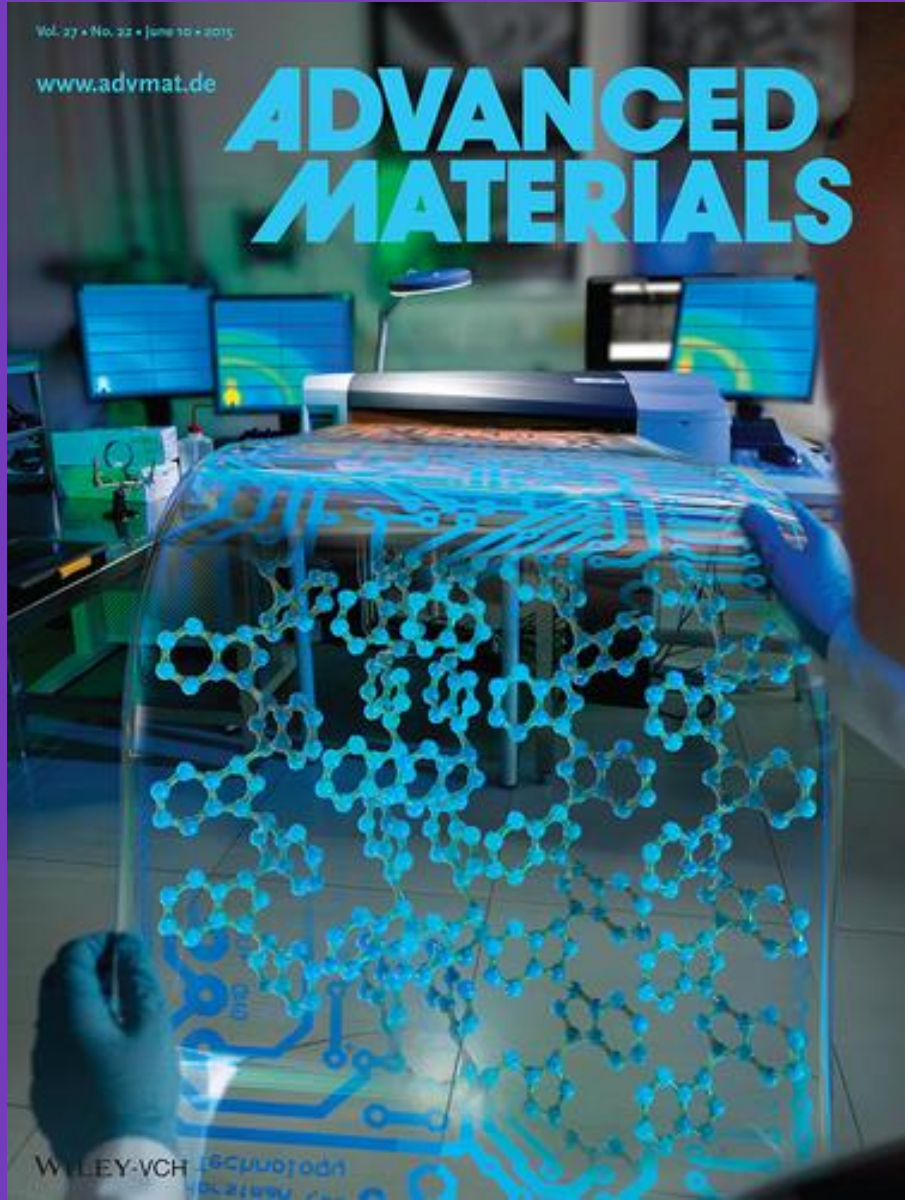
ELEC-E9210 Organic Electronics: Materials, Devices & Applications

