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Designers Lighting Forum

OLED Lighting for Embedded Applications

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

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Learning Objectives

At the end of this course, participants will be able to:

1. Understand basic OLED technology, what embedded lighting applications are, and how they may be used in such projects.

2. Recognize the form factor differences between OLED lighting and other light sources and how to effectively use OLED lighting.

3. Understand OLED panel high-contrast segmentation capability and how to apply segmented OLED technology to explore new and unique designs.

4. Appreciate the unique design options available when using OLED as a building block for embedded lighting design projects.

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- Based in Rochester, NY USA and Aachen, Germany
- Rochester is a hub for the optics industry
- Practical OLED technology was invented at Eastman Kodak
- OLED is a popular technology for display (cell phones, wearables, TV's, etc…)

The Organic in OLED is for Organic Carbon-Based Chemistry, not Organic Chicken!
(more on this later…)

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OLED Lighting Technology

The future of light

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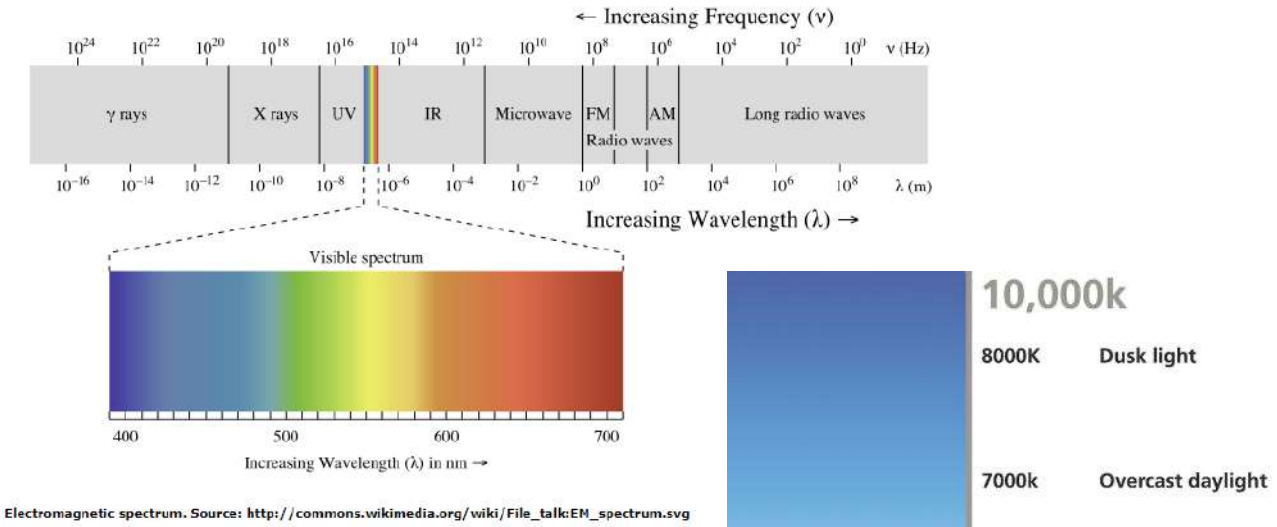
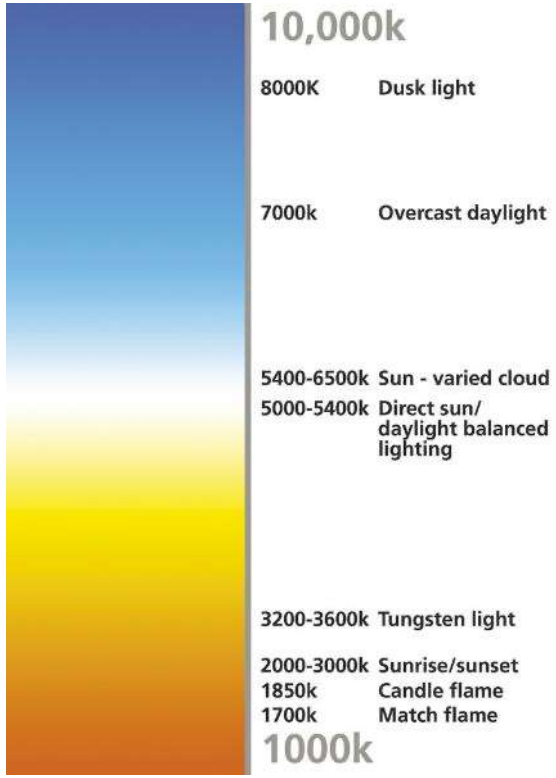
Natural Light



Electromagnetic spectrum. Source: http://commons.wikimedia.org/wiki/File_talk:EM_spectrum.svg



The original light source, **the Sun!**

White light covers the entire visible spectrum (380nm – 750 nm)

Sunlight isn't always white light

The atmosphere changes surface illumination between blue and red spectral dominance

White light isn't always white (at least for humans)

Correlated Color Temperature (CCT) is used to map various light sources to a black body ideal (such as the Sun)

http://www.lightingschool.eu/portfolio/understanding-the-light

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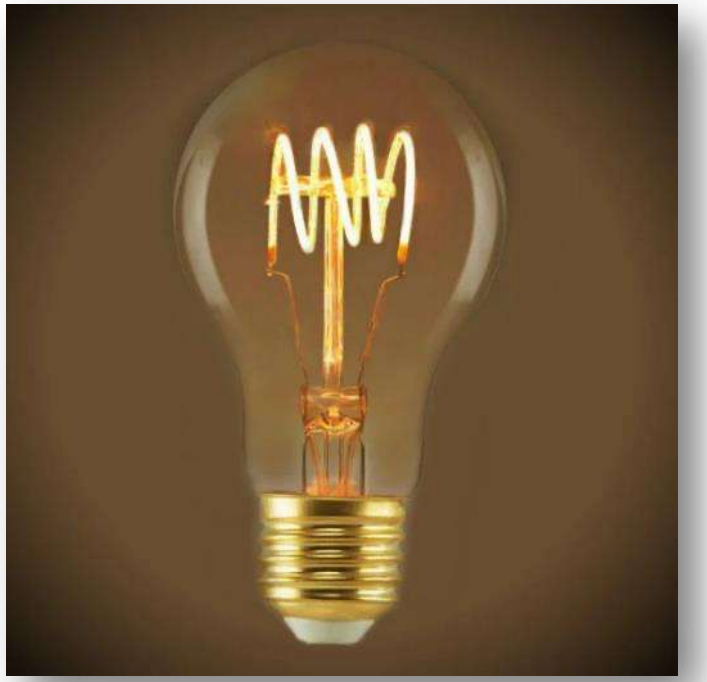
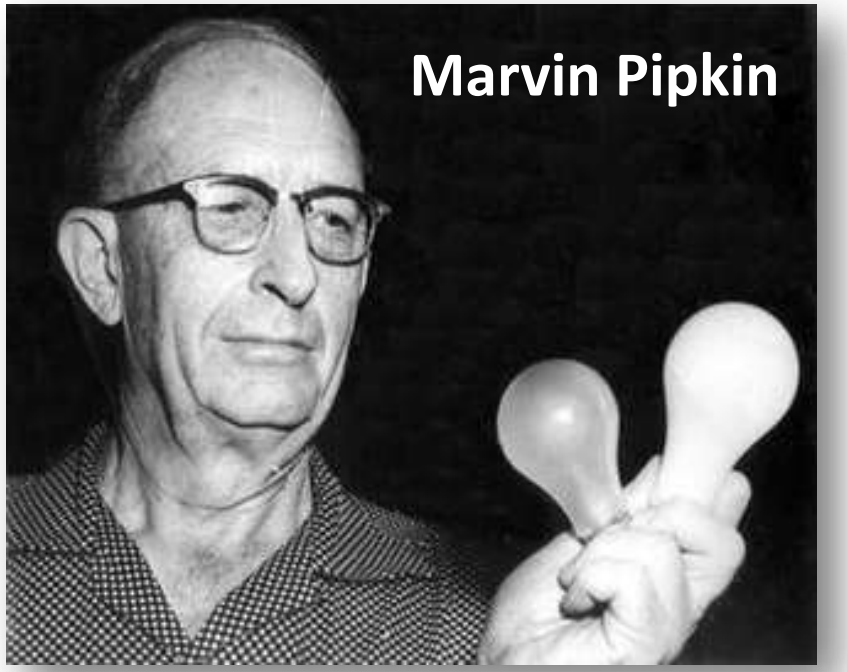
In the beginning… Incandescent Lighting



1880
(Thomas Edison)



1925 – double acid etch
1947 – internal silica coating

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Moving beyond the filament…
Fluorescent Lighting

Fluorescent light bulb

1938

Compact Fluorescent light bulb

1980s

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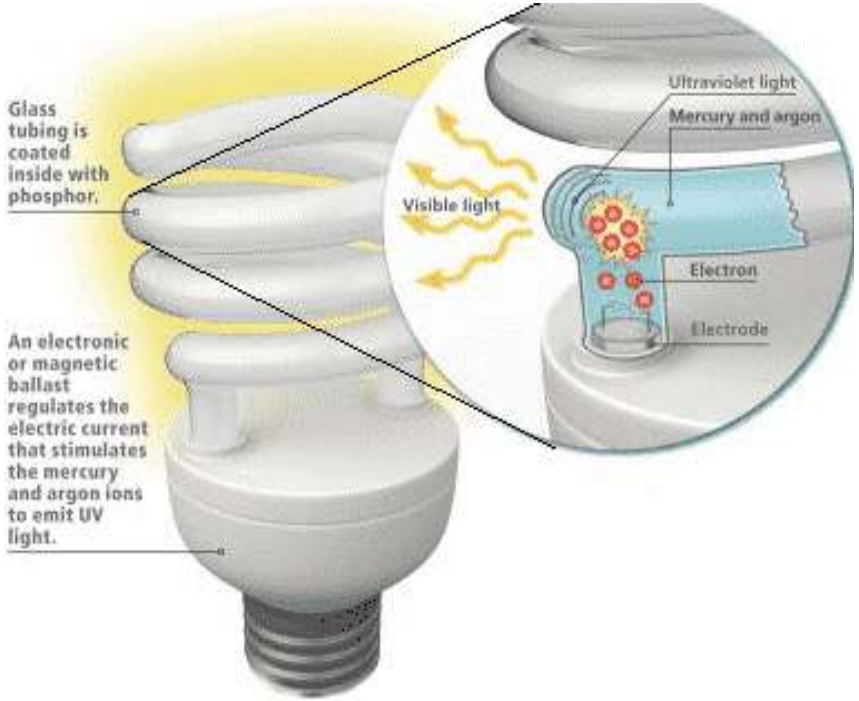
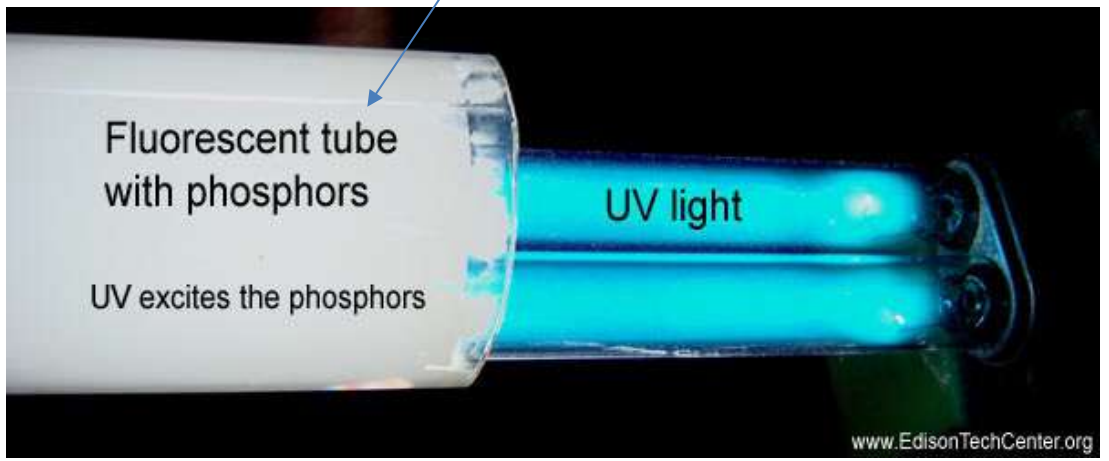
Fluorescent Lighting



