# Efficient WOLED Using A Single Emitter

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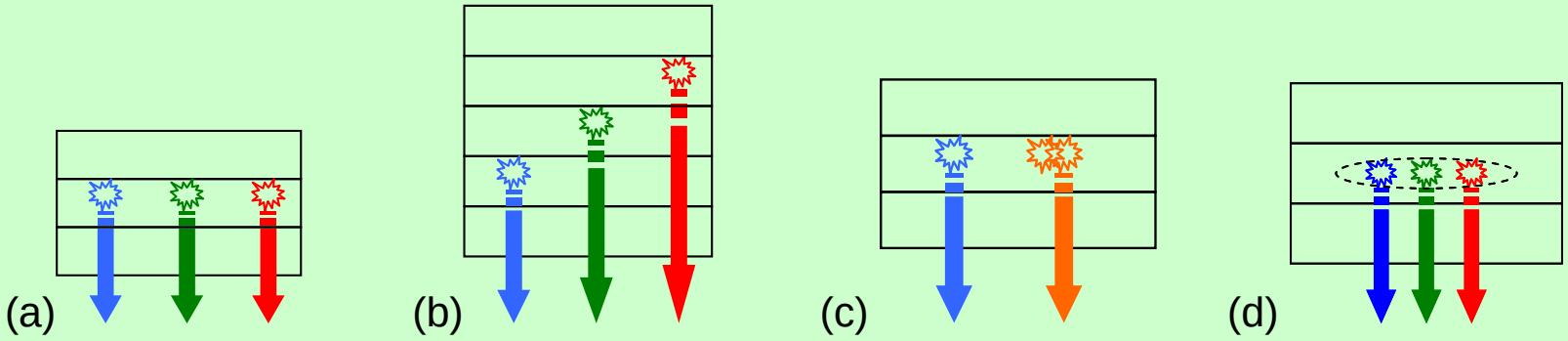
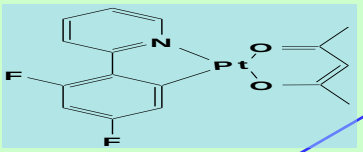
# How to Produce White Light?



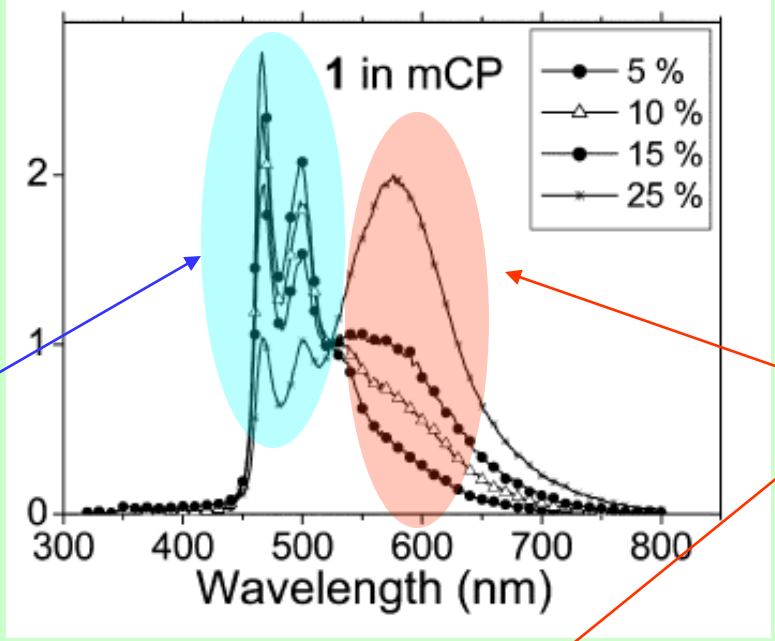

Schemes for 4 possible WOLED architectures:
(a) triple-doped emissive layer,
(b) multiple emissive layers;
(c) emissive layer with monomer and excimer
(d) emissive layer with a single broadband emitter.

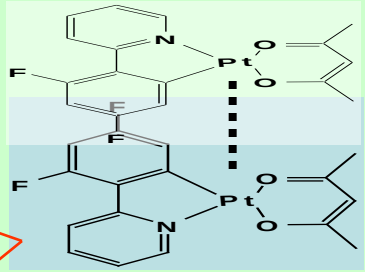
The typical FWHM range of organic emitters are between 40-60 nm.

