pixelligent

pixelligent

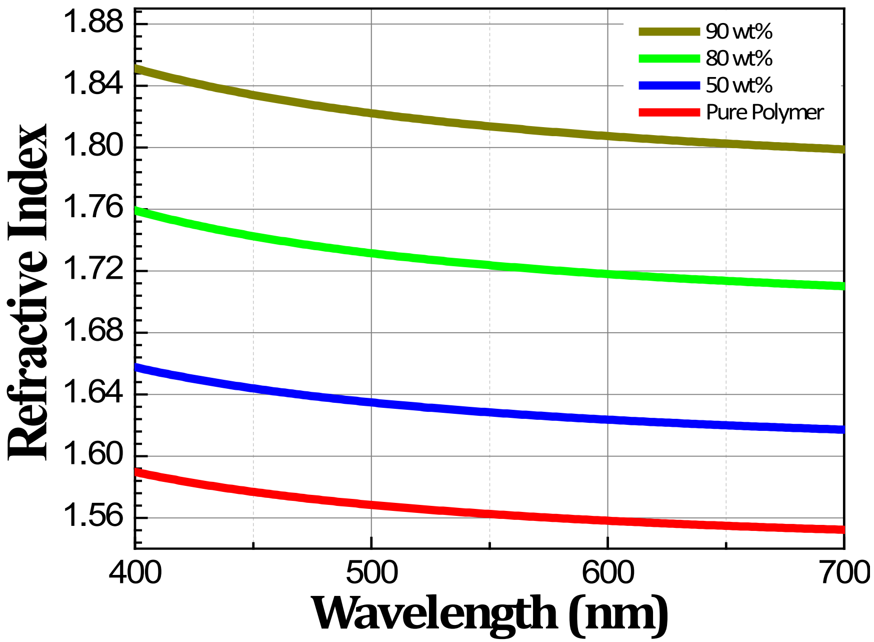
The Clear Solution ™

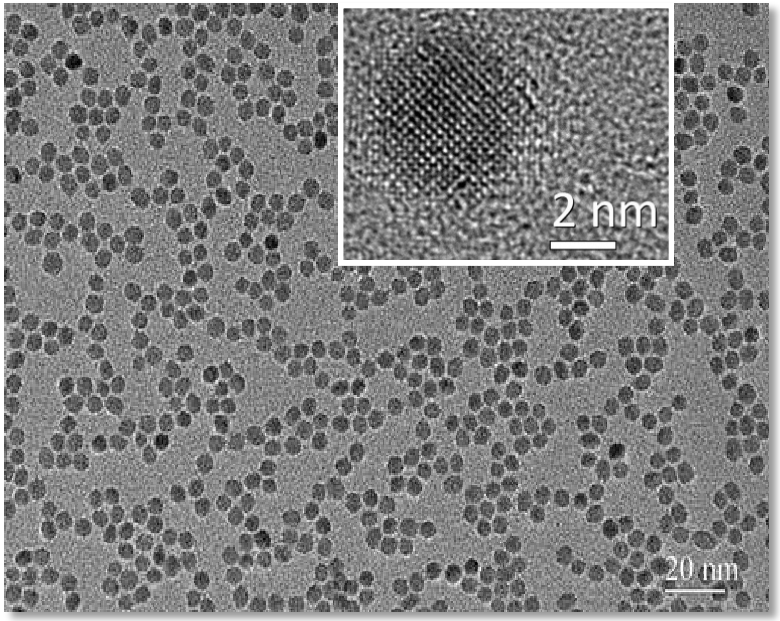
Light Extraction for OLEDs

www.pixelligent.com

Greg Cooper, PhD, Founder and CTO
Gene Chen, PhD, VP Engineering

Pixelligent Overview

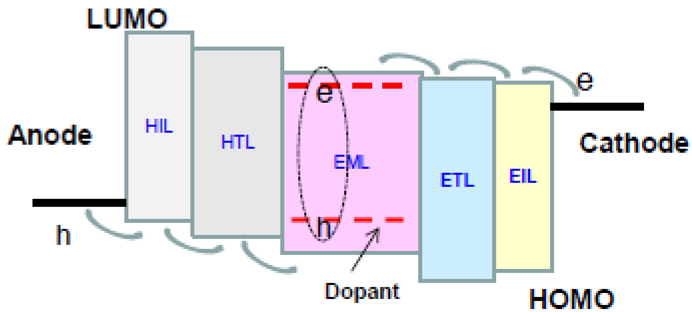


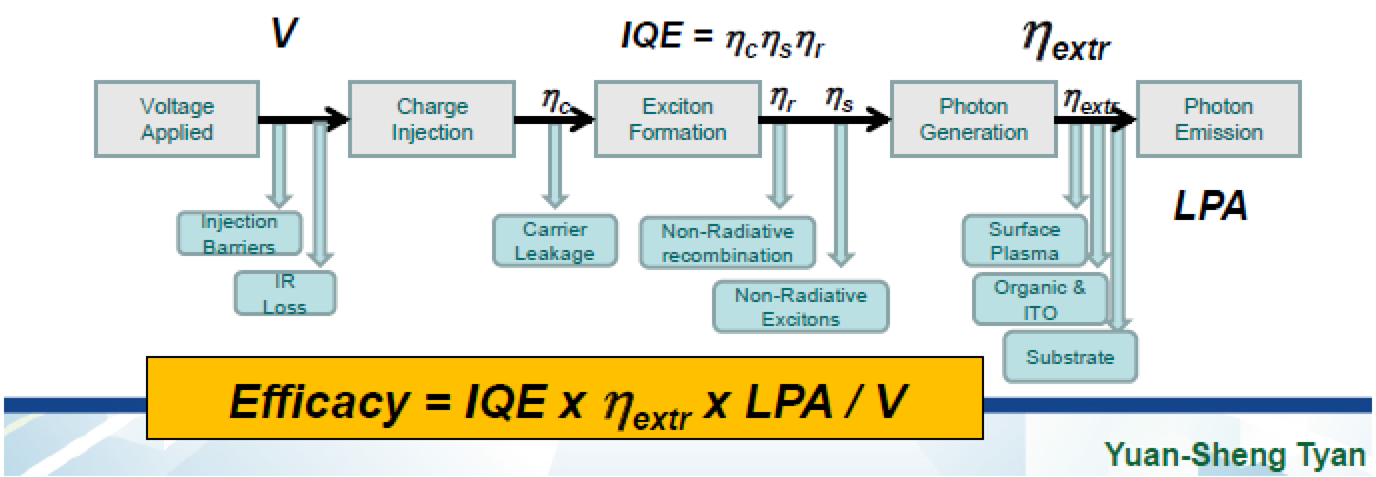


- ZrO_2 Nanocrystals & Dispersions
- No agglomeration
- High loadings (>80wt%)
- Highly scalable process
- State-of-the-Art Pilot Manufacturing Facility

OLED Light Extraction Principles

- Goal is to maximize Efficacy not η_{extr}
- Many other sources of loss in OLED – Does light extraction approach affect Efficacy





OLED World Summit 2013

pixelligent

OLED Light Extraction Principles

- Some light escapes naturally – most needs to be redirected
- Different light extraction schemes vary in how and where light is redirected
- Where – Substrate/Air, Substrate/ITO, In device, Cathode (4 choices)
- How – Structures, Photonic Crystals, Scattering Particle, Index Gradients, Plasmons (5 choices)
- Many possible combinations – how do we choose?

Where Should Light Extraction Occur?

Substrate /Air

Substrate /ITO

In Device

Cathode

Deeper in Device

More Light Available

More Disruptive to Device

How Should Light Extraction Occur?