Organic Light Emitting Diode II

Aalto University
School of Electrical
Engineering

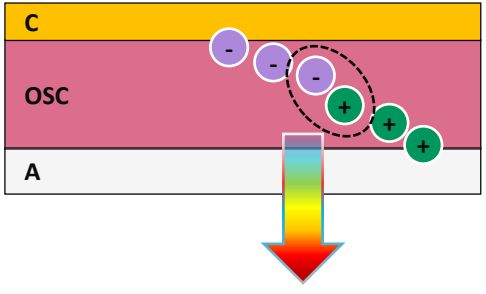
organicelectronics.aalto.fi

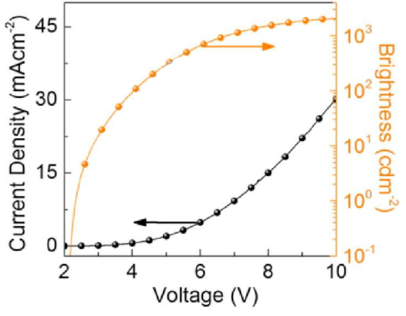


Today´s Class

Previously…

- **OLED working principles** and **materials**
  working principles, host-guest systems, materials





Today

- **Application(s)** of organic light emitting diodes

OLED Applications I: Organic Photodetectors

photo-conductors

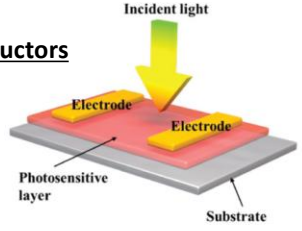


photo-diodes

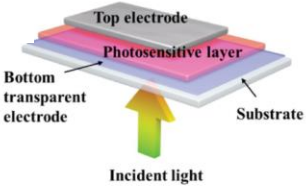
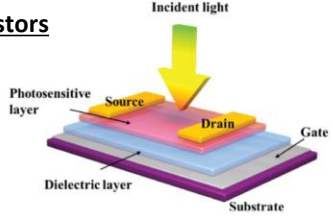
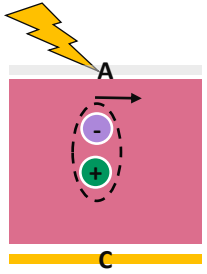


photo-transistors

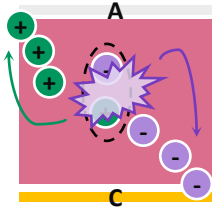


Organic molecules enable *lightweight*, *low-cost*, *large-scale* yields and *flexible* photodetectors applications

light absorption (at specific λ) → exciton formation → exciton diffusion → exciton dissociation → carrier collection & transport



light absorption & exciton dynamics



exciton dissociation & charge collection

8K Organic Image Sensors (Panasonic)

Camera employs an ***organic photoconductive film*** placed on top of CMOS assembly:

- ***large viewing angle***
- ***global shutter***
- ***variable ND filter***

https://news.panasonic.com/global/press/data/2018/02/en180214-2/en180214-2.html

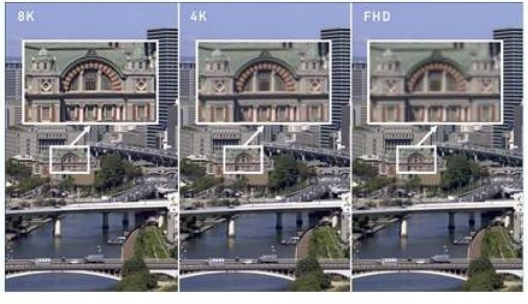
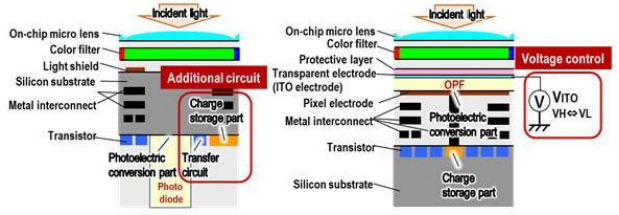


Fig2. 8K sensor High resolution imaging Distant city view (Comparison of resolutions)

Rolling shutter

Global shutter



Conventional Si image sensor OPF image sensor

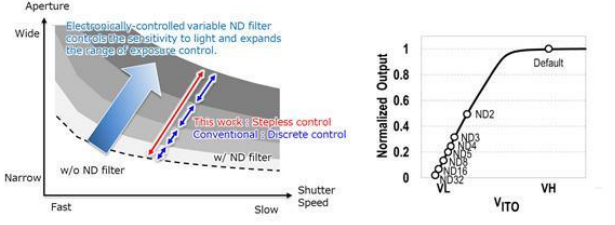


Fig.10 Effect of electrical ND filter sensitivity of OPF (photoelectric conversion efficiency)