# Single-doped WOLEDs

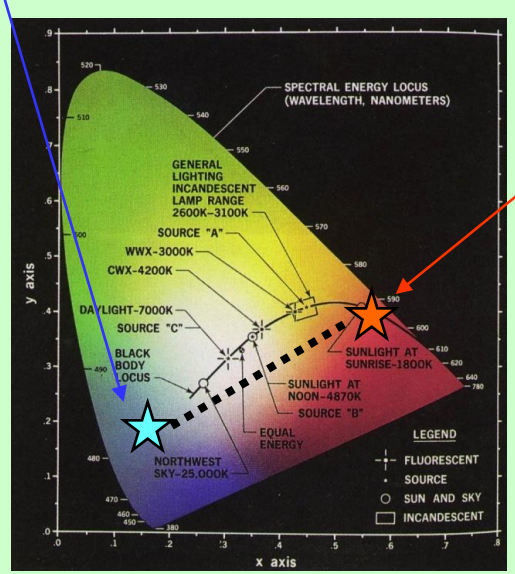


FPt
blue-green like
emission



[FPt-FPt]*
orange like emission

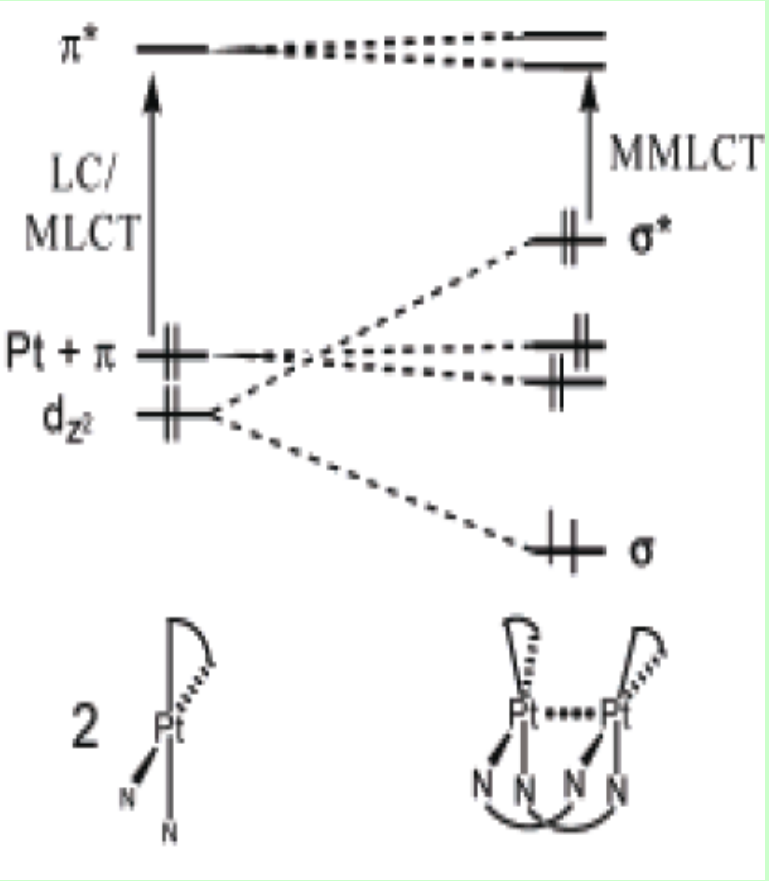



***Benefits***

(a) No problem of energy transfer from blue to red emitters
(b) No problem of Differential Aging
(c) Spectrum is voltage independent
(d) Simple structure
(e) Easy to manufacture

Adamovich et al. *New J. Chem.* (2002).

# Technical Challenges




The lowest excited state of monomer is $^3$LC/$^1$MLCT state, the excimer has MMLCT transition.

Ma et al. *JACS* (2005)

- improving the emission efficiency of molecular dopants and excimers
- controlling emission color of emitters and their excimers,
- improving optical and electrical stability of emissive dopants.

# First Reported Single-doped WOLED

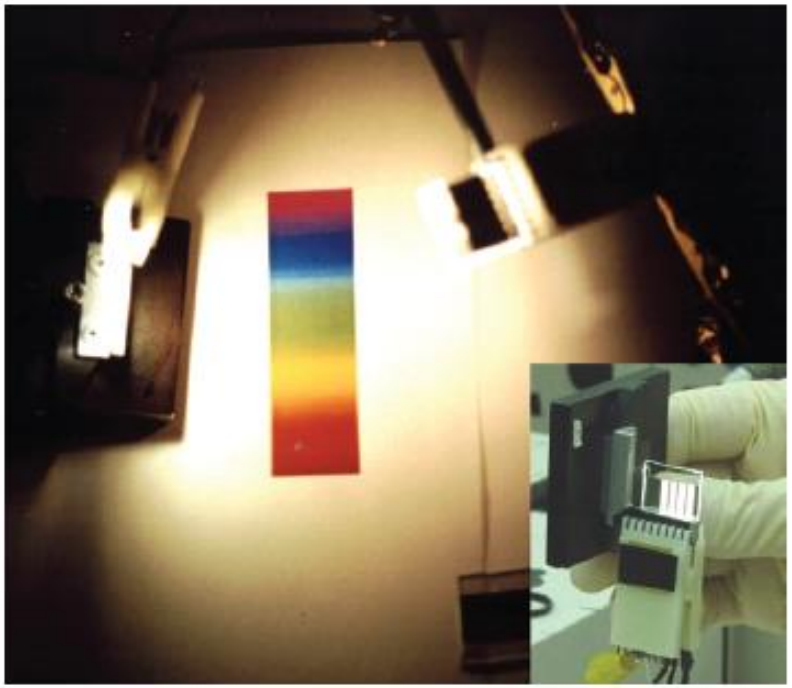
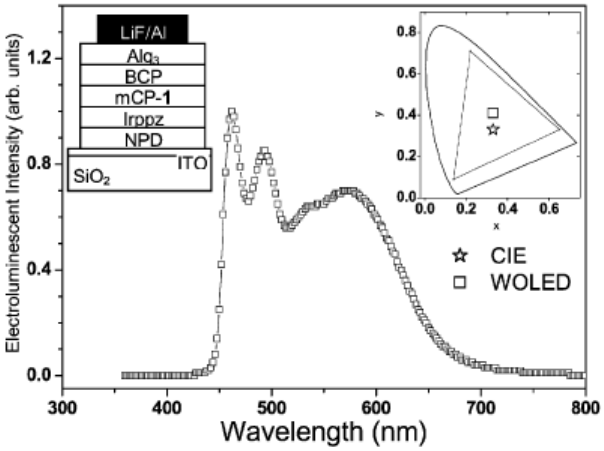
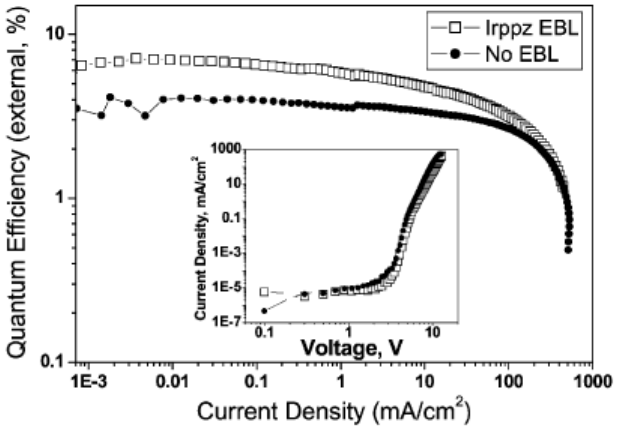