Mixture of red, green, and blue emitting phosphors



https://electricalfundablog.com/cfl-works-circuit-explanation-advantages/

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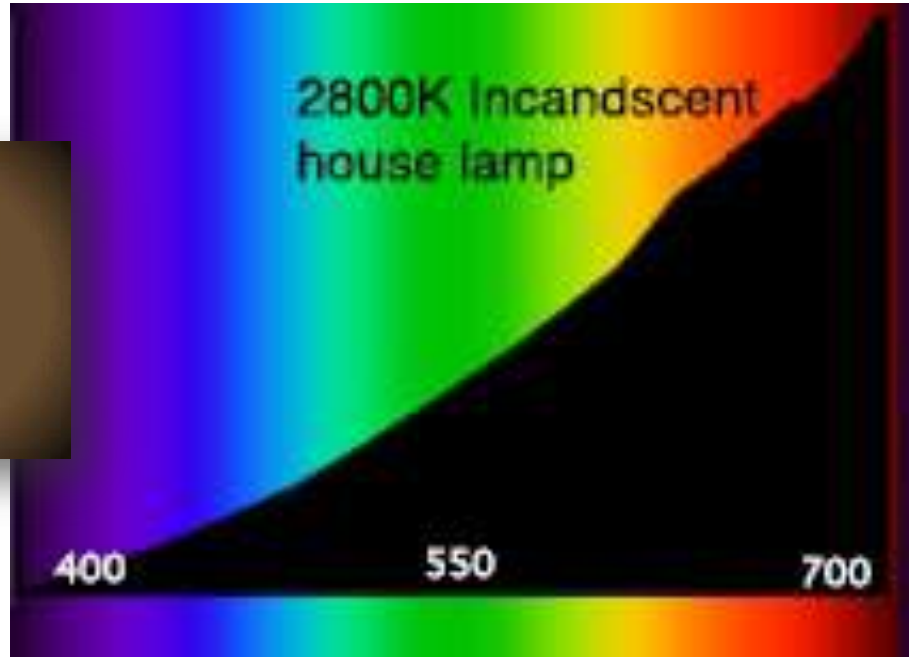
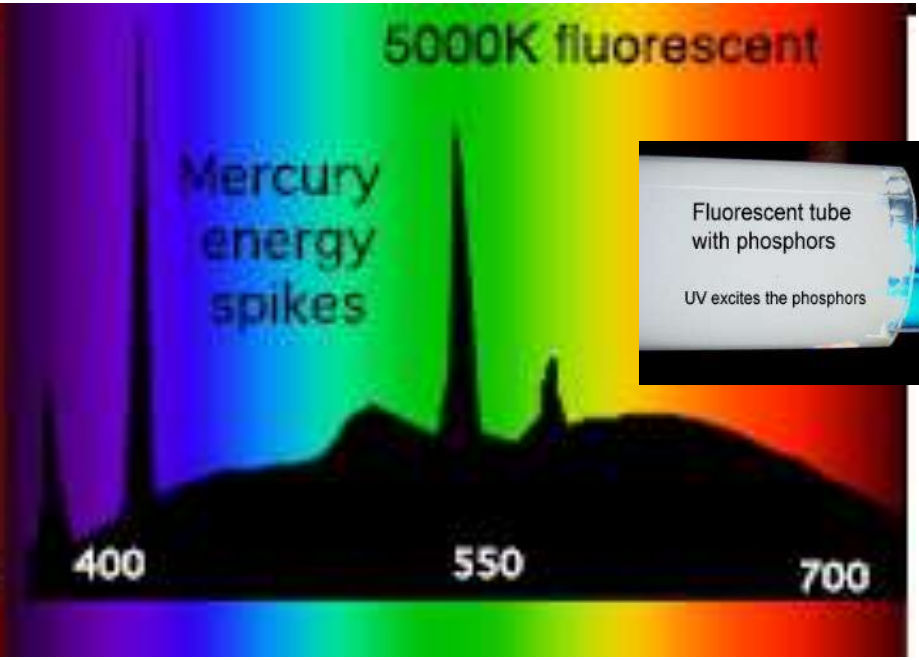
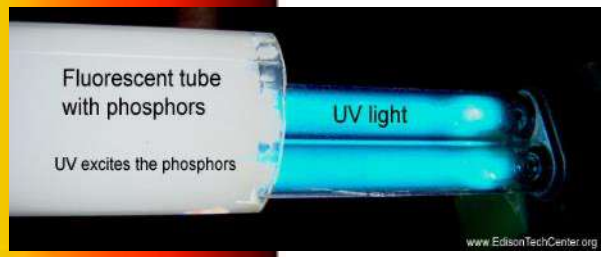
Spectral Distribution of Incandescent and Fluorescent Bulbs







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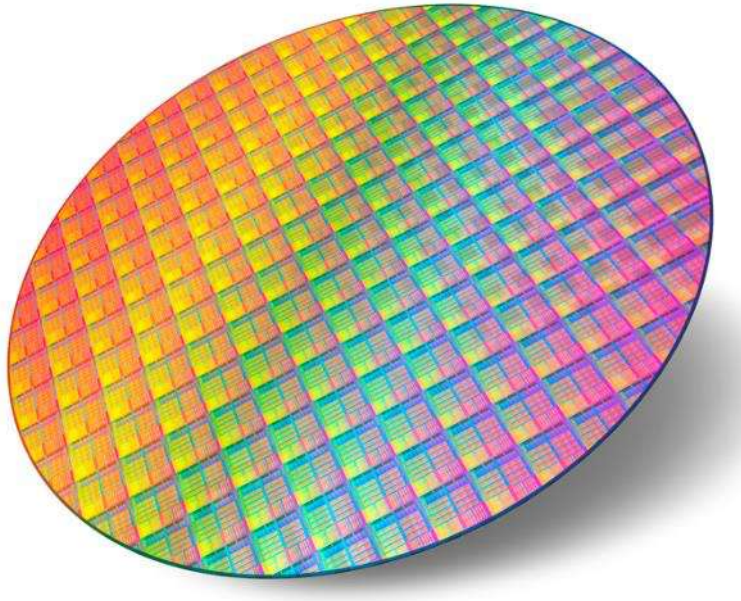
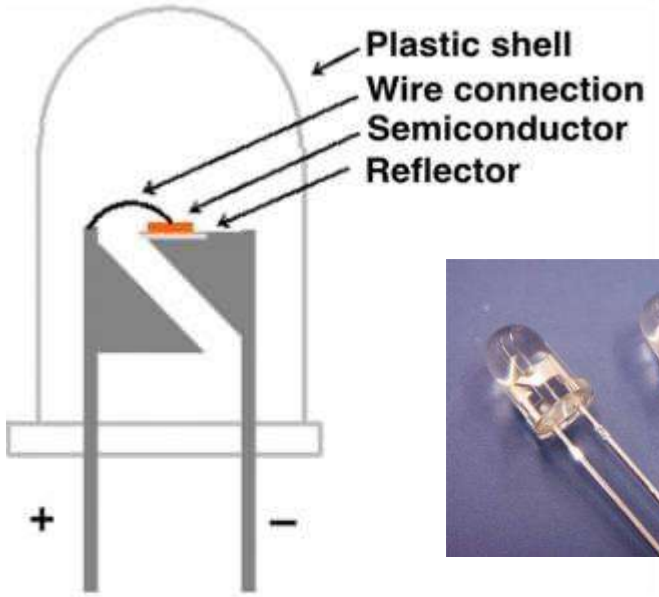
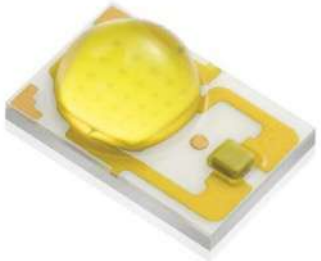
The Next Generation: LED Solid State Lighting

Indium-Gallium-Nitride on sapphire/GaN wafer





Packaged LED chips
(~ 5 x 5 mm)



LED light

Solid state lighting = No gasses or vacuum used

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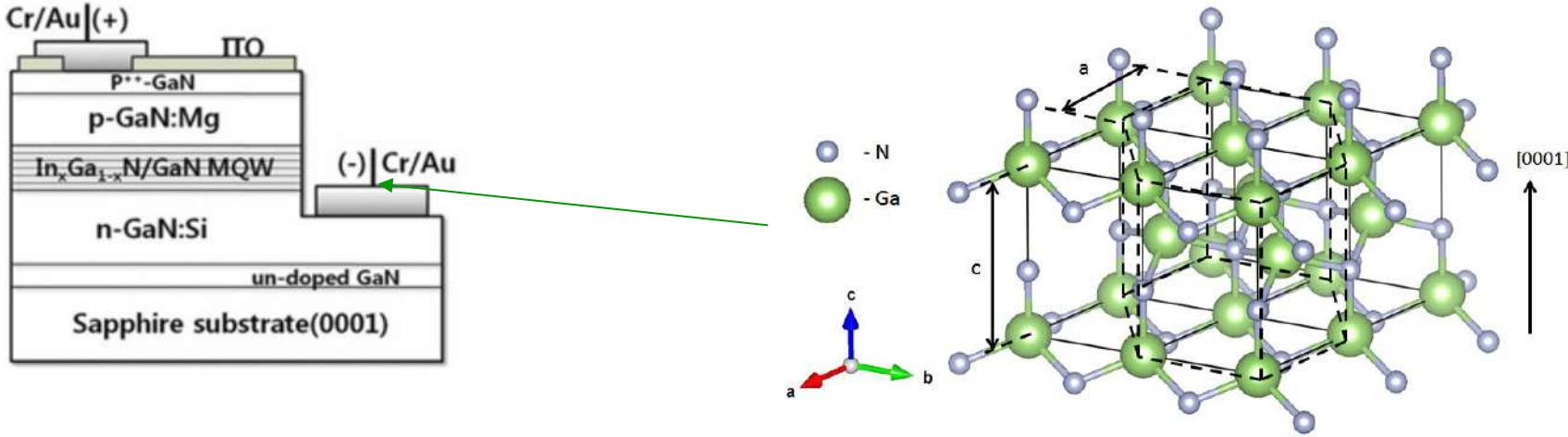
Inorganic LED Device Structure and Materials



Materials in inorganic LEDs (e.g. InGaN) are **crystalline** and must have a low level of defects to emit efficiently.

Area of low defects for emission is small (< 1 mm x 1 mm)

http://www.semiconductor-today.com/news_items/2011/MAY/CNU_300511.html

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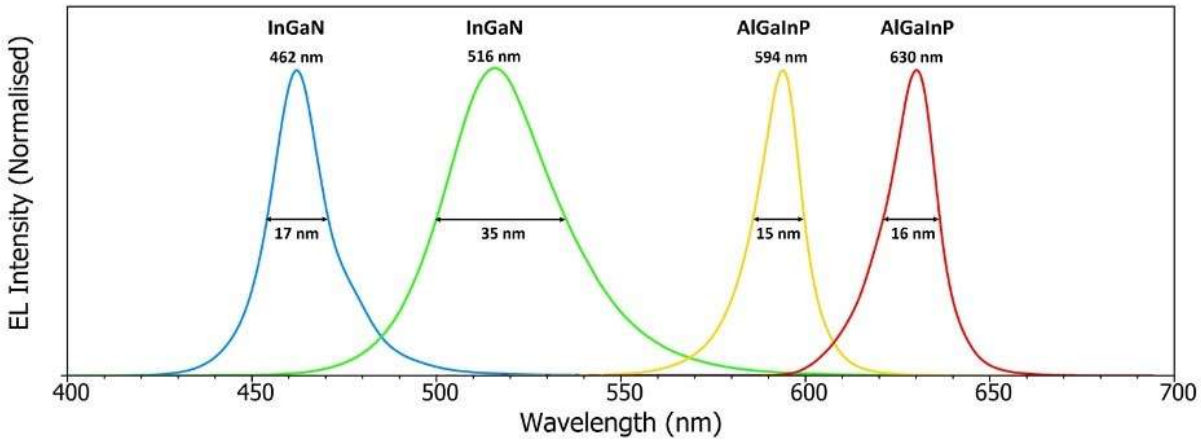
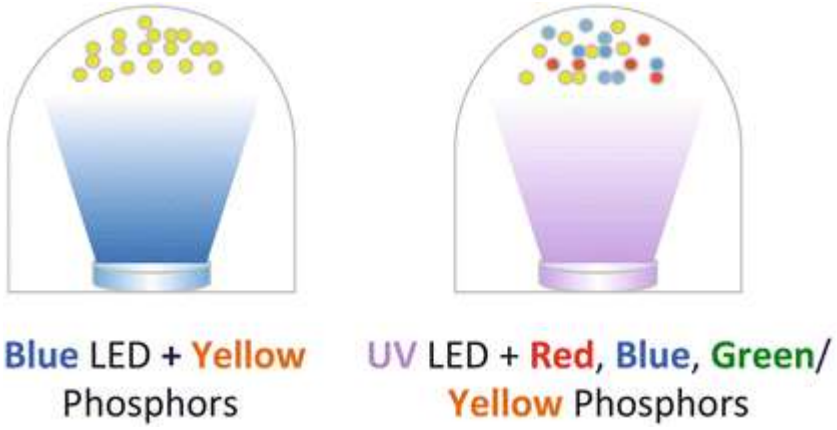
Inorganic LED Emission Spectra & White Light



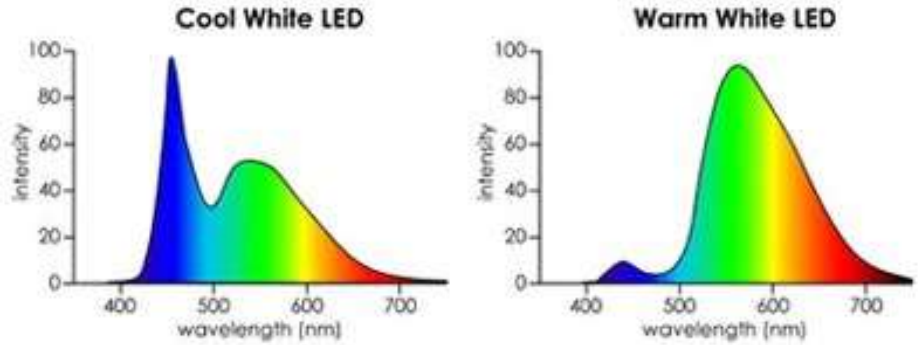


Blue LED + Yellow Phosphors

UV LED + Red, Blue, Green/ Yellow Phosphors

The **white light LED** is achieved through

- Direct blue/UV emission (~ 450 nm) plus
- Excitation of yellow or red + green phosphors coated on the optics.



http://www.lightingschool.eu/portfolio/understanding-the-light

Inorganic LED Assemblies



- Larger emission areas require arrays of many LEDs
- LED arrays have hot spots, often requiring a thermal sink
  - Increases the fixture thickness and complexity.
  - Increases environmental impact in manufacturing and disposal at end-of-life.

