九十二學年度第二學期Grooup Meeting

Research Status---

High-Efficiency Organic Light-Emitting Diode

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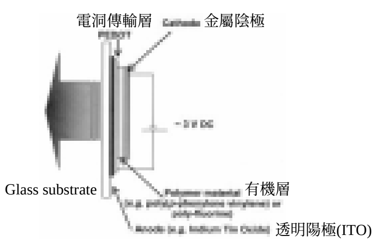
Outline

- The content is mainly extracted from **IEEE JSTQE, Vol. 8, March/April 2002, p.346-361**. The authors are N. K. Patel, S. Cinà, and J. H. Burroughes.
- **4 major Losses (and improvements) of OLED**:
  - **Charge balance**
  - **Singlet triplet ratio**
  - **Luminescence efficiency**
  - **Optical output coupling**

Typical device structure



- OLED can be divided into 2 kinds: small molecules (小分子) OLED and conjugated polymer (共軛高分子) OLED.
- This is a typical device architecture for a **polymer based OLED**.

The equation of the external quantum efficiency (η $_{ext}$)

$$\eta_{ext} = \gamma \times r_{st} \times q \times \eta_{coupling}$$

- η_{ext} : the external quantum efficiency
- γ: the coefficient of charge balance
- r_{st} : the singlet triplet ratio
- q : the luminescence efficiency
- $\eta_{coupling}$: the coefficient of output coupling

Charge balance

- The maximum quantum efficiency is achieved when both cathode and anode form an ohmic contact with the polymer (i.e., there is no barrier for charge injection from the metal into the polymer layer), and when the mobility of the two carriers is identical.
  - However, barriers (位能障) are almost always present *at the polymer electrode interface*.
  - The mobility of the two carriers is *rarely matched* in organic semiconductors. It can differ by several orders of magnitude, and the relative difference can be *a function of the applied electric field*.
- This inequality effects on charge balance, on excitons formations, on the recombination process, and on device efficiency.

How to improve the charge balance?

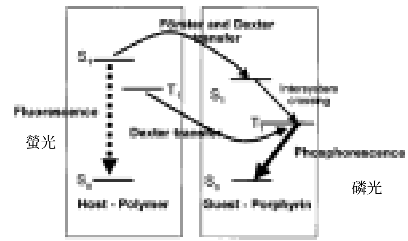
- In order to minimize the barriers for charge injection, the work function of the electrode should be as close as possible to the energy levels of the organic layer.
  - Indium-doped Tin Oxide (ITO) is normally used for the transparent anode, due to its relatively high work function.
  - Cathode requires the use of low work function metals, usually Ca, Ba, Mg, and Yb.
- Polymers or copolymers can be used in order to improve charge balance and to optimize the device efficiency.

Singlet triplet ratio

- The singlets can relax radiatively (Fluorescence，螢光), whereas for the triplet states relaxation occurs via nonradiative processes.
- Recent studies have shown that the singlet to triplet ratio is close to 1:1 in polymer devices as opposed to 1:3 for small molecules.
- **Improvement:** Triplets can radiate phosphorescece（磷光）through doping. [Ex. IEEE LEOS 2003– High Efficiency Phosphorescent OLED Technology]

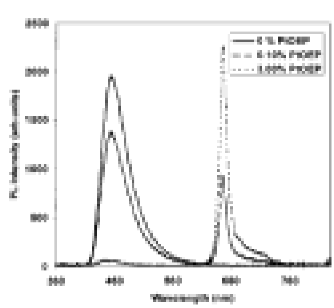
How to improve the triplets?

Schematic diagram of the fluorescent and phosphorescent transitions for host–guest systems.



How to improve the triplets?