Fig. 7 A color bar illuminated only by the singly doped white OLED described in Fig. 6. A picture of the WOLEDs in room light is shown to the lower left.

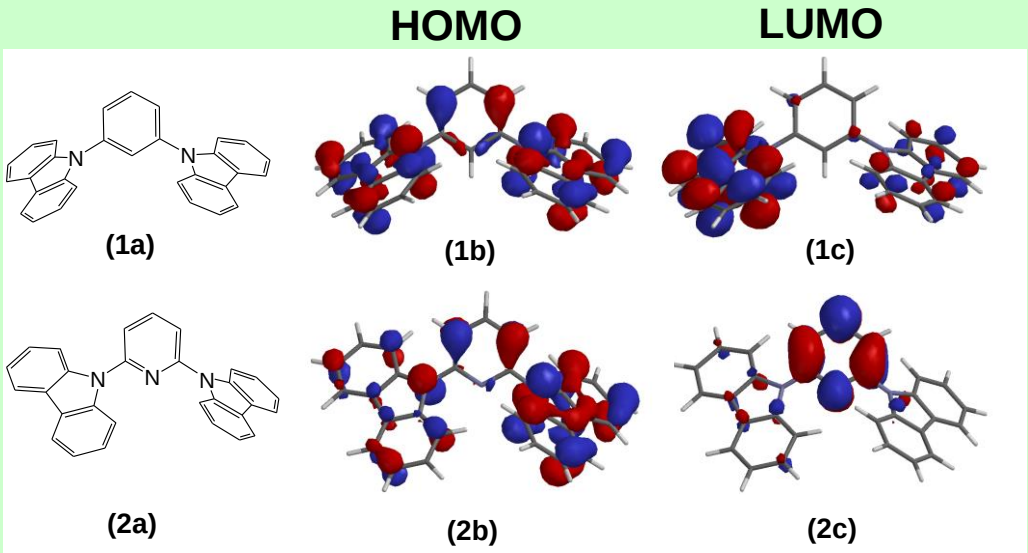


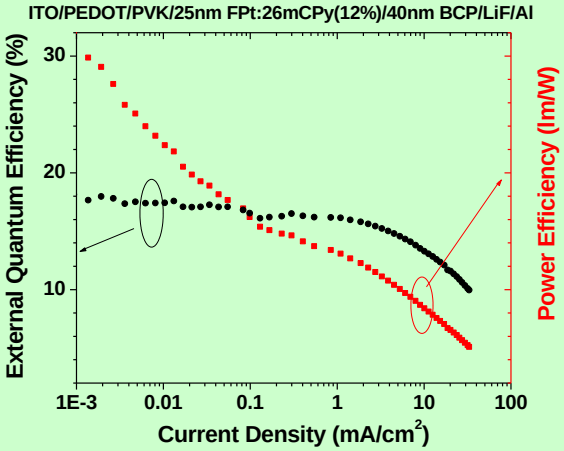



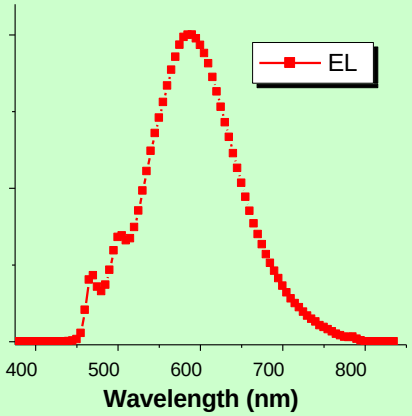

- at 1 cd/m$^2$, quantum efficiency is 6.4±0.6% (12.2 ±1.4 lm/W, 17.0 cd/A).
- at 500 cd/m$^2$, quantum efficiency is 4.3±0.5% (8.1 ±0.6 lm/W, 11.3 cd/A).