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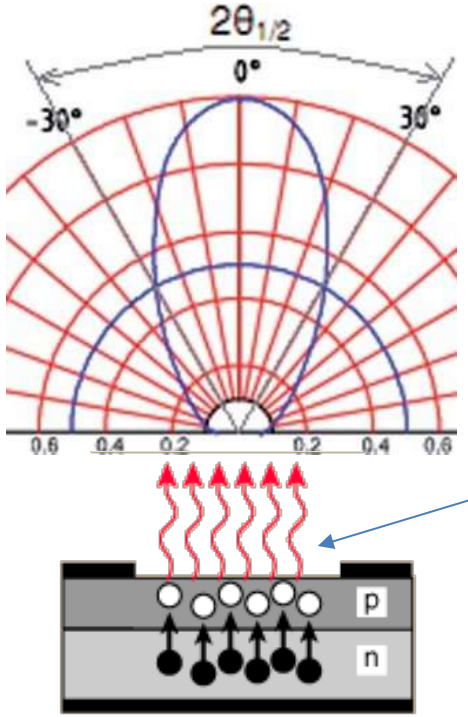
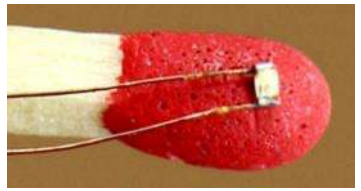
Inorganic LED Light Output



Highly directional light output

- Excellent for directed light beams
- Requires optics to create softer lighting

Small emission area
~ 2mm x 2 mm



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The Future Is Now…
Organic Light Emitting Diode (OLED)

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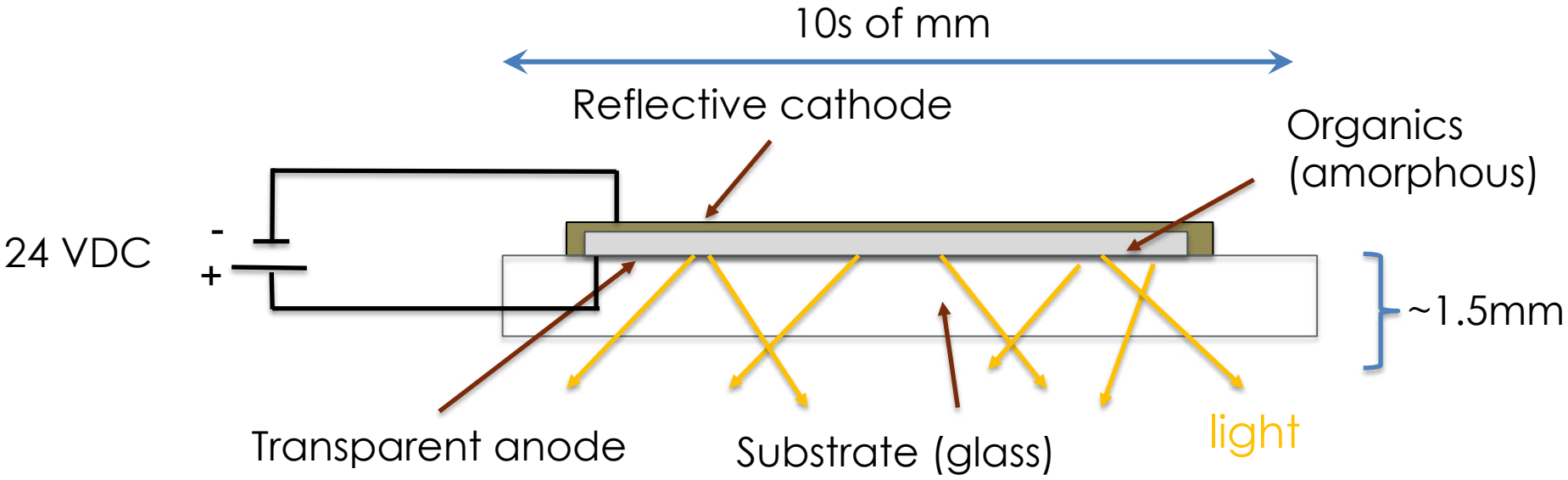
Organic Light Emitting Diode (OLED) Structure



A large area diode – NOT lots of little diodes!

Most of this is the glass substrate → environmentally friendly

The organic layer is the thickness of a human hair.

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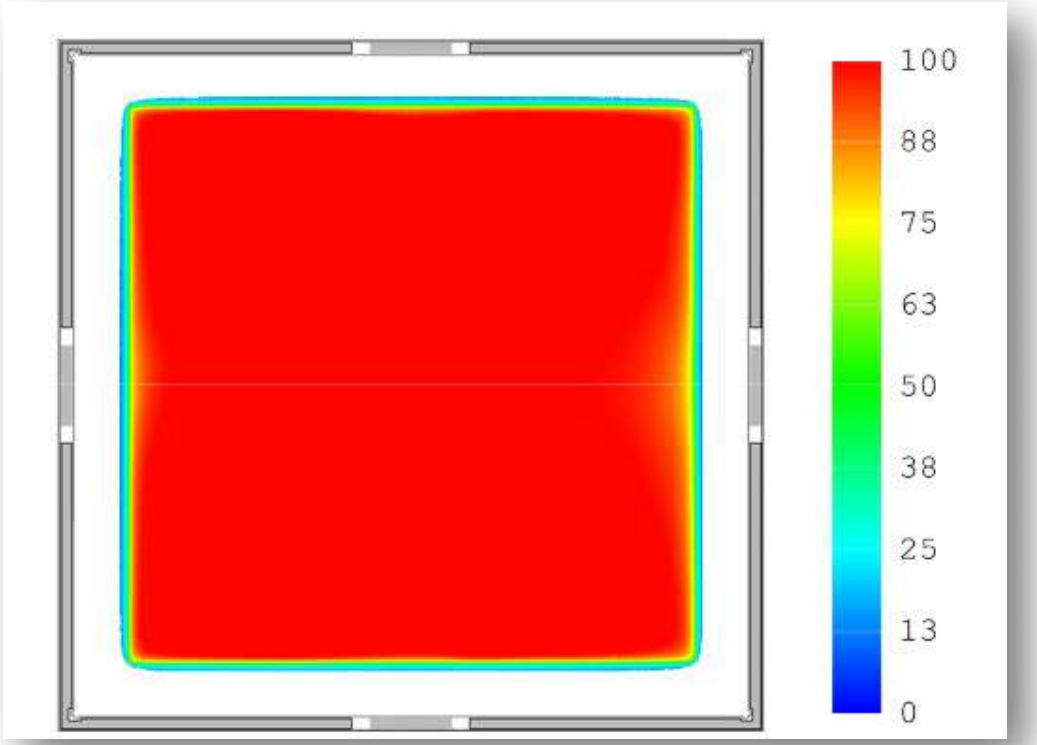
OLED: A Surface Emitter



- Diffuse emission low in glare and contrast → reduced eye fatigue
- Panels are cool to the touch during operation

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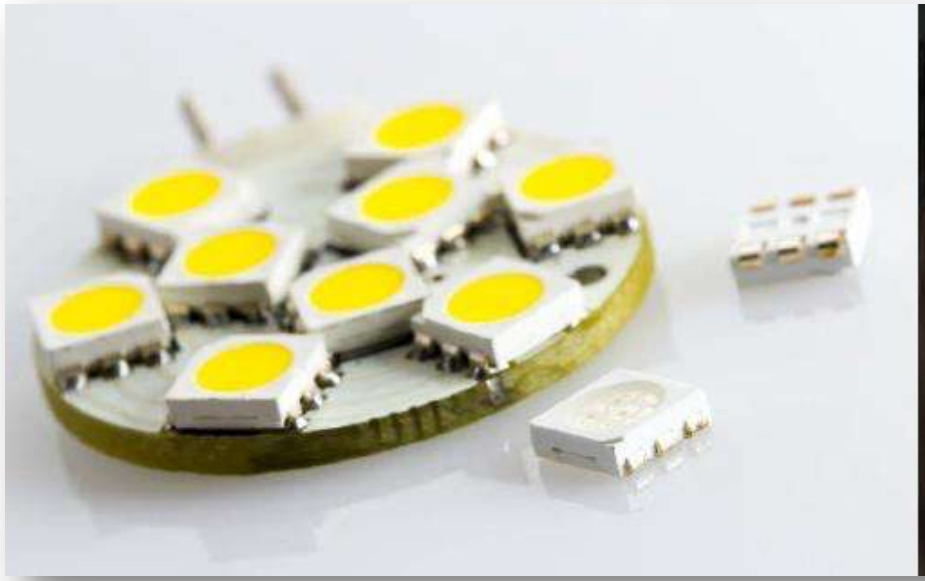
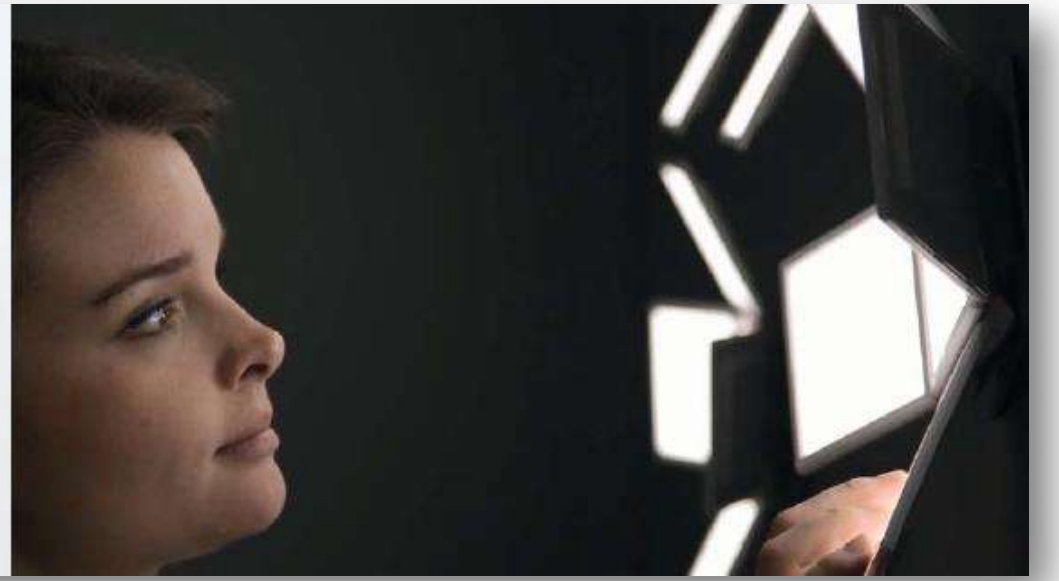
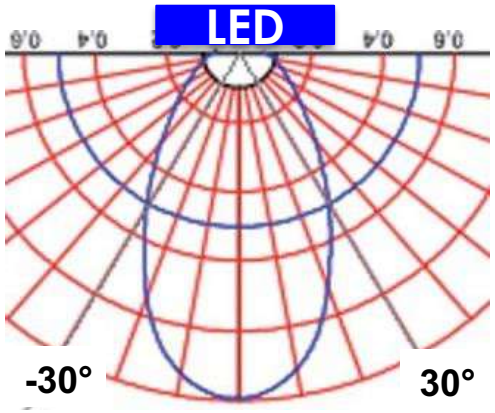
Light Output: LED vs OLED

