Stable, High Efficiency White Electrophosphorescent Organic Light Emitting Diodes (OLED) by Reduced Molecular Dissociation (DE-EE0007077)

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Project overview

- **Project objectives**
  - ➢ Development of long-lived and efficient blue PHOLED
  - ➢ Introduce highly excited state manager into blue PHOLED to recycle multiply excited triplets and/or charges for emission
  - ➢ Implement R+G+B stacked white PHOLED

Y1 goal for blue PHOLED

@1000nits	Current	Target
EQE [%]	9.5 (18.0)	> 15
CIE	[0.16, 0.31]	[0.15, 0.30]
LT70 [hr]	486 (*1,300)	3,000
Size [cm^2]	0.02	1

* Extrapolated. Parenthesis: stacked.

Y2 goal for white PHOLED

@1000nits	Current	Target
η [lm/W]	49 (47)	70
LT70 [hr]	4,000 (13,000)	50,000
CT [K]	2580 (2780)	2750
CRI	83 (89)	85

Parenthesis: stacked.

- **Task summary**

Task	Task title	Target Q	Status
1	**Stable blue phosphors and host materials**		
1.1	Efficient blue phosphors	1	Complete
1.2	High energy electron conducting hosts	4	Complete
1.3	Matched host and dopant materials	4	Complete
1.4	Long-lived blue PHOLEDs	8	Complete
G/NG1	Blue PHOLED: eff.>15%, LT$_{70}$>3000hr at 1000 nits	4	Passed
2	**Excited state sinking to enhance lifetime**		Complete
2.1	Development of excited state sinks	2	Complete
2.2	Employing excited state sinks blue PHOLEDs	4	Complete
2.3	Materials and device characterization	7	Complete
G/NG2	Blue PHOLED: 2x lifetime by excited state sink	4	Passed
3	**Lifetime validation and scaling**	4-8	Complete

- **Project Roles**
  - ➢ UM: Device physics and characterization
  - ➢ USC: Material synthesis and analysis
  - ➢ UDC: Panel fabrication, validation and scaling

- **Requirements: High performance WOLEDs**
  - ○ **Lifetime**
    - ➢ Reduced blue intrinsic degradation
    - ➢ Stable green blocking layer
  - ○ **CRI**
    - ➢ 3 emitter balanced emission spectrum
    - ➢ Balanced exciton profile & emitter degradation rates

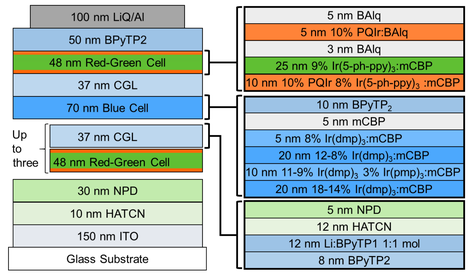
R&D approach

Reliable, All-Phosphorescent Stacked WOLEDs with a High CRI

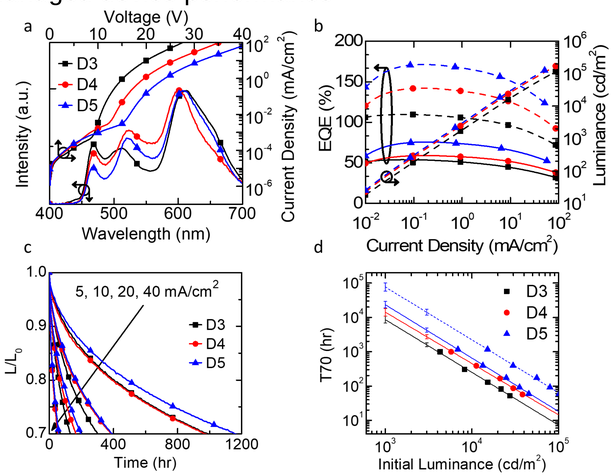
Three device types: D3-D5 have 3-5 cells, respectively.

Each cell and the CGL were optimized in individual test structures

Fabricated using vacuum thermal evaporation (VTE)



- Managed device performance



SWOLEDs D3, D4, and D5 have one, two, and three CGL/red-green element pairs below the blue emitting element, respectively.

- ➢ Degradation of blue emission reduced by 40% at T70
- ➢ RG cell achieves high efficiency and stability simultaneously
- ➢ Stable CGL does not significantly contribute to voltage rise

Table 1: Performance Characteristics of SWOLEDs

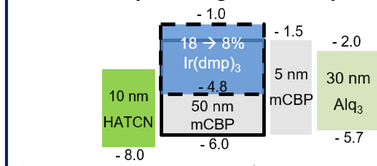
Device	CCT$^{(a)}$ (K)	CRI$^{(a)}$	CIE$^{(a)}$	J$^{(b)}$ (mA/cm^2)	V$^{(b)}$ (V)	EQE$^{(b)}$ (%)	LPE$^{(b)}$ (lm/W)	T70$^{(b)}$ (10^3 h)	ΔV$_{T70}$ (V)
D3	2978	79	(0.44,0.40)	0.5	14.2	107	40.6	26±7	2.7±0.1
D4	3300	85	(0.43,0.44)	0.4	17.8	141	47.2	50±15	3.2±0.1
D5	2780	89	(0.46,0.43)	0.3	21.5	170	44.7	80±20	4.3±0.1

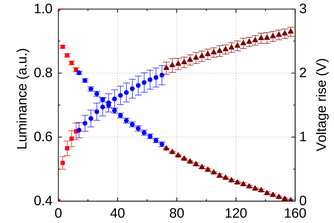
(a) Measured at *T100* / *T70* and *J* = 10 mA/cm^2 (b) Measured with outcoupling at L0 = 1,000 cd/m^2

R&D approach

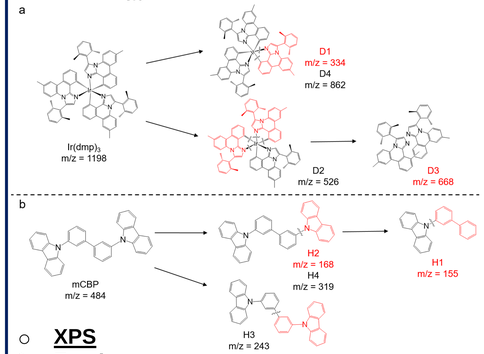
Understanding Molecular Fragmentation in blue PHOLEDs

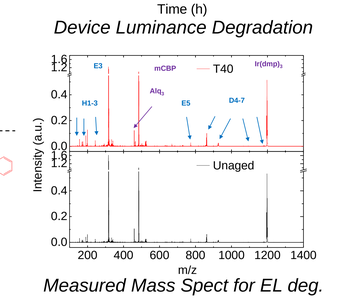
- ○ **Concept**
  - ➢ Understand the mechanism during electrical degradation of blue PHOLEDs
- ○ **Findings**
  - ➢ **Loss of ligands from the phosphor → Dominant** fragmentation
  - ➢ **Phosphor fragments → quench** excitons & **trap** charges than **mCBP**





Device Luminance Degradation





Measured Mass Spect for EL deg.

- ○ **XPS**
  - ➢ **Fresh**
    - Ir(dmp)$_3$: 61.5/64.5/399.3/401.2 eV
    - mCBP: 400.7 eV
  - ➢ **Aged**
    - Fragmental peaks appear
    - Ir(dmp)$_3$ peak ↓
    - mCBP less change
- ○ **DFT**
  - ➢ Phophor fragments quench excitons & trap charges than mCBP