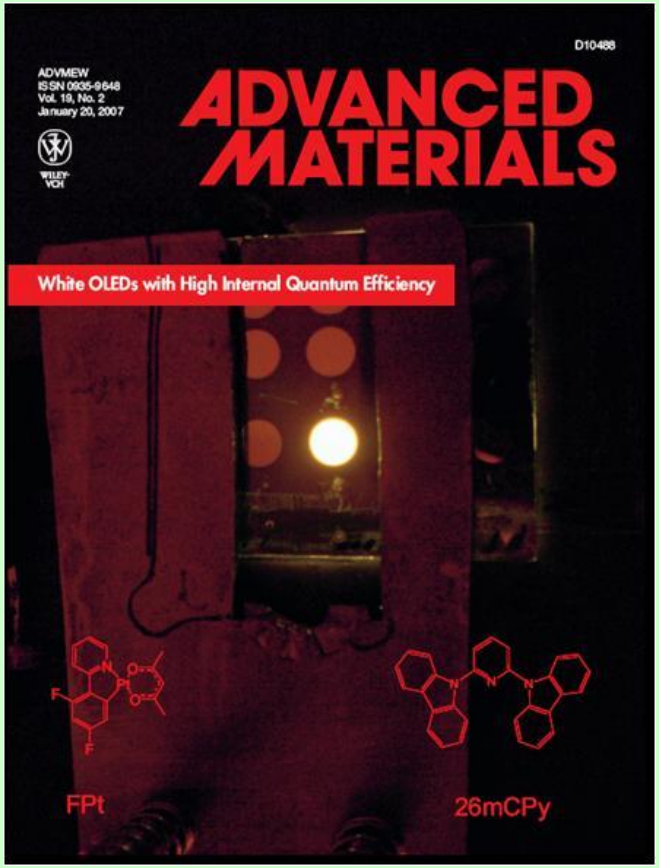
Adamovich et al. *New J. Chem.* (2002)

# First Efficient WOLED Using A Single Emitter



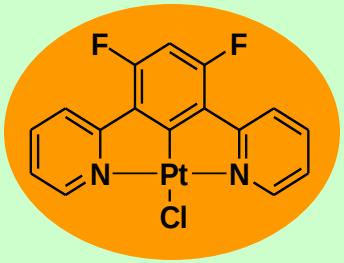



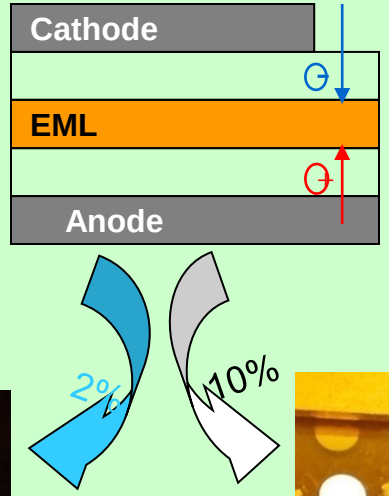



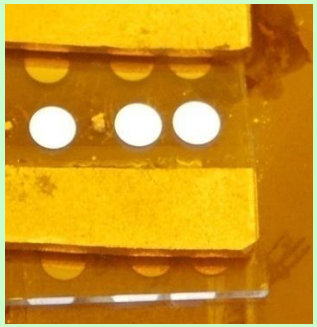

Williams et al. *Adv. Mater.* (2007)

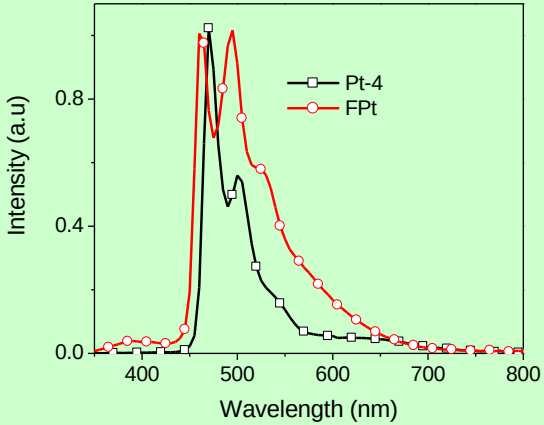
- **IQE is approaching 100% ( > 18% in FWD; 29 lm/W, 42.2 cd/A), CIE(0.48, 0.47), CRI 68.**

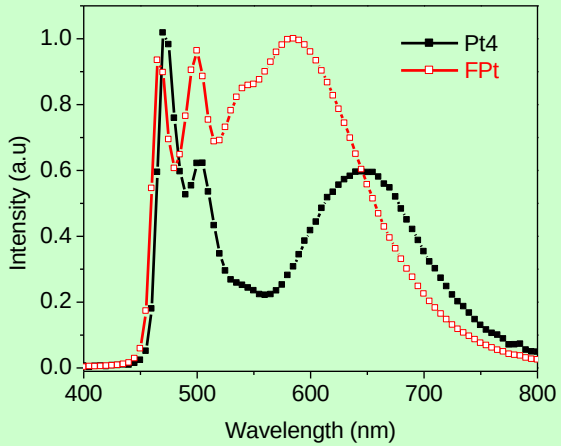
# World's First Efficient Blue OLED Using Pt complexes