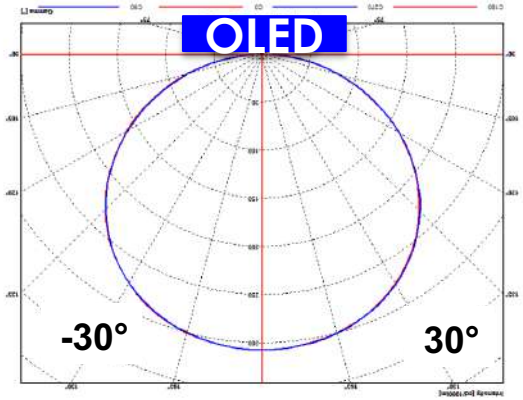






LED

OLED



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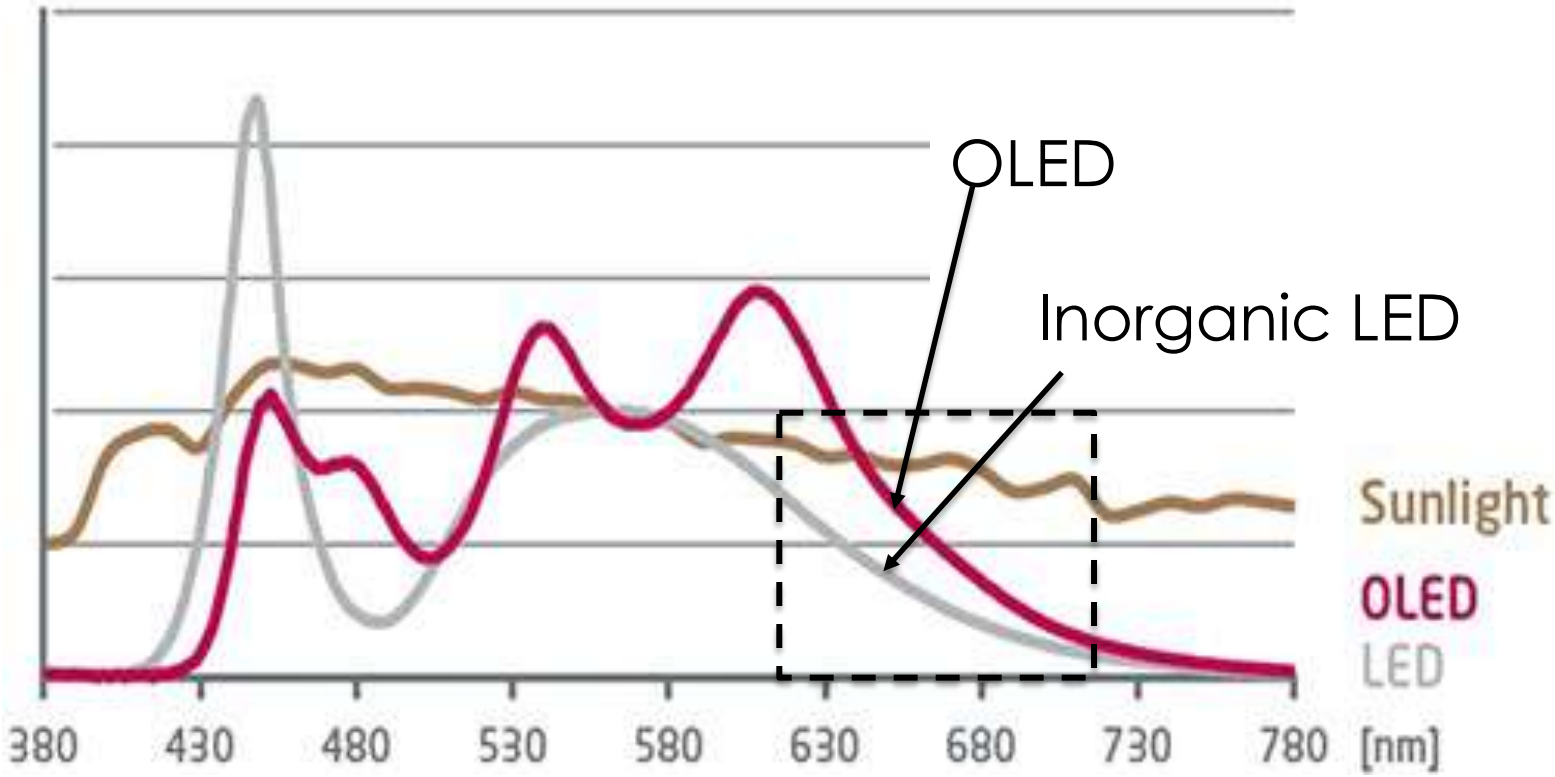
Light Spectra: LED vs OLED



White light with CRI > 90, R9 > 50 with OLED lighting

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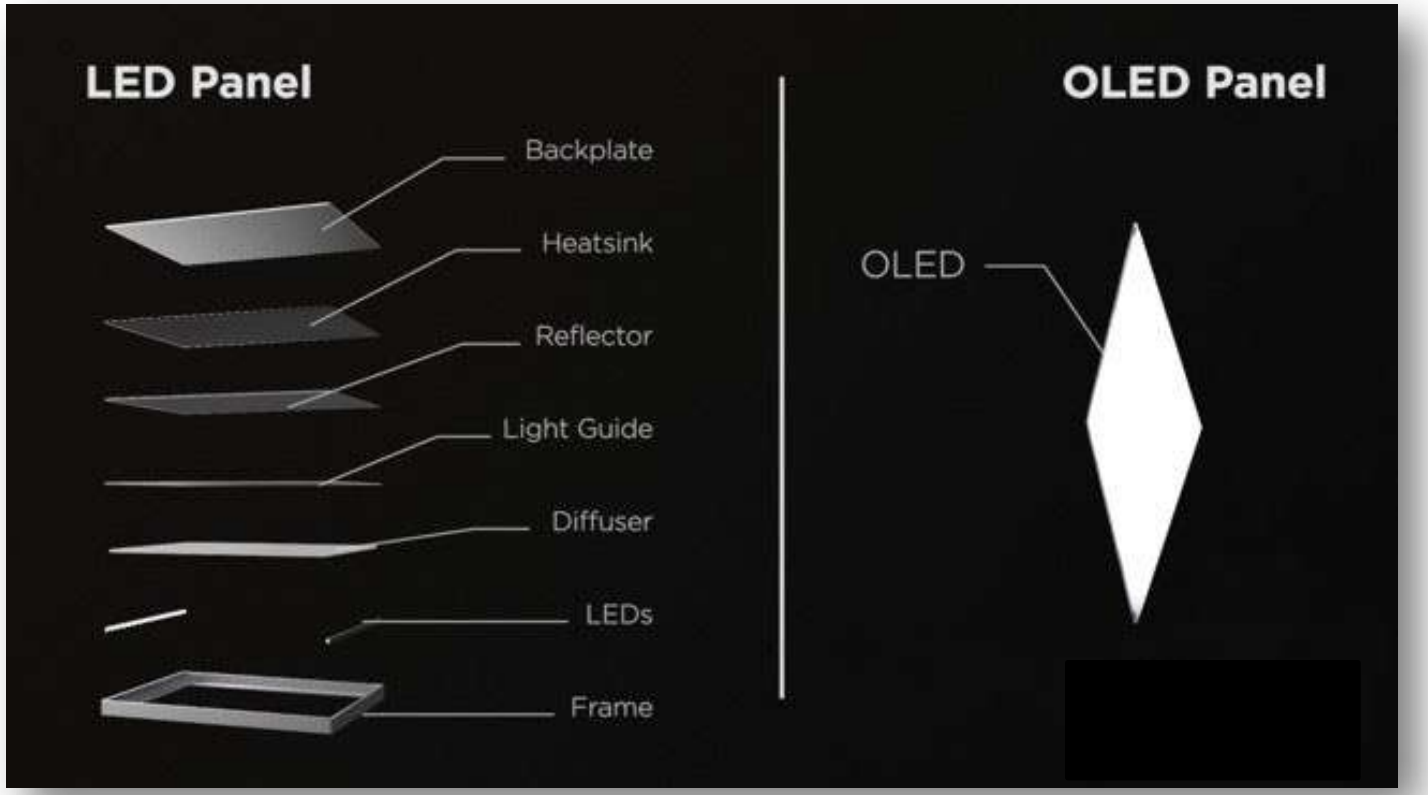
Fixture Comparison: LED vs OLED



OLED lighting **does not have local hot spots** → no heat sink

- Simpler, fixture with fewer parts
- Lighter, thinner overall design

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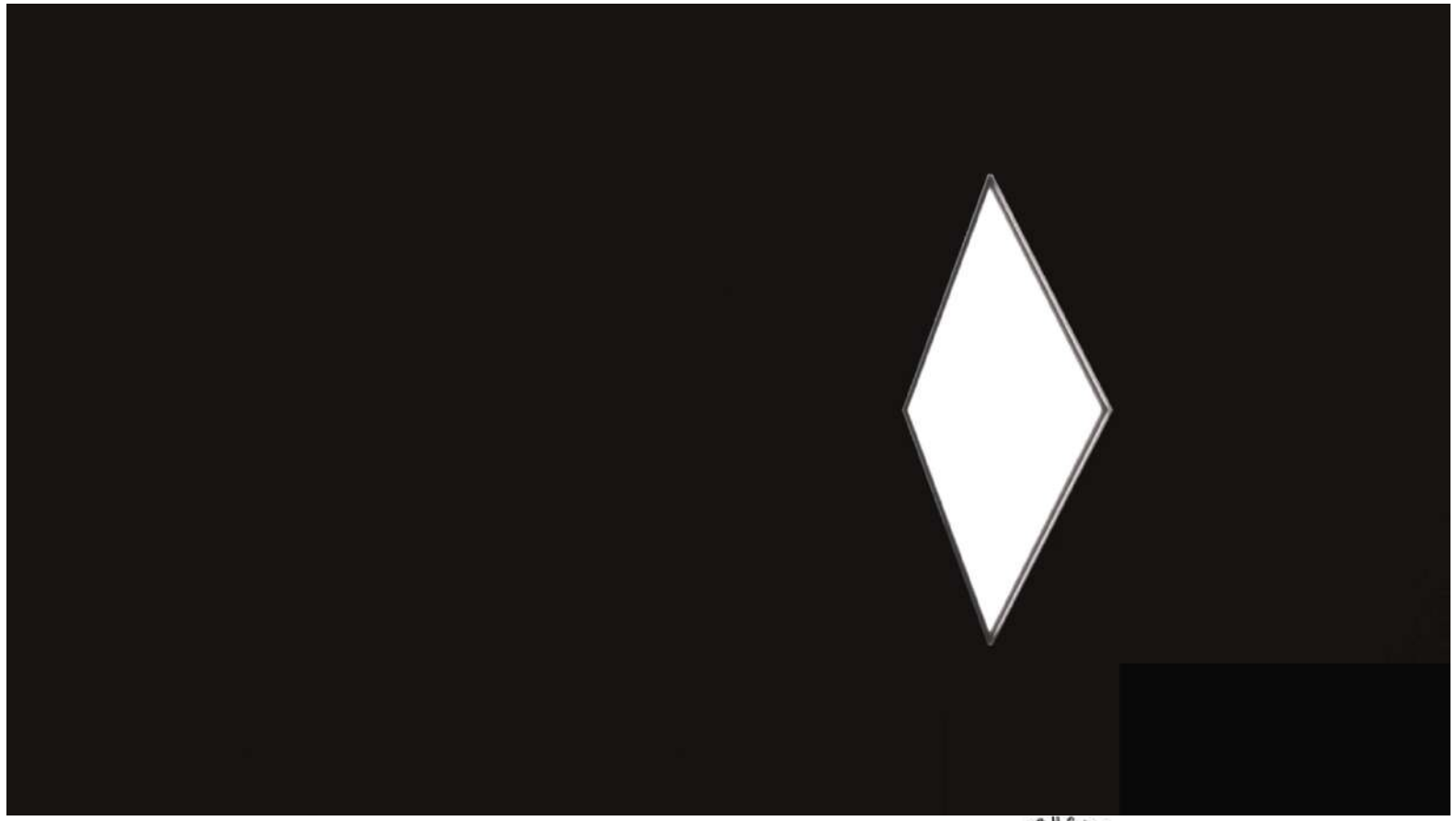
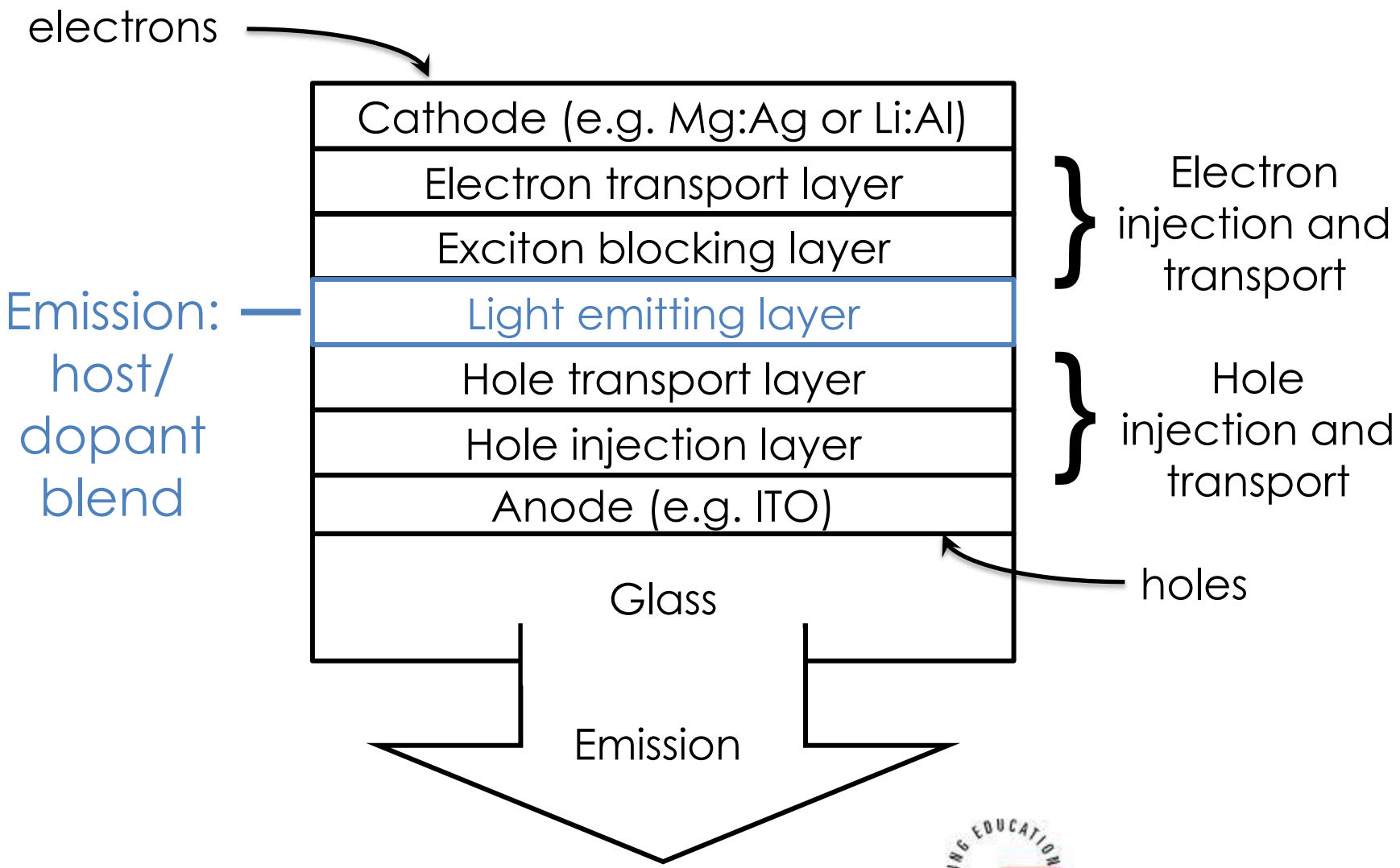
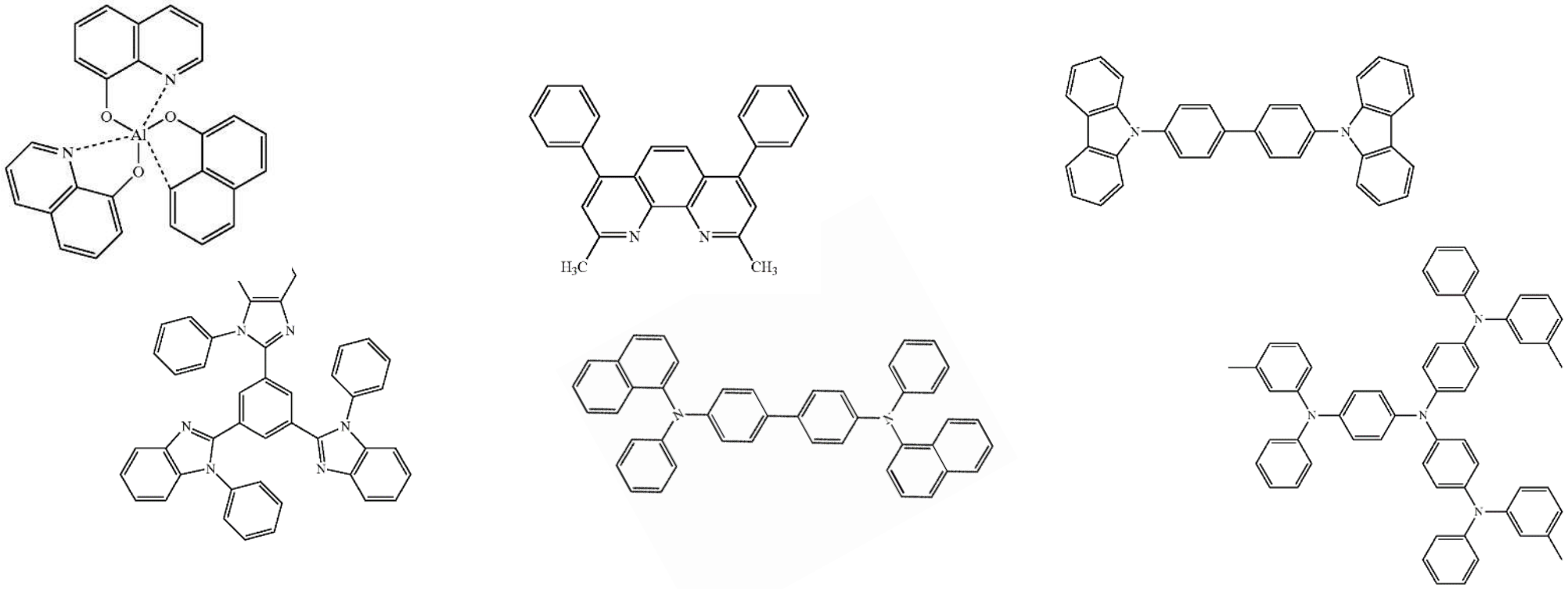
How OLED Lighting Panels are Made