OLED Applications II: OLED Display

iPhone 11 Pro

5.8 & 6.5inch

- Super Retina XDR display
- 5.8 (6.5)-inch (diagonal) all-screen **OLED Multi-Touch** display
- HDR display
- 2436x1125 (2688x1242)-pixel resolution (458 ppi)
- 2,000,000:1 contrast ratio

Virtual Reality (VR): near-eye display which completely blocks the real world and replaces it with a simulated display

Although concepts and attempts have been out since 1960s, only in 2012 that development and implementation receives a boost, when Oculus Rift raised $2.5M$ on Kickstarter to develop its VR HMD.

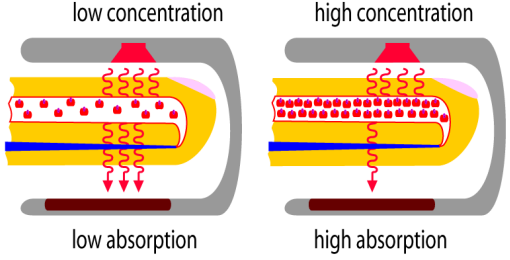
Less than 2 years later, the company was acquired by Facebook for $2B, and VR market finally emerged

A good VR experience requires a high-end display with fast response time, high resolution, power efficiency, light weight.
There are three ***main OLED display types*** used in VR headsets:

- smartphone sized (~5") displays (originally in Oculus' prototypes-first generation)
- 2 smaller displays (around 3-3.5"), one for each eye
- OLED micro-displays

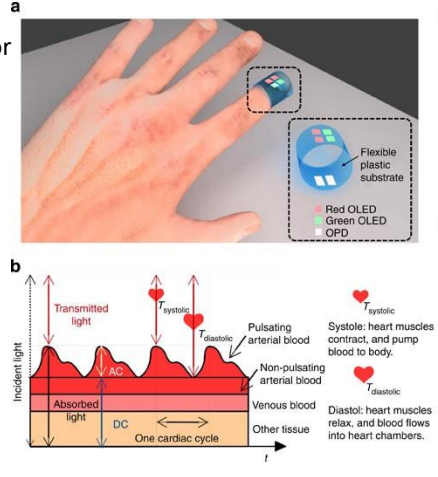
OLED Applications II: Pulse Oximeter

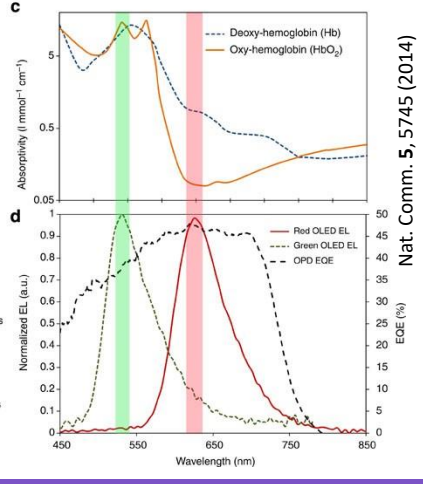
Pulse **oximeter** (**finger** or ear) includes an LED, with emits two types light through the tissue. A sensor on the other side of the tissue picks up the light ***transmitted*** through the tissues



https://www.amazon.com/Easy-Home-Fingertip-Saturation-Co-branding-CMS50DA/dp/B088JZM4HC

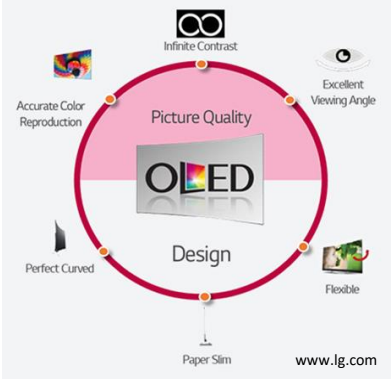
light source and sensor are organic devices