Photoluminescence traces

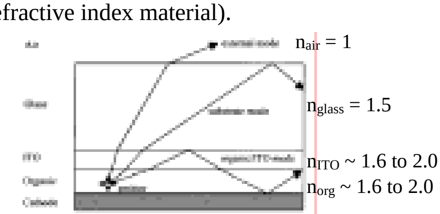


Luminescence efficiency

- Important factors leading to the reducing of luminescent efficiency in OLED devices is the presence of impurities diffusing from the electrodes into the organic layer and the interaction between the excitons and the metal electrodes.
- Thicker layers of cathode produce larger metal diffusion into the organic layer.
- **Improvement:** The cathode layers can't be too thick while comparing with organic layers.

Optical output coupling

- The large mismatch between the refractive index of the polymer and air results in a large proportion of the light rays undergoing total internal reflection (as light tries to pass from a high to a low refractive index material).

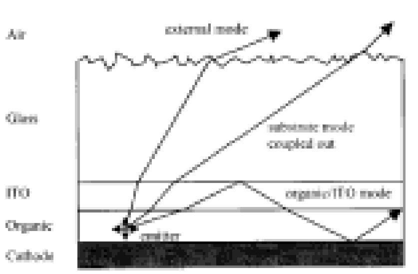


How to improve the output coupling?

- The techniques can be divided into two main categories:
  - **Method 1**: Reduce the total internal reflection at the glass air interface.
  - **Method 2**: Corrugating the emission region (like wave), altering the refractive index of layers in the device and patterning the device to produce photonic crystal behavior.

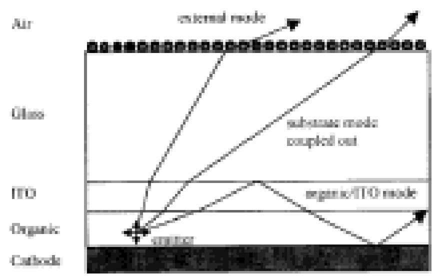
How to improve the output coupling?

Method 1-1



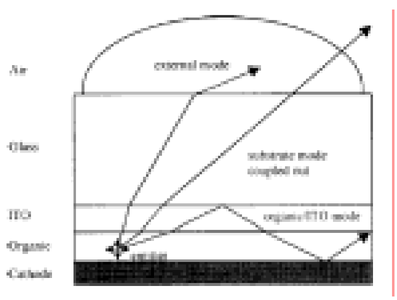
How to improve the output coupling?

Method 1-2



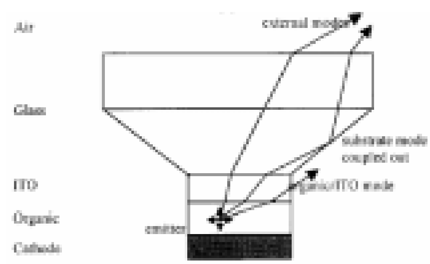
How to improve the output coupling?

Method 2-1



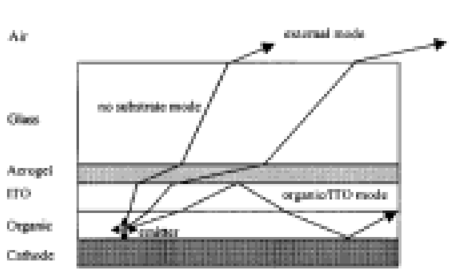
How to improve the output coupling?

Method 2-2



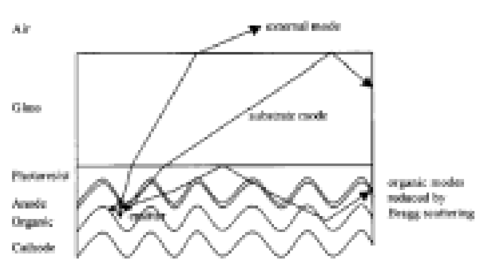
How to improve the output coupling?

Method 2-3



How to improve the output coupling?

Method 2-4



Conclusion

- There are many issues in putting these factors together to improve the efficiency of OLED. However, it still doesn’t meet commercial constraints for device applications.
- Development of highly efficient OLEDs has been rapid and is expected to maintain this pace in the future. The OLEDs will be the famous material in plane display applications after overcoming these losese.

Thanks for your attention!!