OLED Structure

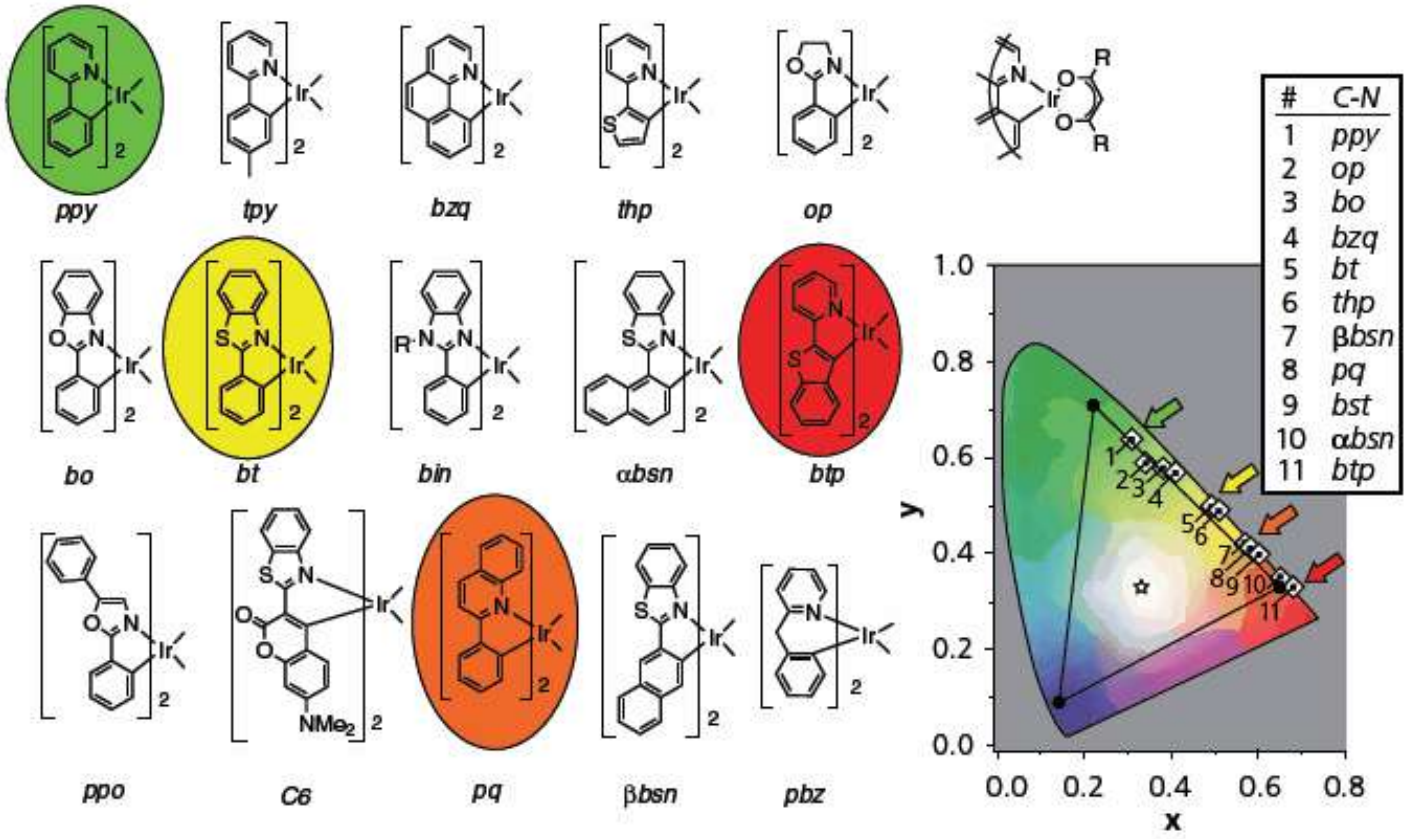


OLED Materials: Transport and Hosts



- These materials are **amorphous** → can be coated over large areas.
- Panel size is not limited by the organic material.

OLED Materials: Dopants



OLED dopants provide wide color gamut and saturated colors

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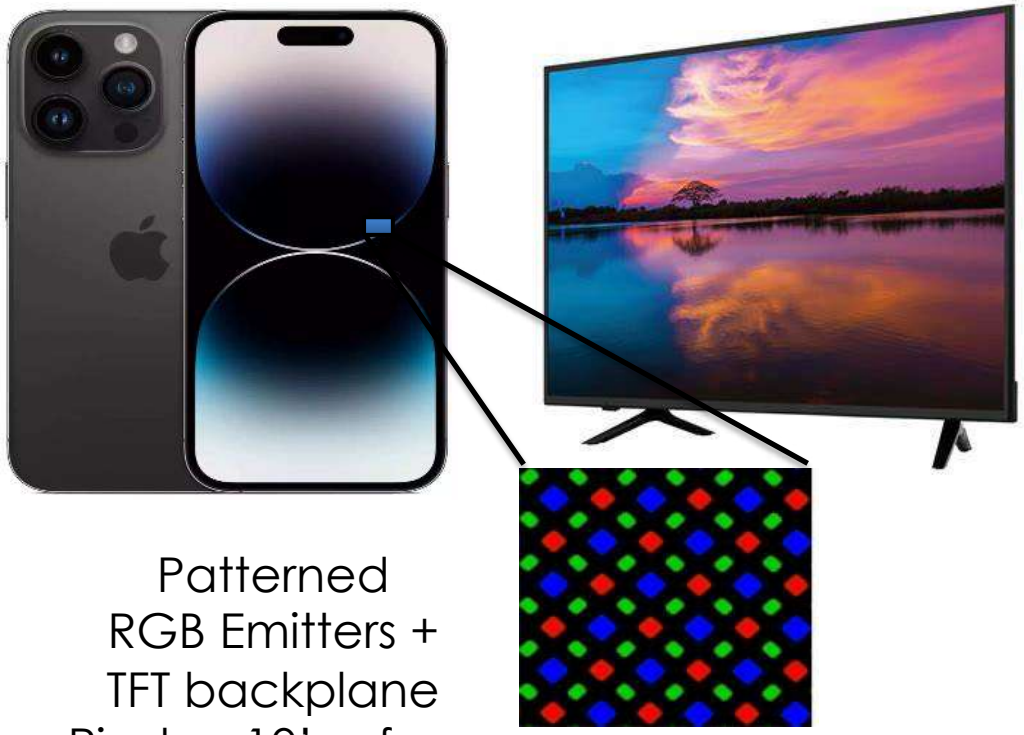
OLED Display vs OLED Lighting

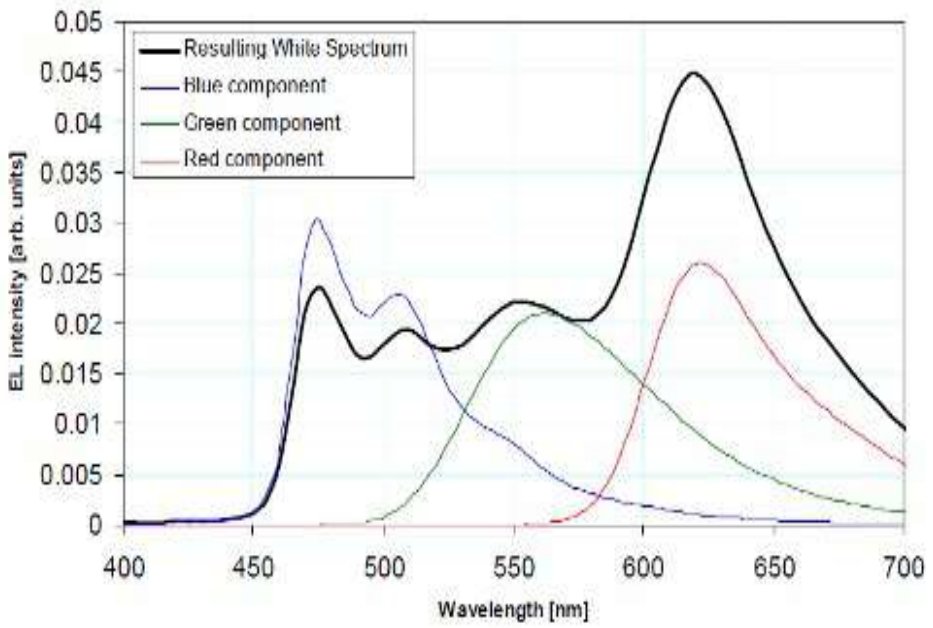
OLED Displays – Phones and TVs



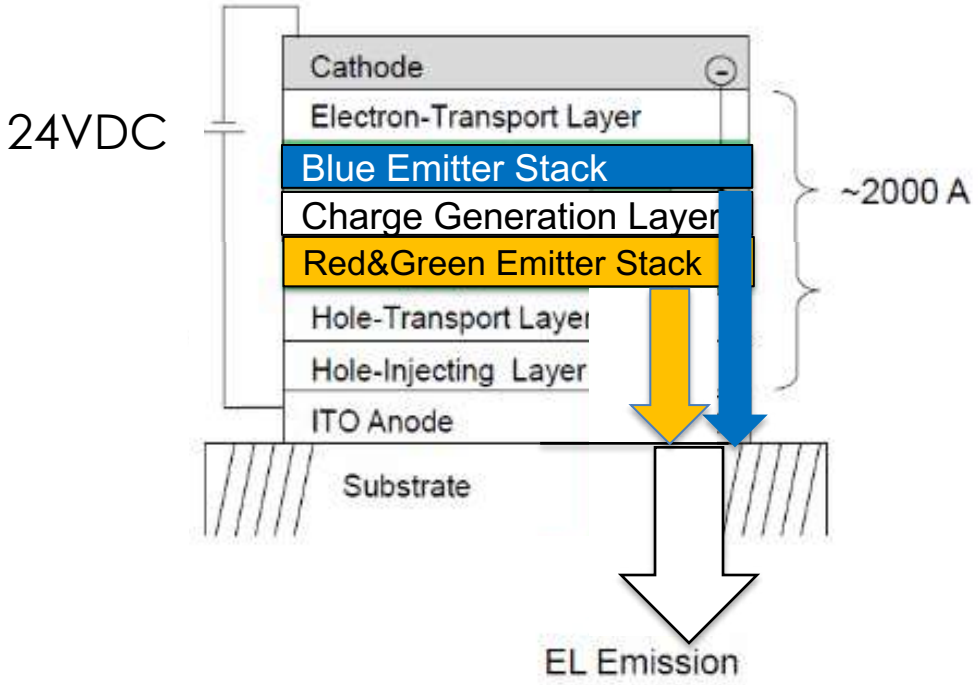
Patterned
RGB Emitters +
TFT backplane
Pixels ~ 10's of μm