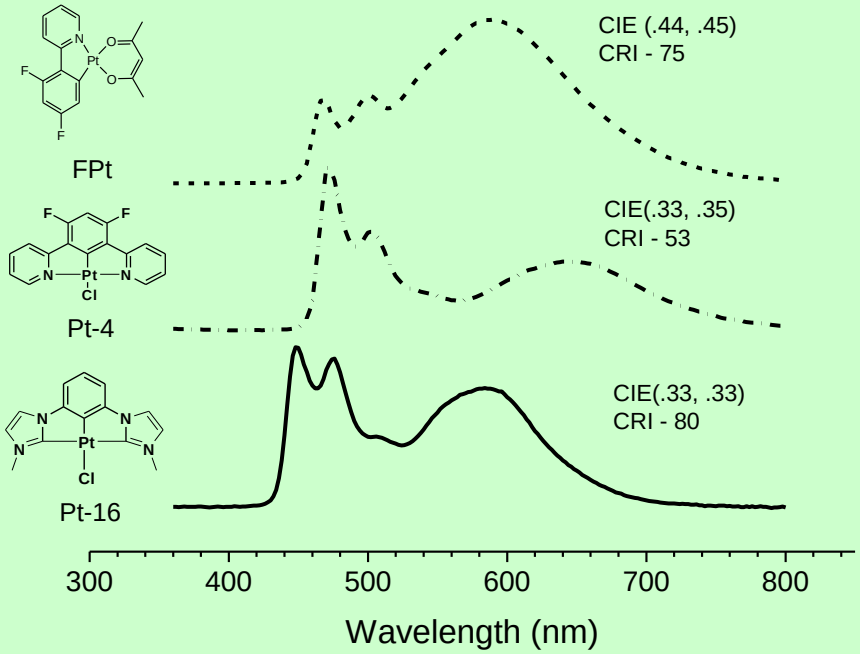


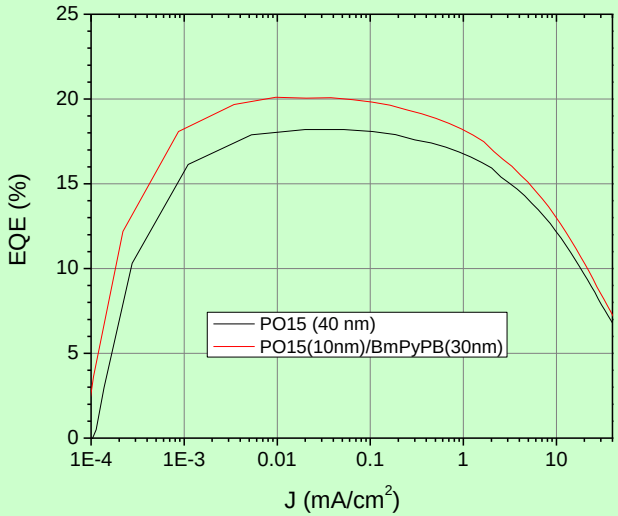

High concentration Pt-4 device showed a peak EQE of ca. 9.3% ph/el and CIE (0.33, 0.36).

Yang et al. *Adv. Mater.* (2008)

# Progress of Excimer-based WOLEDs




device structure:ITO/PEDOT:PSS/NPD(30nm)/TAPC(10nm)/ 10%Pt-16:TAPC:PO15(25nm)/ ETL/LiF/Al.