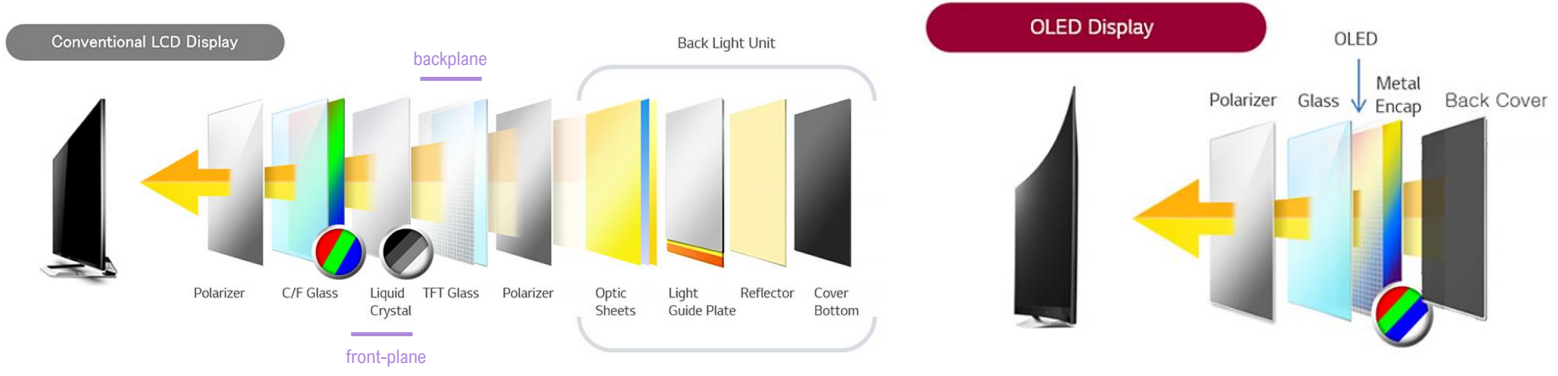


Nat. Comm. **5**, 5745 (2014)

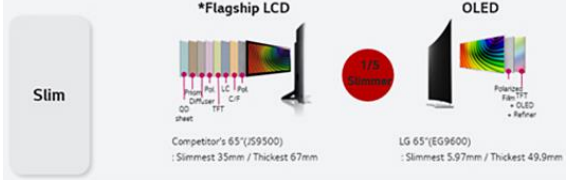
OLED TV: What is on the Market?



OLED TV: Behind the Scene

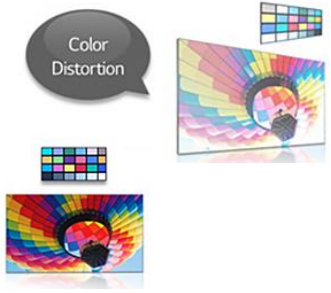
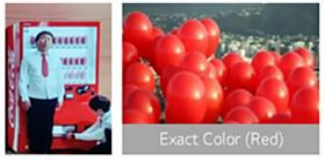
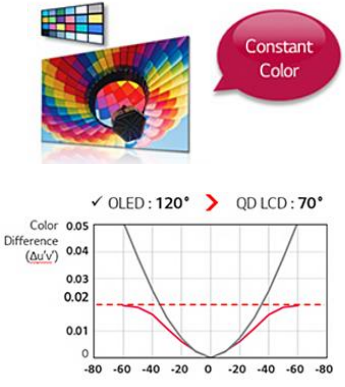


NO backlight illumination



Information available from LG.com

OLED TV: Key Features

	perfect black	NO halo artifact	*perfect* color	*perfect* clear motion	larger viewing angle
*Flagship LCD		 • Black Luminance : **0.2** nit	 Color Saturation (Pinky)	 MPRT (average) 8.8ms	
OLED	 • C/R : Infinite	 • Black Luminance : **0** nit	 Exact Color (Red)	 MPRT (average) 6ms	