OLED Lighting
Broad Area Coverage
Simpler electronics

OLED Lighting: White Light

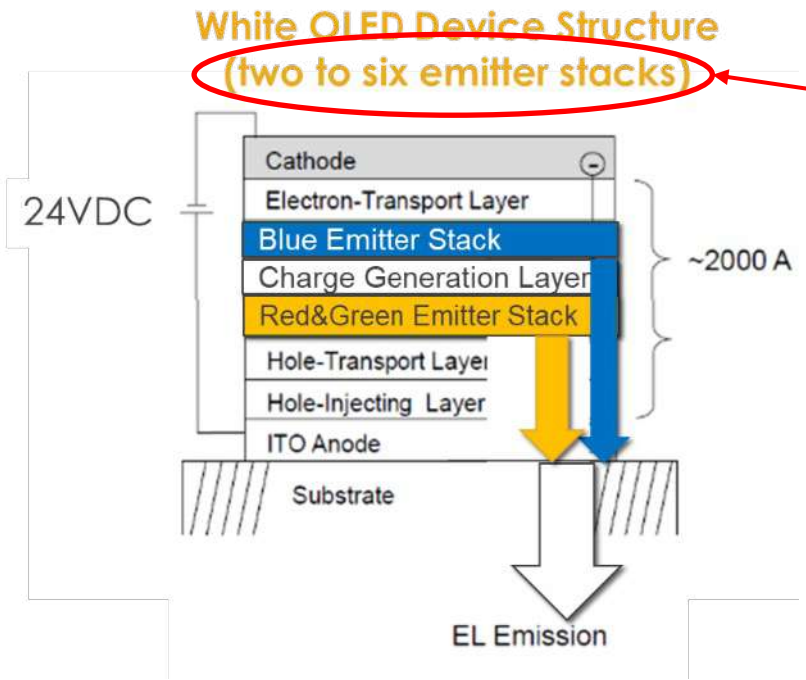


White OLED Device Structure (two to six emitter stacks)



The organic molecules in OLEDs are broadband emitters excited directly with electricity

Multi-Stack OLED

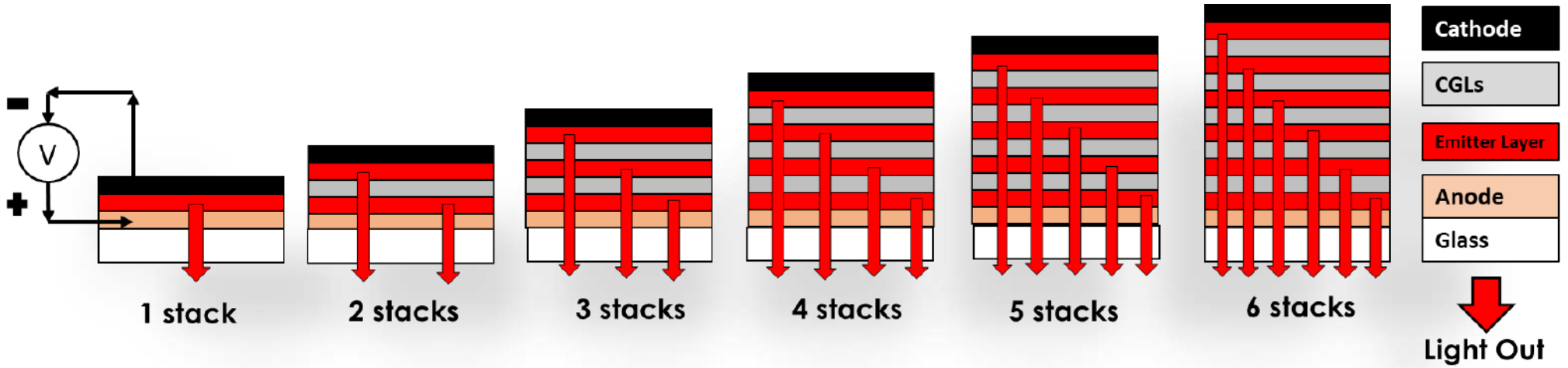


The last slide mentioned "two to six emitter stacks" in describing White OLED devices

This architecture is called a **Multi-Stack OLED**

What does this mean and why is it important?

Multi-Stack OLED



Multi-Stack OLEDs take the Emitter Layers (EML) and separate them from each other with additional layers in-between called **Charge Generation Layers (CGL)**

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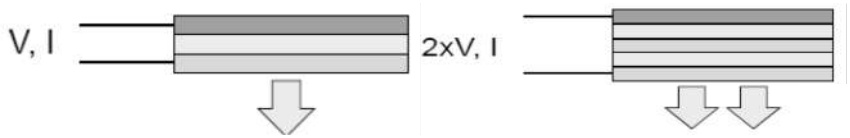
Multi-Stack OLED

What is the advantage of an OLED with a Multi-Stack architecture?

Multiple stacks benefit OLED by…

- Increasing lifetime and reliability by reducing current requirements in each layer for the same total output

Two emitter stacks used to produce same luminance as one.



Less current in each stack layer = greater reliability and lifetime!

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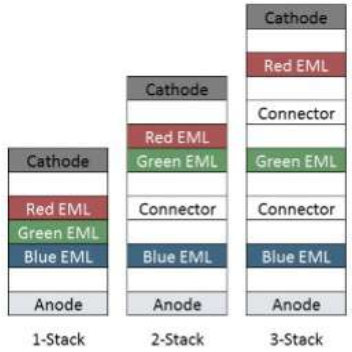
Multi-Stack OLED

What is the advantage of an OLED with a Multi-Stack architecture?

Multiple stacks benefit OLED by…

- Allowing flexibility in color adjustment



Generate targeted CCT instead of vague "warm" and "cool" by adjusting individual RGB EML properties

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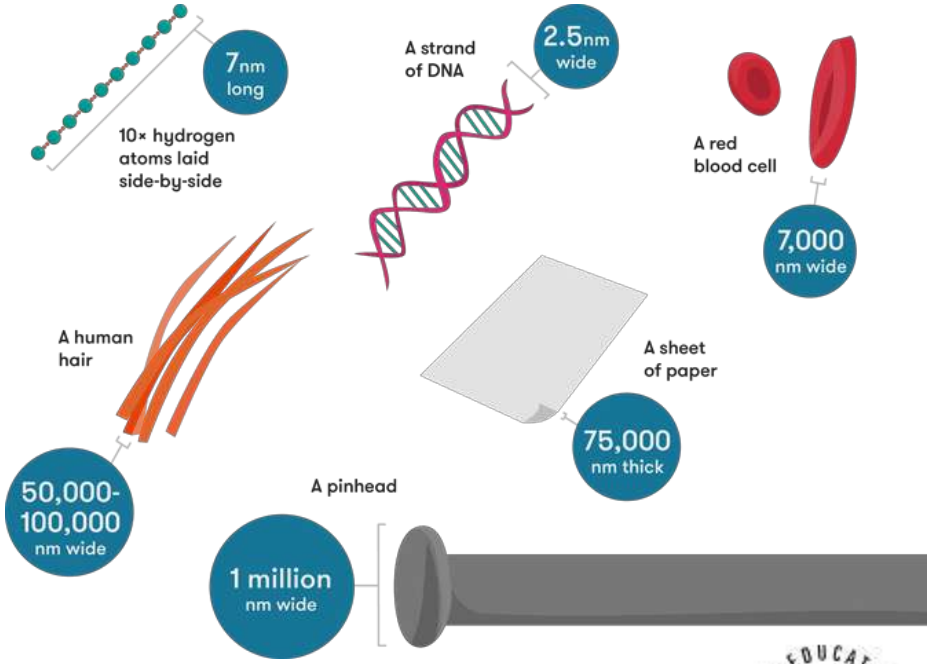
Multi-Stack OLED

Do multiple stacks affect device thickness?

No, since each layer can be measured in nanometers, the OLED panel retains its millimeter thinness



[How small is nanoscale small? - Curious (science.org.au)]

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Multi-Stack OLED

Is this a mature technology?

Yes!

OLEDs with 1 – 3 layers are used in the display industry

OLEDs with 2 layers are used in automotive applications

For lighting, OLEDs with up to 6 layers are commercialized

Additional layers are in R&D phase

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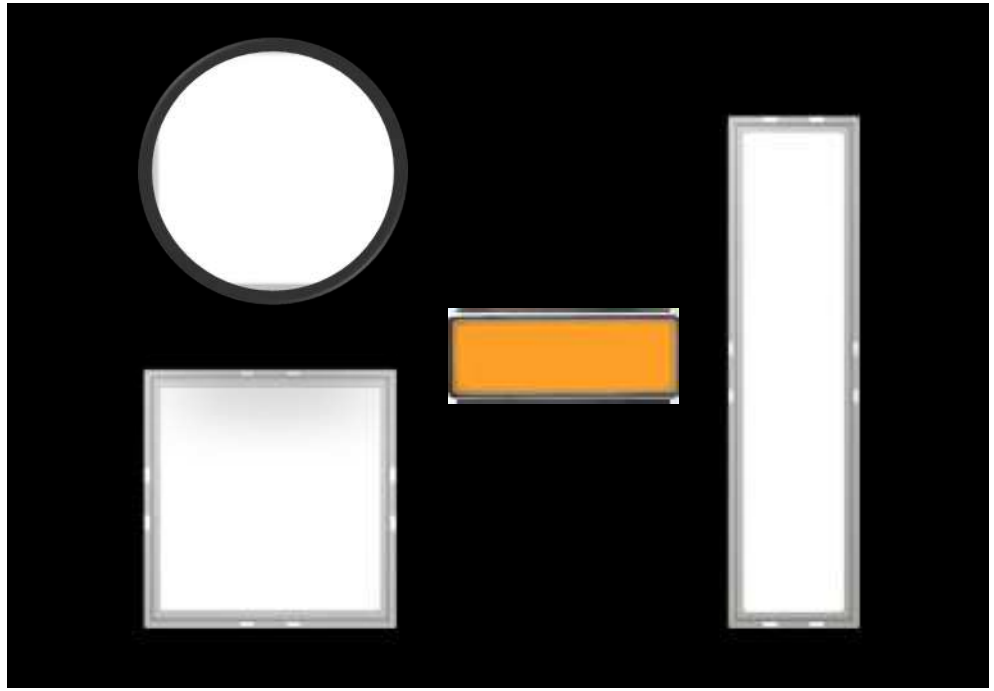
OLED Lighting Panels



Emitting area ranges from
94 mm dia, 102 x 102 mm,
46 x 222 mm

Features:

Brightest commercial OLED panel, up to 300 lumen, fully dimmable.

Available in warm (3000 K) and neutral (4000 K) white, as well as amber.

CRI > 90, R9 > 50.

Low thickness of 1.4 mm to 2.1 mm.

<u>Lifetimes and efficacies suitable for many applications</u>

- 30,000 hrs = 8hrs/day for 10 years
- 60 – 75 lm/W @ 300 lm

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OLED Lighting Panels: Electrical Integration

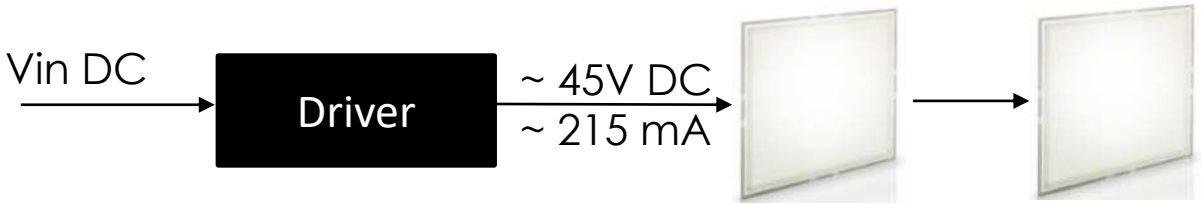
OLED panels use constant current drivers. Voltage and current depend on OLED stack.

- Example: 215mA @ 19 V DC (4 W). End-of-life: 22 V DC (4.7 W)

Can be powered from a lower DC voltage supply with use of a constant current boost driver.