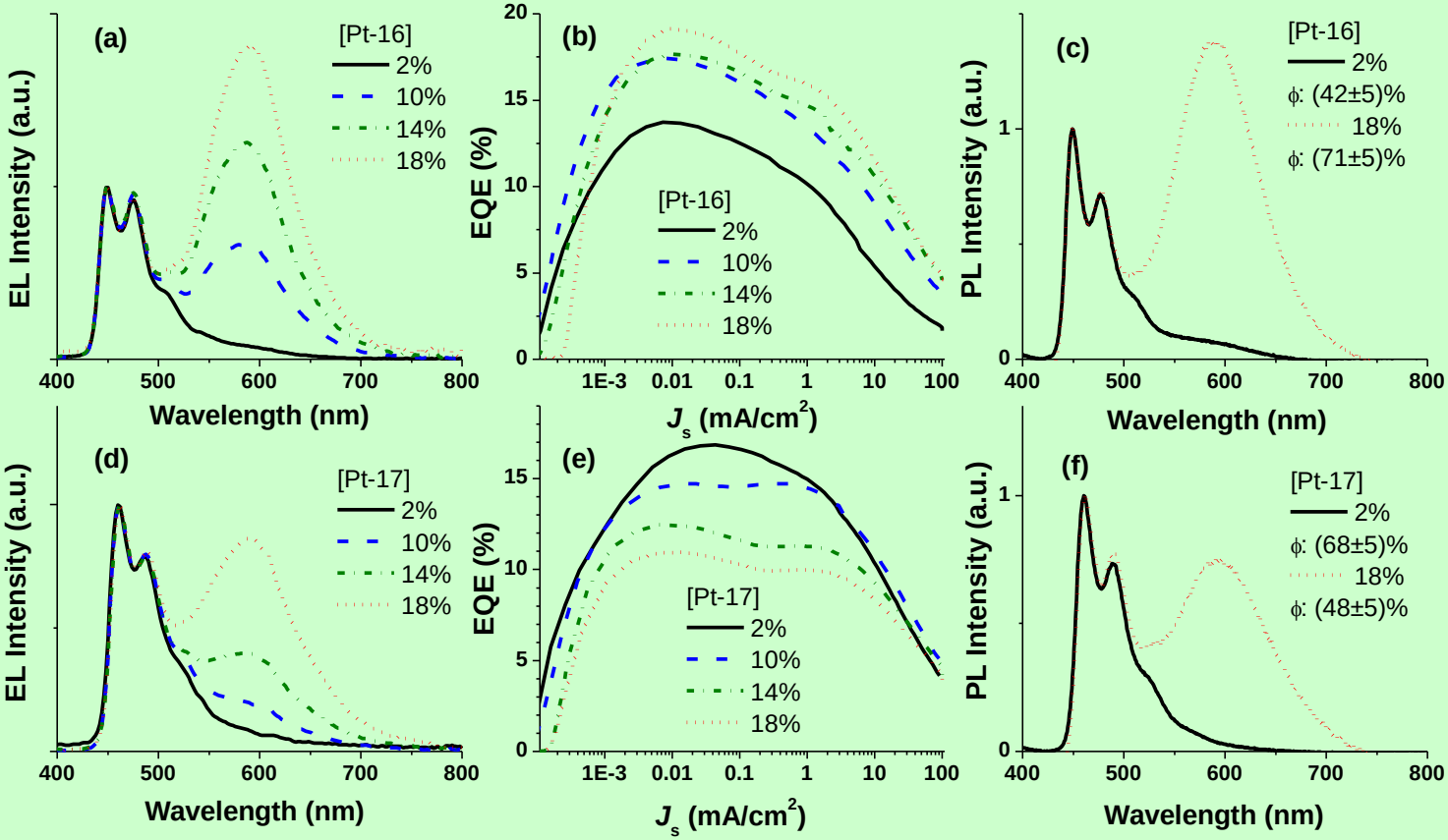

For Pt-16 WOLED, power efficiency exceeds 50 lm/W (no n/p-doping and enhanced coutcoupling), CIE (0.33, 0.32), CRI >=80, showing promise for lighting applications.

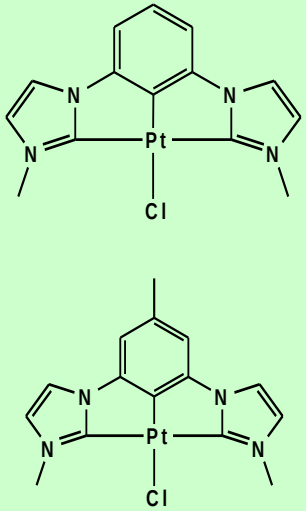
Power efficiency is 29 lm/W at 1000 cd/m$^2$

Fleetham et al. *Adv. Mater.* (2013)

# Pt-16 vs. Pt-17

device structure:ITO/PEDOT:PSS/NPD(30nm)/ TAPC(10nm)/x%dopant:26mCPy25nm)/ PO15(40nm)/LiF/Al.



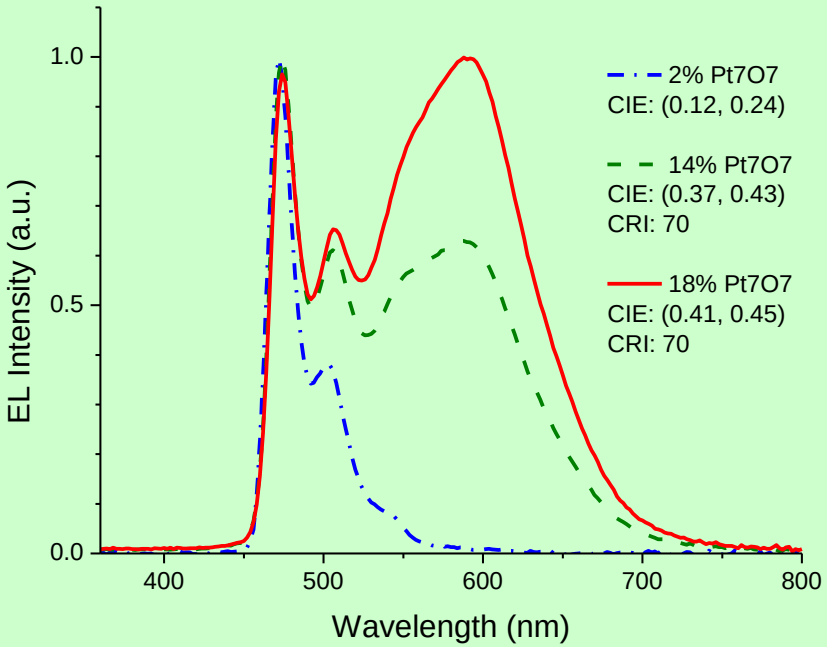



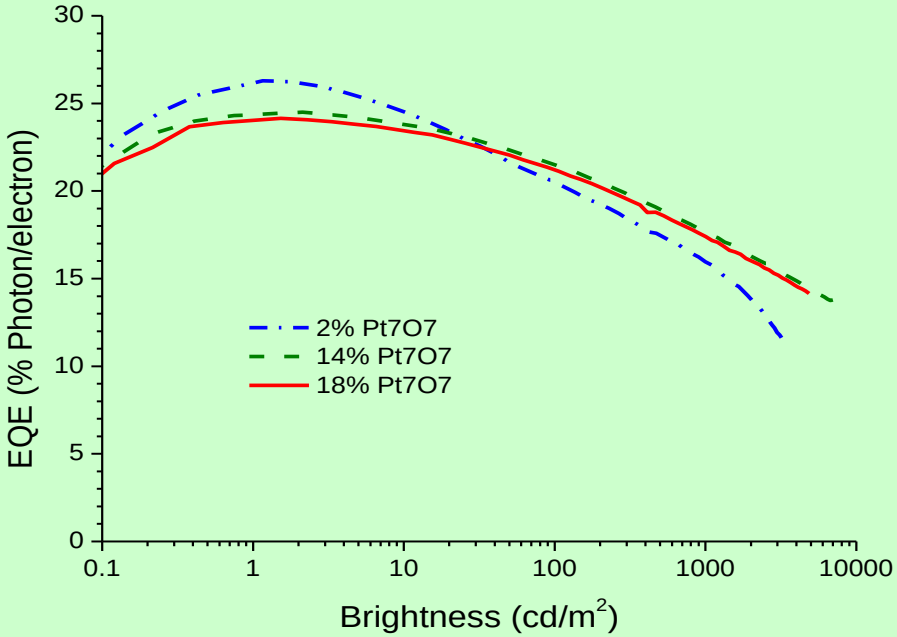

It is very interesting to find out that the behavior of excimers could be so different with similar monomer structures.