Pixels themselves are producing the light (for black, pixels are switched off completely). With no backlight, remarkably realistic blacks, so-called 'infinite' contrast, lightning-quick refresh rates and a muted brightness ideal for movies

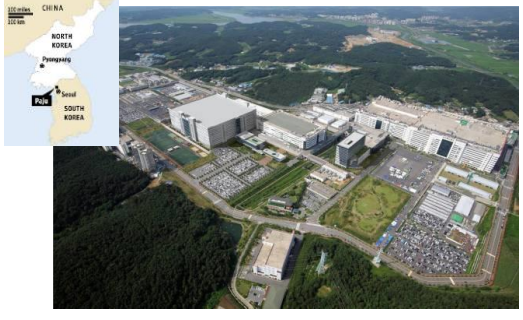
OLED TV: Frontiers Technology

First rollable TV (OLED-R by LG) was presented at CES in 2019.

Have a look here
(from YouTube)

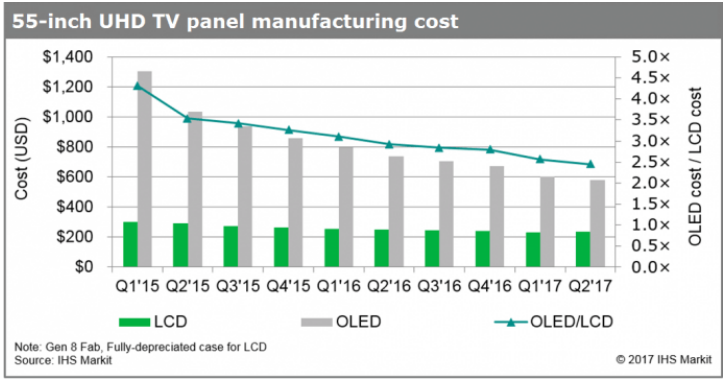
OLED TV: A Look at Production

LG has restarted OLED plan in Guangzhou, China in July 2020 with a targeting monthly production rate of 60,000 sheets (55” display)



LG has invested (planned total 5,000,000,000 KRW) in its **10.5´Gen** (2940x3370) in Paju, Korea with a target production rate of 30,000 from first half 2022 (additional +15,000 from the first half of 2023)

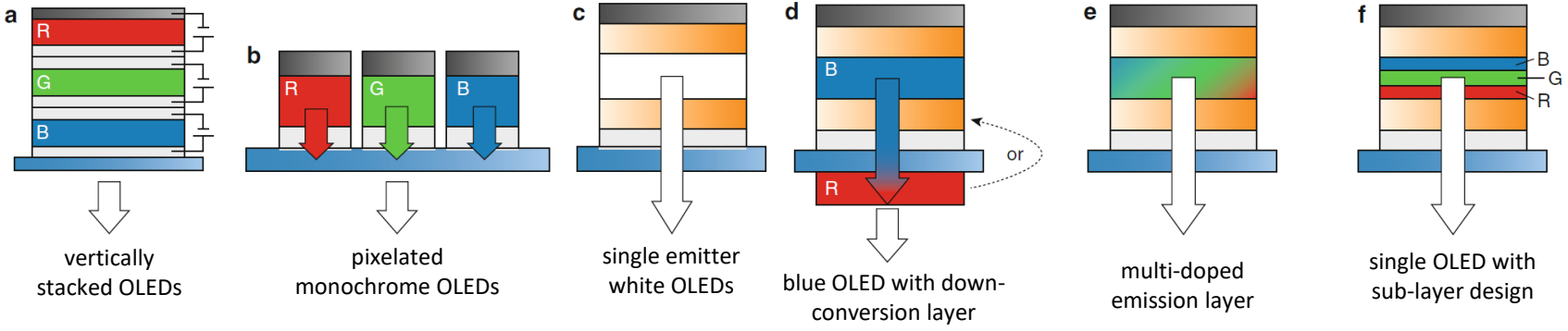
Generation	Size (mm)
1st	300 × 400
2nd	400 × 500
3rd	550 × 650
4th	680 × 880 or 730 × 920
5th	1000 × 1200 or 1100 × 1300
6th	1500 × 1800
7th	1900 × 2200
8th	2200 × 2400
9th	2400 × 2800
10th	2850 × 3050
11th	3200 × 3600 ← now



https://www.displaydaily.com/index.php?option=com_content&view=article&id=56134:costs-of-55-inch-oled-tv-display-production-catch-up-to-lcd-tv-panels-ihs-markit-says-2&catid=274:press-releases