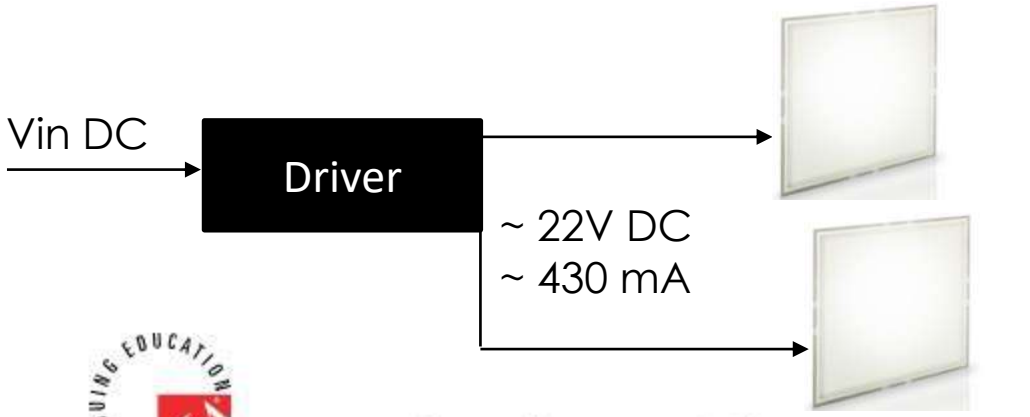
- 110 V AC operation requires an AC to DC power supply
- Multiple panels can be connected in series or parallel

Series



Parallel

multi-channel current driver recommended



Note Class 2 → < 60VDC, < 96 W, < 8 A, Class 1 > 60VDC

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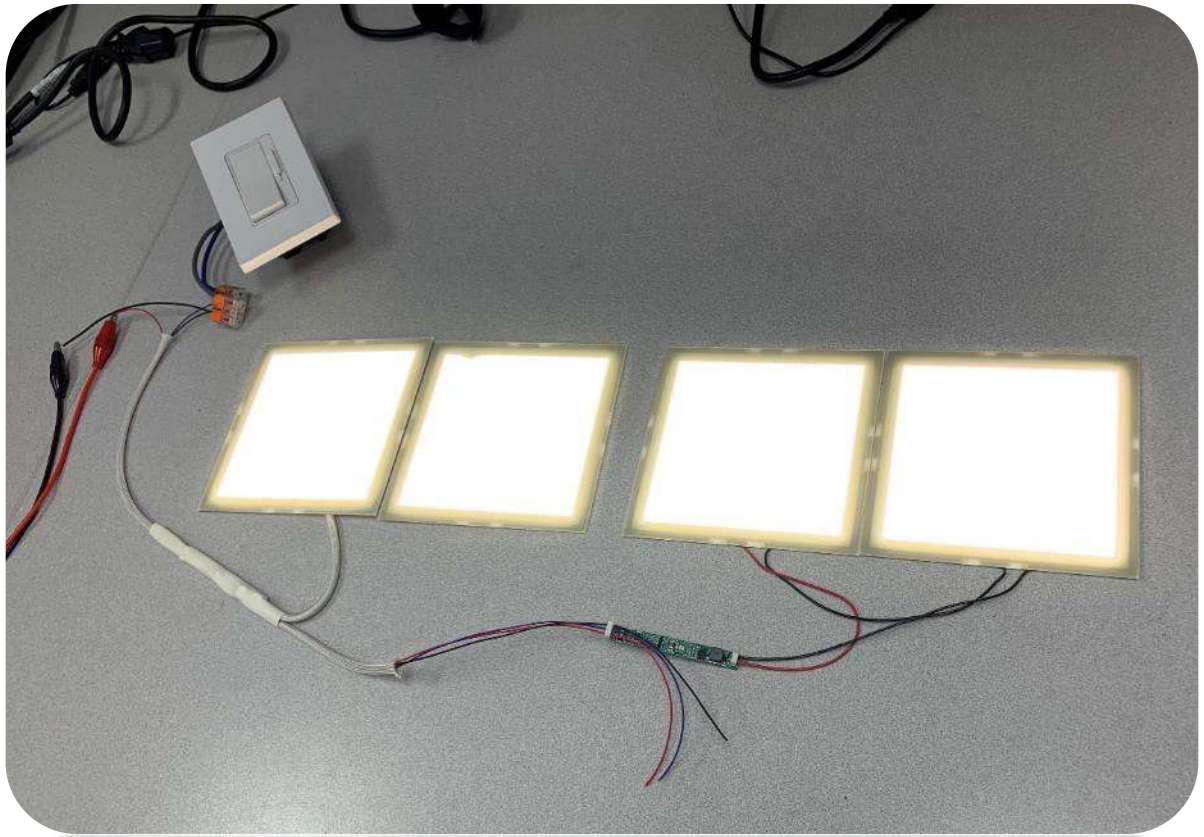
OLED Lighting Panels: Electrical Integration



24 V operation
0 – 10 V dimmable

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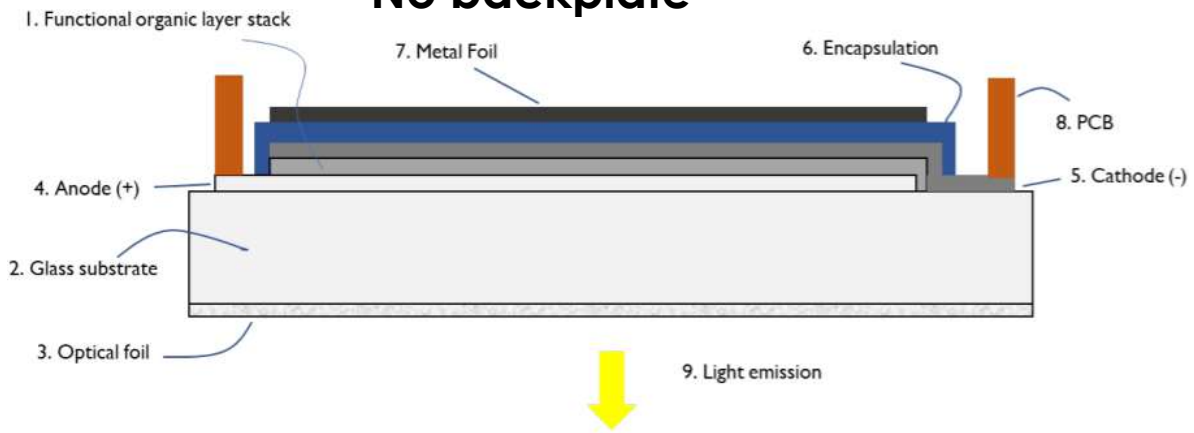
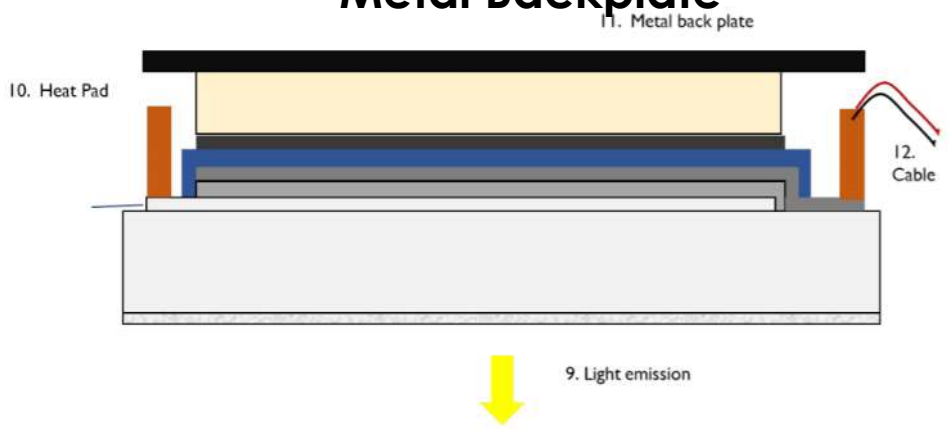
OLED Lighting Panels: Physical Integration

No backplate



Metal Backplate



- Panels are designed to be mechanically fixed into housing units.
- Panels can be attached to surfaces with glue or adhesive tape.
  - Solvent-free, electrically insulating, low temperature cure adhesives are suitable.
  - Formation of bubbles, point loads or other local forces should be avoided.
- If a backer plate is used screws can be used when mounting to a flat surface.

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OLED Lighting: Embedded Applications

Light everywhere

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What is an Embedded Application?

Anywhere light is required but traditional lighting is insufficient

Built-into walls, ceilings, or furniture

Lighting for transportation

Lit wayfinding, branding, or signage

Industrial use

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Embedded Lighting: Architectural

- Custom kitchen downlight installation
- OLED panels integrated into wooden ceiling element
- Low clearance and minimal space available
- OLED panel thinness and low heat output made integration simple

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Embedded Lighting: Architectural

- Custom undercabinet lighting
- OLED panels integrated into wooden cabinets
- Low clearance and minimal space available
- Lambertian emission prevents dark spots and brightens tight spaces

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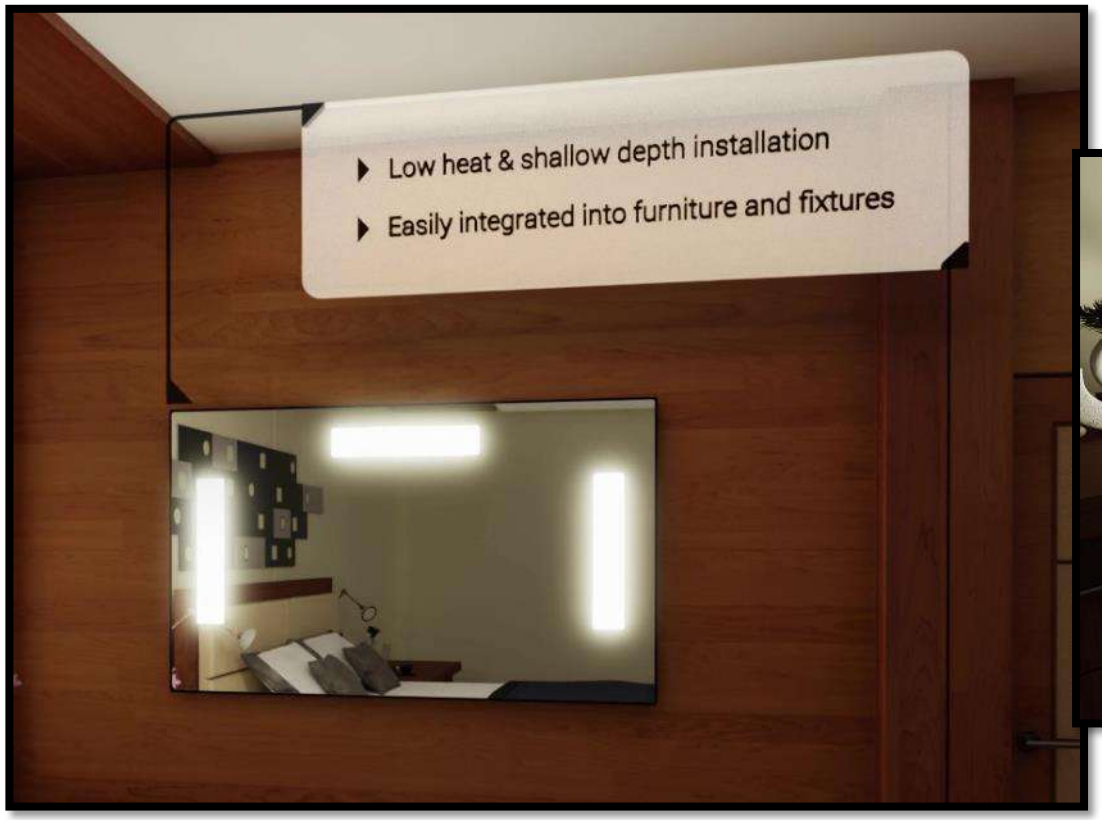
Embedded Lighting: Architectural

- Integrate lighting into mirrors and furniture
- Unobtrusive with minimal space required
- Ideal for small spaces such as boats and recreational vehicles
- OLEDs ideal for low clearance installations



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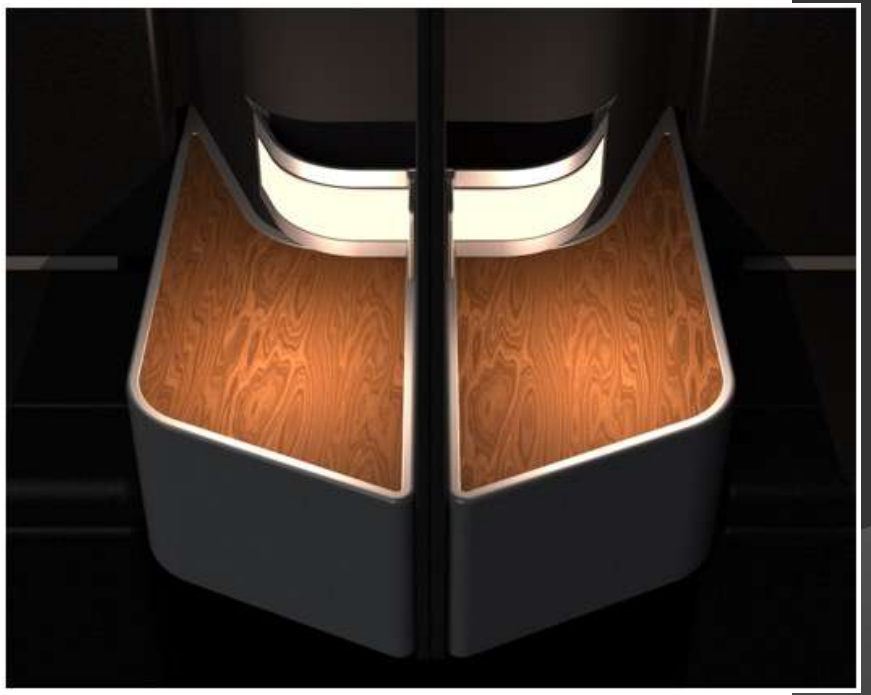
Embedded Lighting: Transportation