Fleetham et al. *Adv. Mater.* (2013)

# A New Emitter for both Efficient Monomer and Excimer

ITO/HATCN(10nm)/NPD(30nm)/TAPc(10nm)/x%Pt7O7:mCBP (25nm)/DPPS(10nm)/BmPyPB(40nm)/LiF/Al.

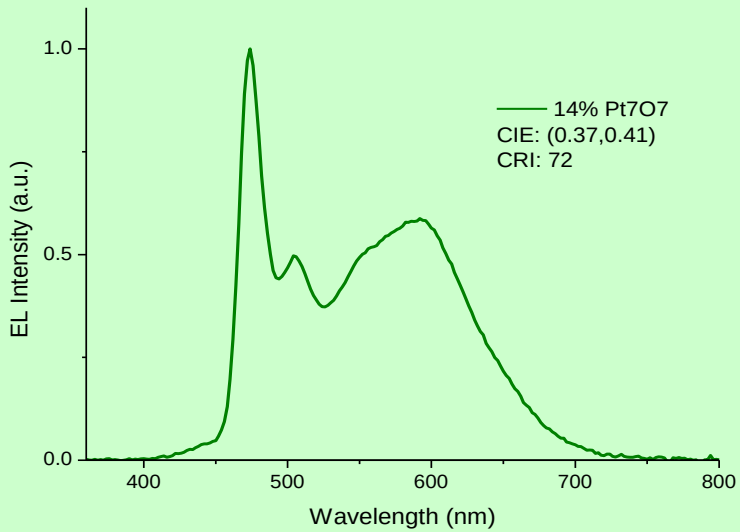


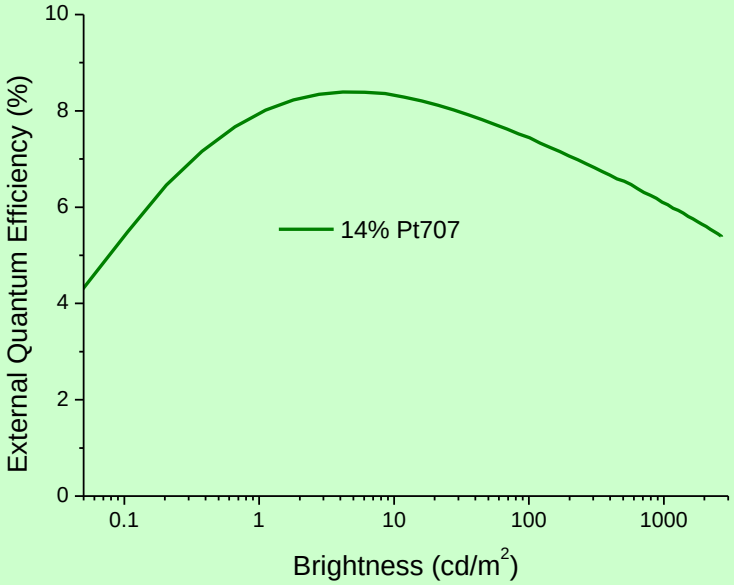




Our recent data suggest that monomer can be as efficient as excimers.

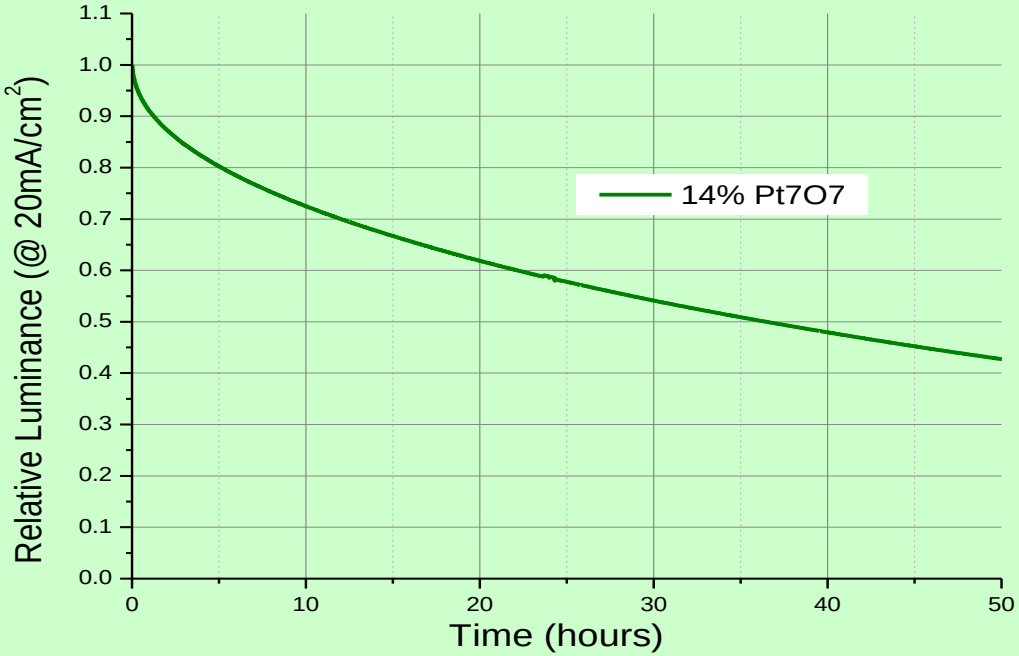
Li et al. *Adv. Mater.* In press.

