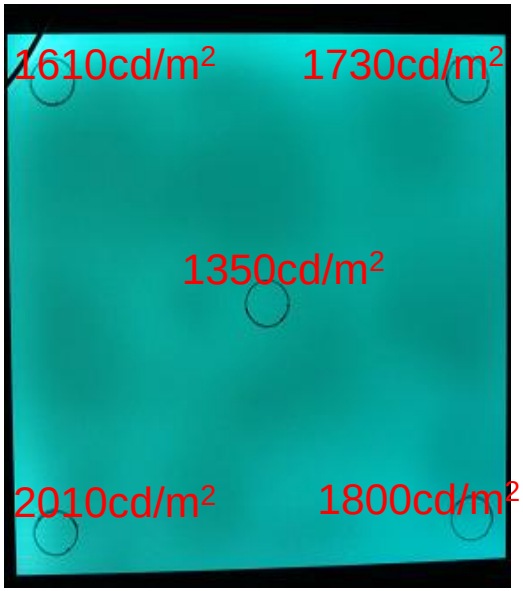


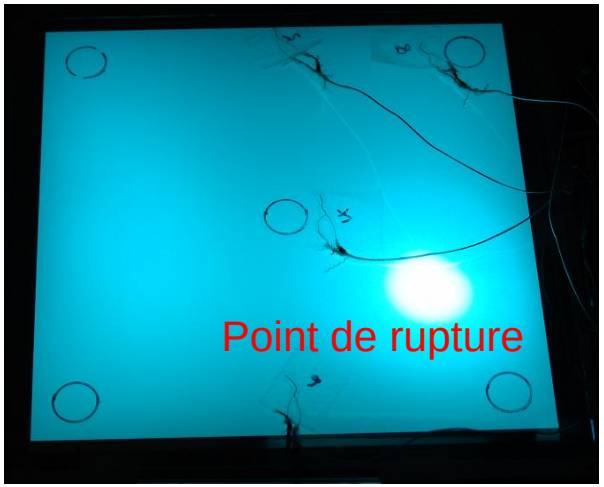


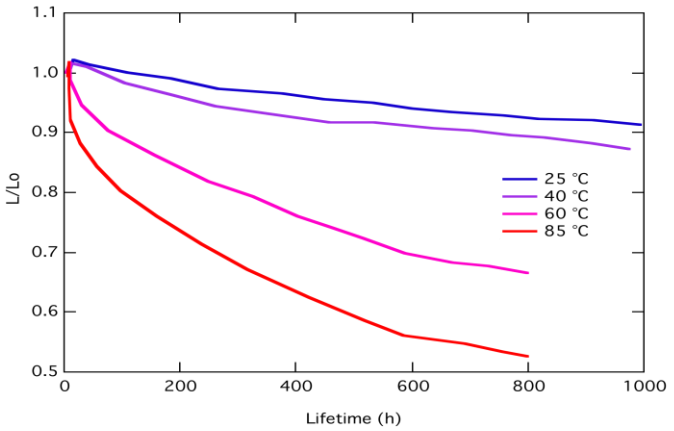




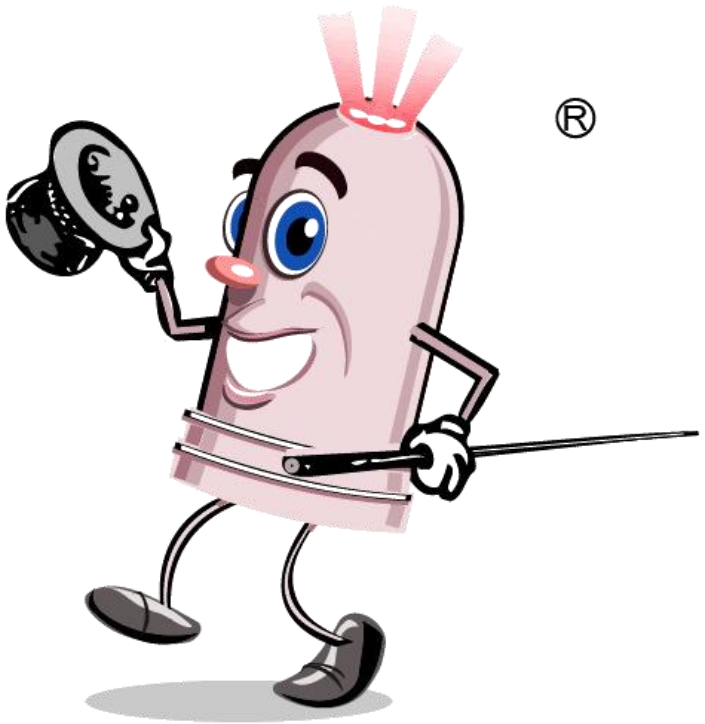
- Comprendre le mécanisme de "Hopping"
- Comprendre le vieillissement
- Améliorer l'extraction de la lumière
- Augmenter la puissance
- Inventer des nouvelles molécules
- Augmenter la durée de vie
- Améliorer l'encapsulation
- Augmenter l'uniformité
- Baisser le coût de production
- Adapter la source d'alimentation

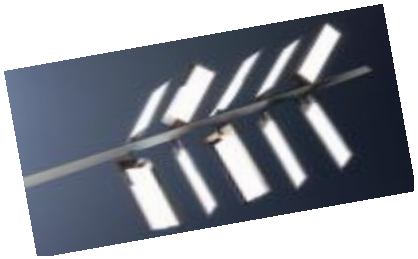






OLED la lampe du future...





...rève ou réalité ???