- Premium class aircraft cabin lighting concept
- Integrated with seat bulkhead and reading light
- Bendable OLED panels conform to shapes instead of vice-versa
- Lambertian emission is low glare, ideal for aircraft interiors



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Embedded Lighting: Transportation

- High-speed double-decker train concept
- Existing infrastructure limits height available
- OLED thinness allows for minimal bulkheads
- Lambertian light provides even lighting with no dark spots even with low ceilings

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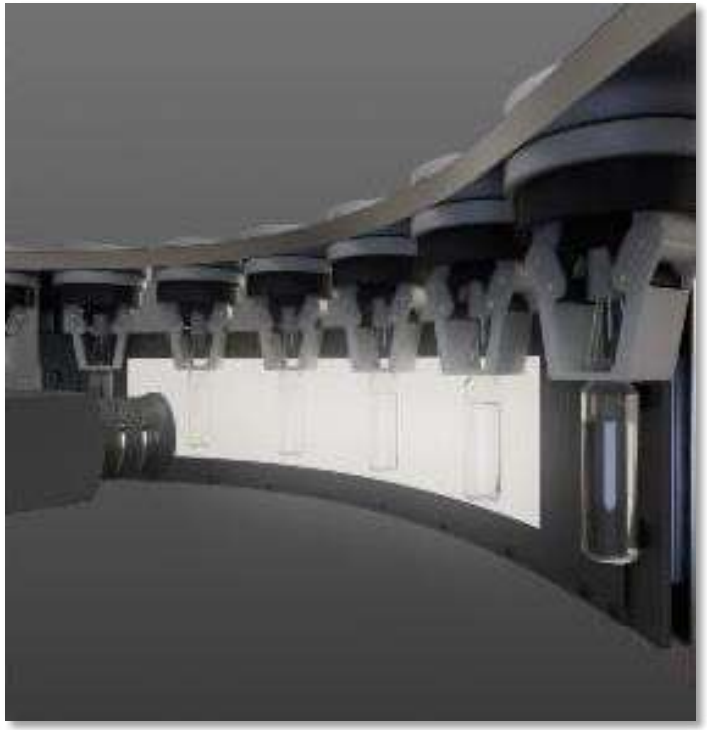
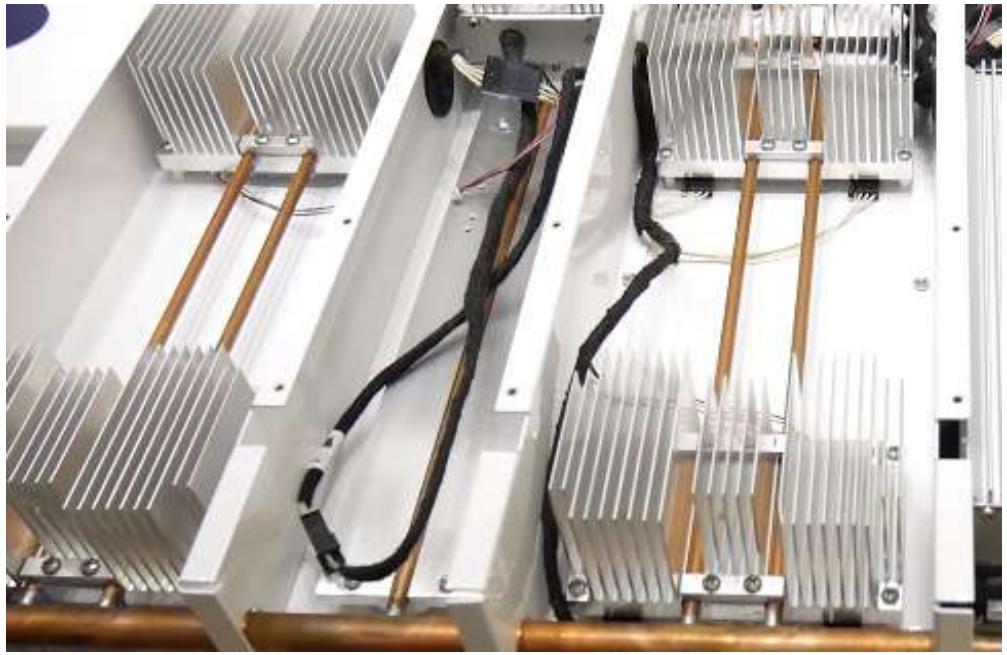
Embedded Lighting: Machine Vision



- Combination of large area, uniform and diffuse emission + thin profile + low heating offers a unique approach to lighting for machine vision inspection.
- Used in red and white light emitting colors

Embedded Lighting: Horticulture

Liquid Cooled LED Grow Light Heatsinks



Prototype OLED vFarm Setup

- Panel thickness is ideal for indoor and vertical farming
- No heatsinks or active cooling required
- Uniform light distribution for even lighting across all plants

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OLED Capabilities: Segmentation

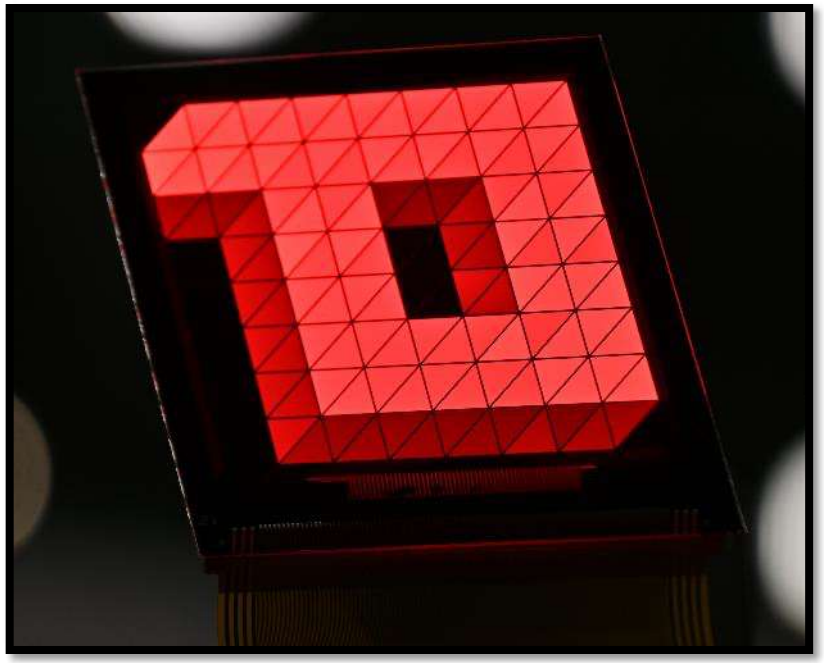
Dynamic display without the screen

OLED Capabilities: Segmentation

Regular OLED

- OLED layers deposited across entire substrate
- Electrically, acts as a single diode
- Originally brought to market as a luminaire source

OLED Capabilities: Segmentation



Segmented OLED

- OLED layers deposited across entire substrate as before but…
- …Now there is a mask to make the pattern
- Electrically, acts as multiple diodes (passive, not active matrix)
- Originally brought to market as an element for automotive taillights

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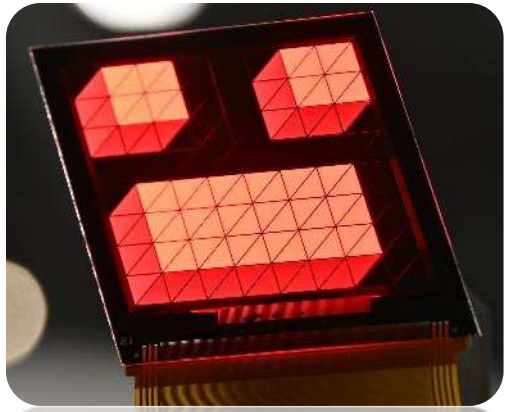
Segmentation & Embedded Applications

Segmentation can be incorporated into Embedded Applications

Branding

Wayfinding



Aesthetics

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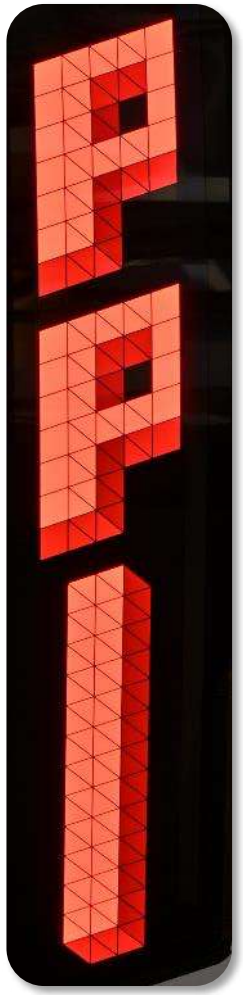
OLED Capabilities: Segmentation



- Can be installed like ordinary OLED lighting panels
- Provides highly uniform look with crisp separation of segments
- Individual segments or “pixels” dimmable to create “3D effect”
- Can be animated with Arduino

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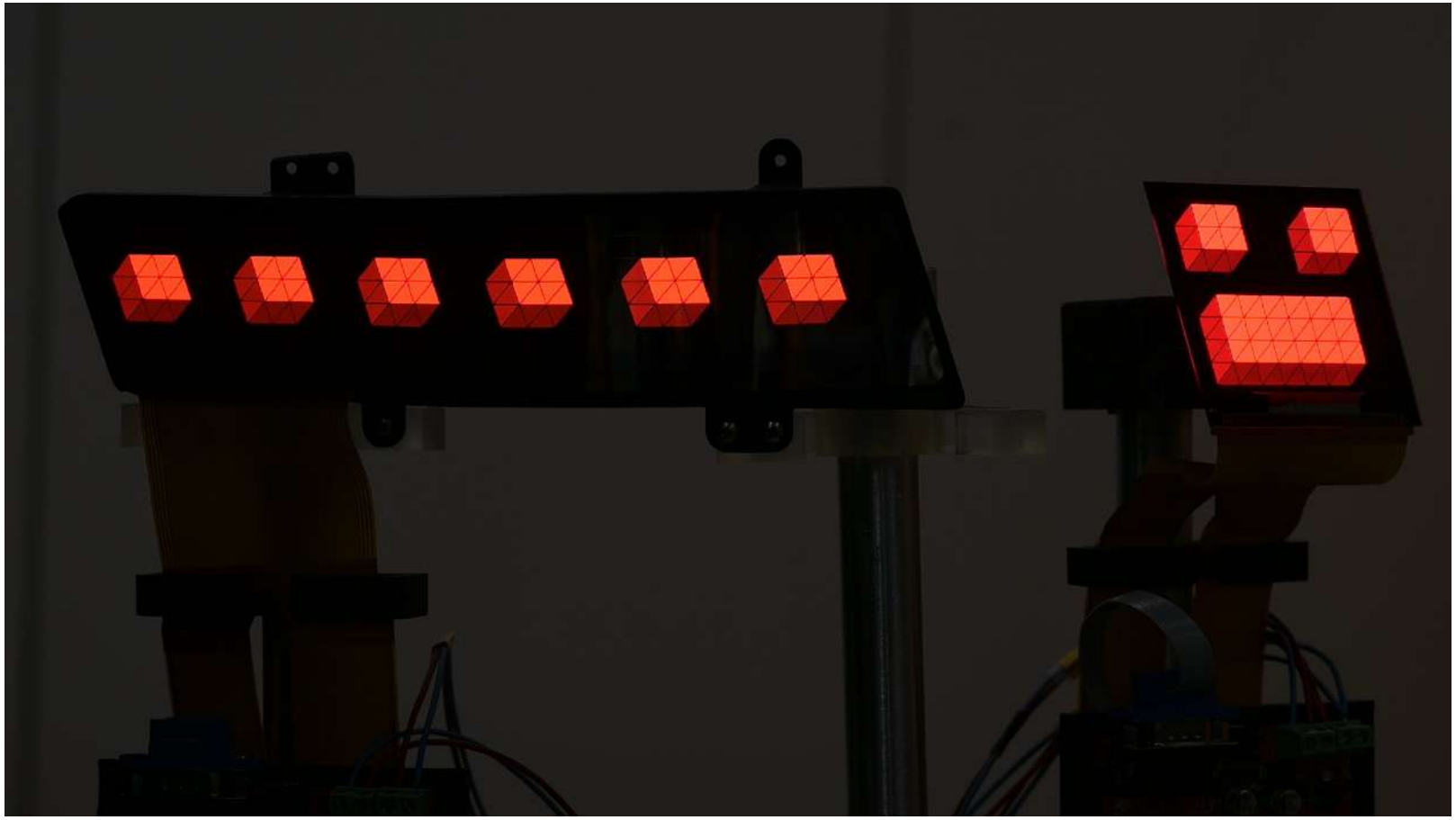
OLED Capabilities: Segmentation



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Conclusion

You can now:

- Understand OLED technology and how it can be used in embedded lighting applications.
- Recognize the differences between OLED lighting and other light sources.
- Understand segmented OLED lighting technology and its potential use cases.

And finally,

- Appreciate the unique design options available when using OLED as a building block for embedded lighting design projects.

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This concludes The American Institute of Architects
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