# 14% Pt7O7- Stability



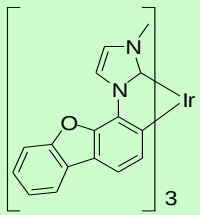

ITO/HATCN(10 nm)/NPD(40 nm)/14%Pt7O7:mCBP (25 nm)/ BAlq(10 nm)/Alq3(30 nm)LiF/Al.



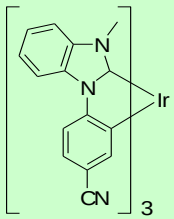

$LT_{50}$(@$L_0$=2775 cd/m$^2$) = 36.5 hrs.
$LT_{50}$(@100 cd/m$^2$) = >10,000 hrs.

Li et al. *Adv. Mater.* In press.

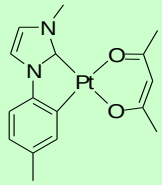
# Blue Emitting Pt vs. Ir Complexes



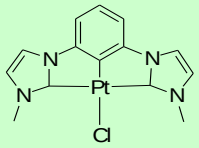

Ir(dpfmi)



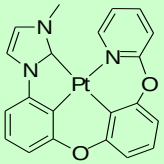

Ir(cnpmic)




Pt(Mepmi)

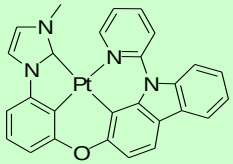



Pt-16




Pt[*pmi*-O-POPy]

PtOO7

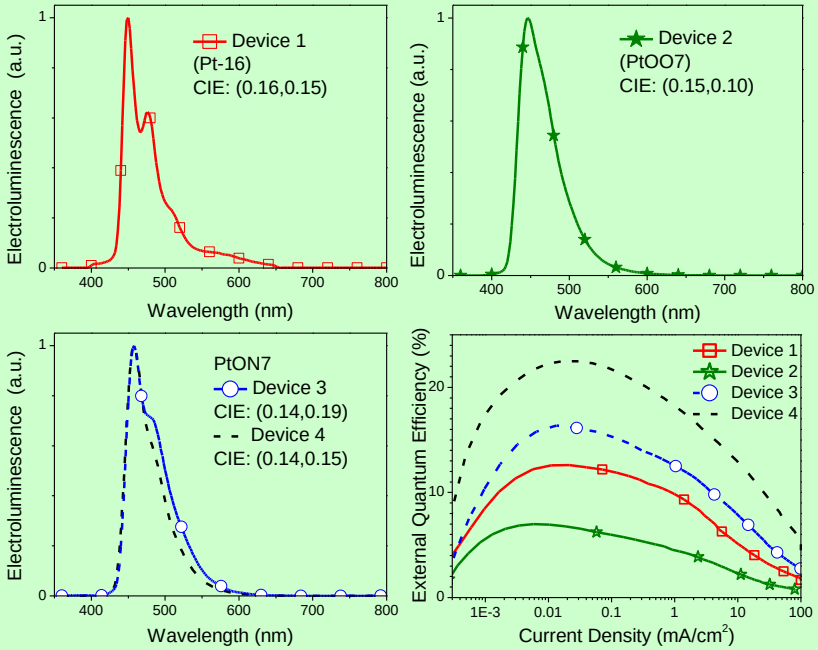



Pt[*pmi*-O-CbPy]

PtON7

| Complex | $\lambda_{max}$ (nm) | $\Phi$(%) | $\tau$ ($\mu$s) | $k_r$ ($x10^4 s^{-1}$) | $k_{nr}$ ($x10^4 s^{-1}$) |
|---|---|---|---|---|---|
| PtON7 | 452 | 89 | 4.1 | 21 | 2.6 |
| PtOO7 | 442 | 58 | 2.5 | 23 | 17 |
| Pt-16[9b] | 450 | 32 | 5.1 | 6.3 | 13.3 |
| Pt(Mepmic)[9a] | 419 | 20 | 25 | 0.8 | 3.2 |
| $Ir(cnpmic)_3$[7b] | 425(sh), 450 | 78 | 19.5 | 4 | 1.1 |
| Ir(dbfmi)[7a] | 445 | 70[a] | 19.6 | 3.6 | 1.5 |
| PtON1 | 449 | 85 | 4.5 | 19 | 3.3 |

ITO/PEDOT:PSS/NPD(30 nm)/TAPC(10 nm)/2% emitter:26mCPy(25 nm)/PO15(40 nm)/LiF/Al.




- With such molecular design principle, PtON7 shows a better photophysical properties than its Pt analogs and Ir analogs;
- A deep blue OLED with a maximum EQE of 22% and CIE coordinates of (0.14, 0.15) was fabricated using PtON7.

Hang et al. *Angew Chem. Int. Ed.* (2013)

# Future Outlooks

- The development of stable blue emitters is key;
- The choice of excimers should include phosphorescent materials, thermal activated delayed fluorescent (TADF) materials and metal-assisted delayed fluorescent (MADF) materials;
- The choice of metal complex based excimers will include platinum and other metal ions.