OLED Lighting

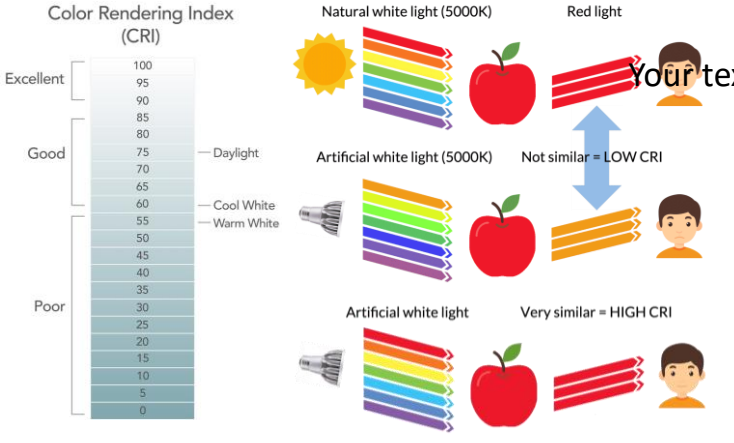
Lighting requires white light



adjusting R, G and B emission allows to tune the color of white light ("warm" → "cold" light)

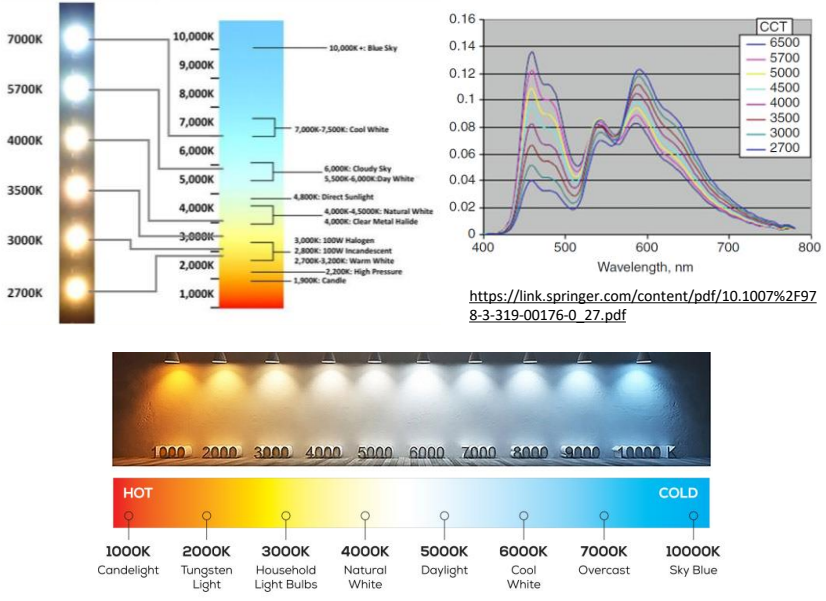
https://link.springer.com/content/pdf/10.1007%2F978-3-319-00176-0_27.pdf

How to Measure *White Light*



Your text here

Color Rendering Index (CRI) measures the ability of a light source to accurately reproduce the colors of the object it illuminates



https://link.springer.com/content/pdf/10.1007%2F978-3-319-00176-0_27.pdf

Correlated Color Temperature (CCT) is a number, expressed in degrees Kelvin (K) which represents the color of a light source, it is equivalent to the *color emitted by a blackbody radiator when heated to that temperature*.