- Efficiency – discriminate between light inside and outside escape cone?
- Compatible with low cost manufacturing process
  - Requirements depend on details approach
  - Produce desired light pattern, lambertian or directional, uniform color, …
  - Want large process window – small variations in manufacturing should not lead to large variations in extraction efficiency

pixelligent

External Light Extraction

How	Scatterers, Structures	Other methods possible, not yet proposed
Where	Substrate air interface	
Amount of light	50%	Can increase with high-n substrate
Manufacturability	Easy	Can be separated from OLED manufacturing
Current spreading	No impact	
IQE	No impact	
Lifetime	No impact	

Internal Light Extraction

How	Scatterers, Structures, Gradients	Other methods possible, not yet proposed
Where	Substrate ITO interface	
Amount of light	50% - 85%	Depends on ETL thickness and index, low index equivalent to external
Manufacturability	Medium	Material made separate from OLED but device built on ILE layer
Current spreading	Compatible with ITO deposition	
IQE	No impact	
Lifetime	No impact	

pixelligent

Buckled Cathode

How	Buckled cathode to disrupt plasmon absorption, waveguide and substrate modes	
Where	Cathode	
Amount of light	>90 %	Depends on ETL thickness
Manufacturability	Hard	Buckles propagate through device, Early Stage
Current spreading	Need good electrical properties in cathode	
IQE	??	
Lifetime	??	

pixelligent

Structured Anode

How	Patterned anode with plasmonic effect	
Where	Anode	
Amount of light	85 %	Depends on ETL thickness
Manufacturability	Hard	Early Stage
Current spreading	How does patterned anode affect current uniformity in device	
IQE	No impact	
Lifetime	??	

pixelligent

Directional Emitters

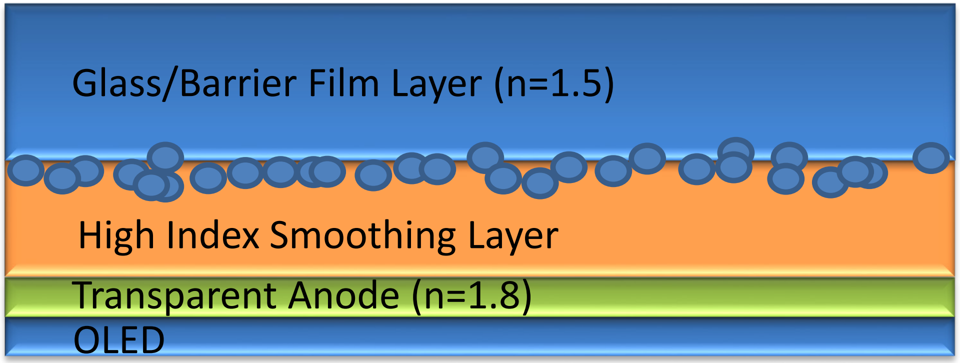
How	Deposit oriented emitters	
Where	Emission layer	
Amount of light	??	
Manufacturability	Hard	Early Stage
Current spreading	No impact	
IQE	??	
Lifetime	??	
Could be combined with other methods – internal or external		

Pixelligent Approach

- Focus on ILE – best combination of available light and impact on device
- Design most efficient light extraction with simple manufacturing
- Use scatterers and gradients
- Put complexity into material and not manufacturing

ILE Generations

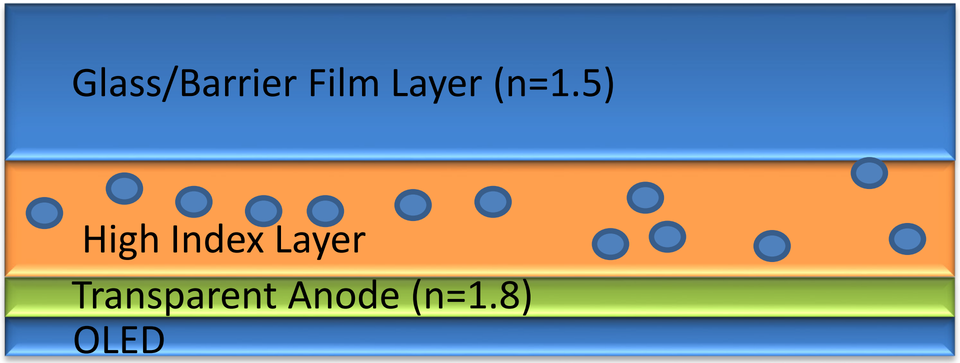
- Generation 1 – Condensed Scattering Layer with high index smoothing



