Getting All the Light Out: Eliminating plasmon losses in high efficiency white organic light emitting devices for lighting applications (DE-EE0007626)

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Project overview

- **Project objectives**
  - ➢ Eliminate Surface Plasmon Polariton Losses in OLED
  - ➢ Highly efficient single color PHOLED with >70% outcoupling efficiency
  - ➢ Implement to white PHOLED with high EQE, CRI

Y1 goal for single color PHOLED

	Target
SPP Mode Coupling	50% Reduction

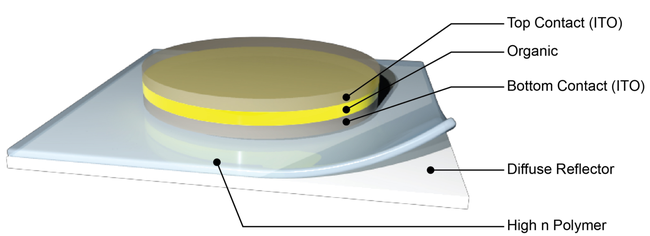
Y2 goal for white PHOLED

	Current	Target
EQE [%]	50	70(210)*
CRI	93	>90
Size [cm^2]	0.01	23

* single EML assumed (stack WOLED)

Task	Task title	Target Q	Status
1	**High efficiency for single color PHOLED**		
1.1	Optical modeling for PHOLEDs	1	Complete
1.2	PHOLED with corrugation of cathode surface	3	Complete
1.3	Bottom-emitting OLEDs with optical gratings	4	Complete
1.4	Top-emitting OLEDs with a metallic scattering reflector	4	Complete
G/NG1	Single color PHOLED: Decrease in SPP mode coupling by 50%	4	Passed
2	**Highly efficient WOLED with high CRI**		
2.1	Develop WOLED with CRI>90	6	Complete
2.2	PHOLED with outcoupling >70%, WOLED with CRI >90 with 10% spectral shifts with angles	7	Complete
2.3	25 cm^2 packaged WOLEDs with outcoupling >70% and validation	8	With OLEDWorks

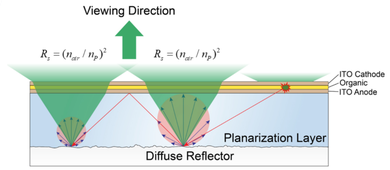
- **Approach 1: Efficient Outcoupling via Light-Scattering Dielectric Layer**
  - ○ **Concept**
    Metal → ITO contact + Teflon(~95% R @ VIS)
  - ➢ **Cheap, Simple and Non-Intrusive**
  - ➢ **Efficient**, x 2.5 EQE by itself (x3.4 theory)
  - ➢ **No Angle/Wvl Dependence, Spectral Shift**



Design Scheme

R&D approach

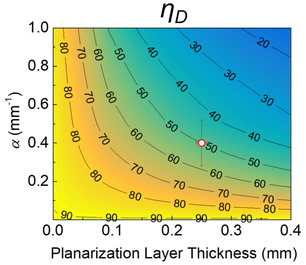
- ➢ Device Structure and Fabrication Process



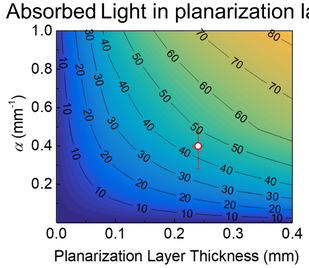
$$\eta_D = R_S + (1-R_S)\cdot R_S + (1-R_S)^2\cdot R_S + \cdots = \sum_{n=0}^{\infty}(1-R_S)^n \cdot R_S = 1$$

- ○ Top emission (η_{TA})
- ➢ ~8-10%
- ○ Bottom Emission
- - Planarization layer extraction (η_S)
- ➢ η_S increase with n_P → n_P = 1.8 wg mode vanish
- ➢ η_D mostly unchanged (< 2%) with device sizes

η_D

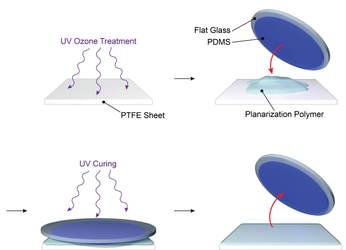


Absorbed Light in planarization layer

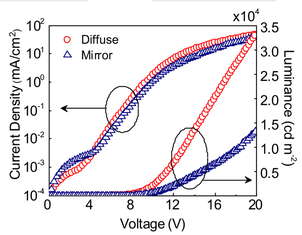


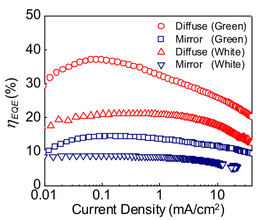
$$\eta_{out} = \eta_{TA} + \eta_D \eta_S$$

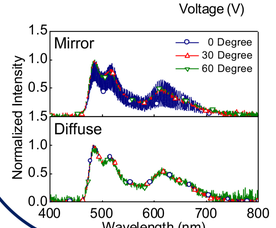
- Outcoupled light from planarization layer (η_D)
  - – Thickness, absorption↓ → η_D ↑
  - – Major loss channel → planarization layer absorption

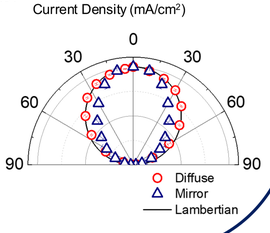


- ○ **Substrate Fabrication**
- ➢ UV treatment → adhesion with Teflon
- ➢ Utilizing glass substrate as mold and window



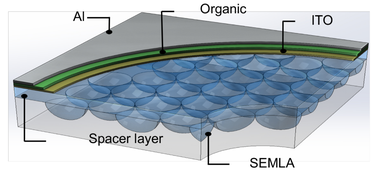




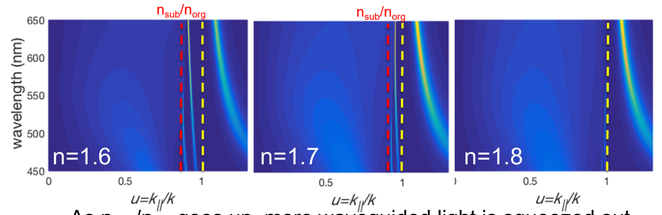


R&D approach

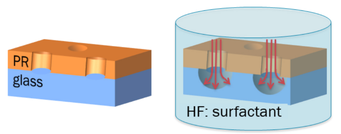
- **Approach 2: Efficient, Nonintrusive Outcoupling via Embedded Microlens Arrays**
  - ➢ **Concept**
    Embed MLA into glass substrate (sub-Anode)
  - ➢ **Simple & Non-intrusive**
  - ➢ **Efficient,** EQE 70%
  - ➢ **No Angle/Wvl Dependence, Spectral Shift**
  - ➢ **No Impact on Image Sharpness**



- ○ **Design Scheme**
- ➢ MLA between anode and glass
- ➢ Flat spacer layer
- ➢ High refractive index



As n_{sub}/n_{org} goes up, more waveguided light is squeezed out



- ○ **Substrate Fabrication**
- ➢ Lithography → Create holes
- ➢ Wet etch to produce MLA hemisphere

- ○ **Image Resolution**
- ➢ No apparent impact on image sharpness
- ➢ Good for display purposes