OLED Lighting

OLED enables creative, efficient and healthy light sources

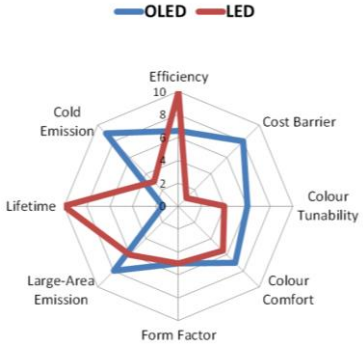
OLEDs lighting properties:

- ***flexible*** and ***transparent*** panels (window or reflective mirrors)
- ***color-tunable*** (OLEDs lighting is the closest light source to natural light)
- ***thin***, ***durable*** and ***lightweight***
- ***fast switch-on time***, ***wide operating temperature*** and ***no noise***

https://www.energy.gov/sites/prod/files/2016/08/f33/ssl_oled-products_2016.pdf

Lighting: LED *vs.* OLED

- ***large heating*** (need for heat sink in the device for thermal management)
- panel can be ***wired parallel/series*** (*V*-driven)
- suitable for ***outdoor*** and ***indoor***
- ***dimmable***



(source: IDTechEx)

- ***limited heating***
- ***flexibility***
- **not suitable for parallel wiring** (*I*-driven)
- ***not suitable for outdoor*** (moisture/water sensitivity), unless encapsulated
- ***warm***, ***pleasant*** and ***homogeneous*** light
- ***dimmable*** (less power consuming)

performances are still far from reaching LED performances

manufacturing costs still high

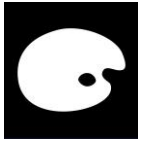
suitable for small-scale lighting

OLED Lighting: Future Impact

Energy saving
• potential to achieve ***> 150 lum/W***
• may help ***reduce consumption*** of non-renewable fossil fuel and greenhouse gas emissions

Environmental & friendly green technology
• ***save energy*** helping to reduce dependence on oil and other non-renewable fuels
• reduce ***environmental impact***
• ***do not contain hazardous substances***/disposal problems
• ***easier to transport*** than fragile glass lamps

Innovative form factor
• excellent ***diffuse lighting*** sources
• much ***thinner*** and ***safer*** form factor than those found in bulky and fragile incandescent bulbs/fluorescent tubes
• enable novel product uses
• ***ultra-thin***, ***lightweight***, ***conformable*** on flexible substrates
• ***suitable for windows***, providing sunshine during the day, lighting at night



Bright, uniform white color quality
• broad spectral emission (***CRI> 80-90***)
• ***color temperatures*** (from warm white of incandescent lamps to the cool white of fluorescent tubes/LEDs)
• ability to produce ***excellent deep red*** component of light

Color tunability and dimmability
• ***innovative W-OLED architectures*** enable custom color (cool → warm white, full color tunability)
• ***brightness levels can be adjusted*** and become even more efficient when dimmed (unlike fluorescent lighting)

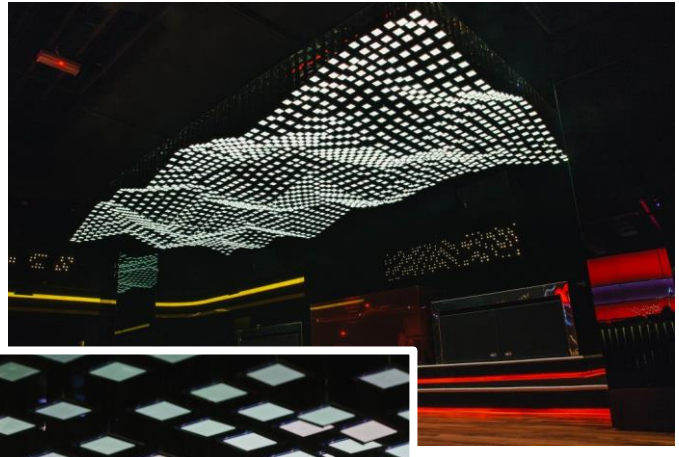
OLED Lighting Installation

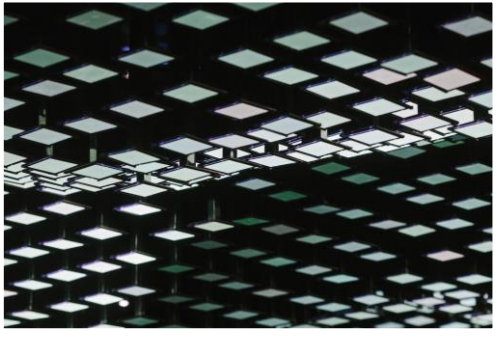
Konica Minolta produced 15,000 OLED panels to create tulips installed at a Japanese tulip festival in 2015 (photo courtesy of Konica Minolta, http://www.oled-info.com/tags/companies/konica_minolta)