- May eliminate need for external light extraction
- Pixelligent currently offers a beta sample high index smoothing layer formulation

ILE Generations

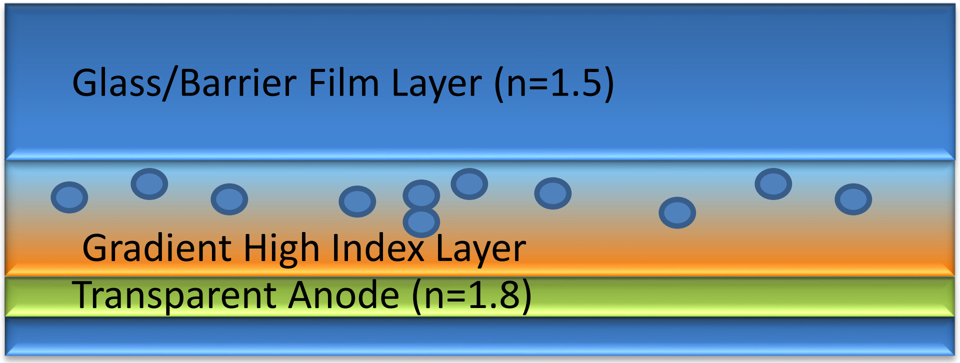
- Generation 2 – Distributed Scattering Layer with high index layer



- More efficient than condensed scattering layer
- More complex material but simpler manufacturing process
- Pixelligent currently developing high index layer with distributed scatterers

ILE Generations

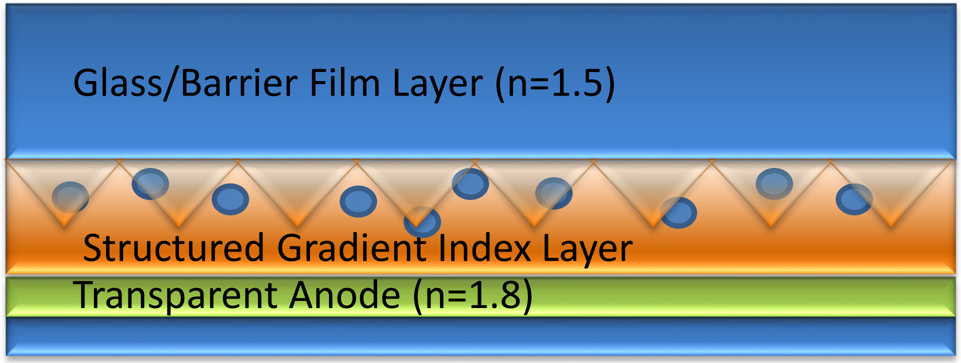
- Generation 3 – Distributed Scattering Layer with gradient high index layer



- More efficient than distributed scattering layer
- More complex manufacturing process
- Pixelligent currently developing materials and manufacturing processes

ILE Generations

- Generation 4 – Distributed Scattering Layer with structured gradient high index layer



- Highest efficiency
- Offers ability to direct light – non-lambertian
- Most complex manufacturing process
- Subject of Future work

Summary

- We don't yet know which light extraction approach is best – need to maximize efficacy in complex system with lots of interdependencies
- Multiple approaches can work together
- Our view – ILE best approach
    - Lots of accessible light – minimal impact to device
    - Still need improvement in device – don't constrain future materials or devices with light extraction
- Pixelligent approach high index nanocomposites with scatterers and gradients

Contact

Gregory Cooper, PhD

Founder and CTO

Main: +1-443-529-8310 x 12

Cell: +1-703-675-8906

Email: gcooper@pixelligent.com