Office of Aurora Lighting Design with a lighting system using OLED panels (photo courtesy of Acuity Brands Lighting, Inc.)

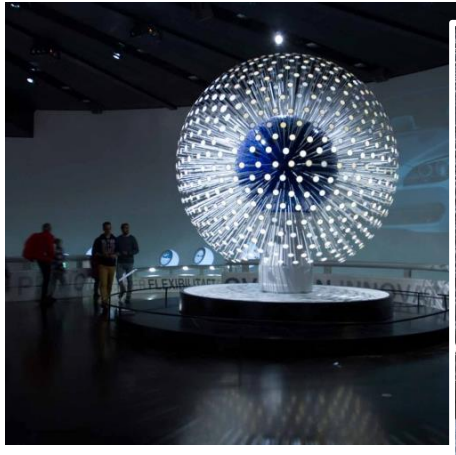
Project Monarch, an OLED Design Kit, highlights the exceptional properties and features of OLEDs - all in a single OLED design in the shape of a butterfly (https://contest.techbriefs.com/2018/entries/electronics-sensors-iot/8994)

OLED Lighting Installation

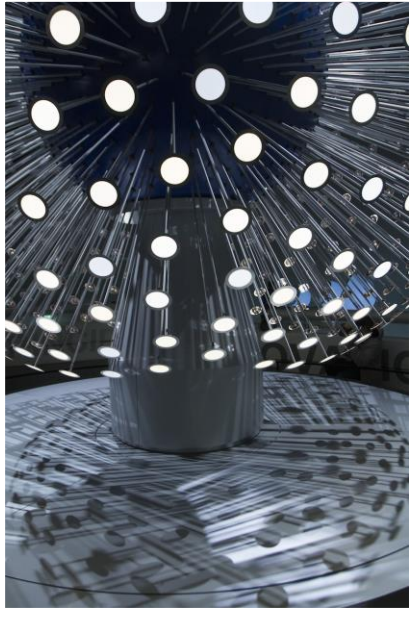




Philips Lumiblade GL26 tiles installed in Providence, Kuala Lumpur
(Photos: SLT Asia).



With nearly 1,000 OLED, OSRAM with DANDELION offers a spectacular contribution to the 2012 theme of “Light” in the BMW Museum, Munich.



OLED Lighting Available in the Market

Audi 2021 Q5 SUV with optional OLED taillights

OLED taillights are built from 3 OLED panels, each with 6 segments, which can show different lighting patterns with locking/unlocking the SUV, or to show a welcome pattern when you are close to the car

Coca Cola *Star Wars* Singapore promotion campaign

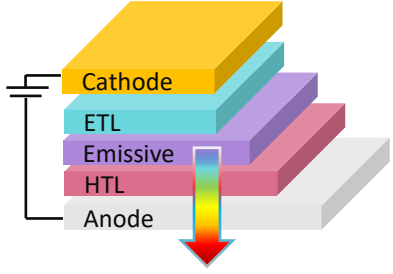
Coca Cola has embedded flexible OLED lighting in 8,000 bottles in Singapore, as part of a new Star Wars promotion campaign.

Have a look here

Summary

Today: Organic Light Emitting Diodes

- charge transport/injection/blocking layer
- host-guest for efficient emission & phosphorenscent/fluorescent/TADF molecules



OLED as light-source for lighting/display applications

→ organic materials enable many applications on **flexible substrates**

Next: Organic Light Emitting Transistors

- **Organic light emitting transistors** (OLETs): **basic principles** and **mechanism**