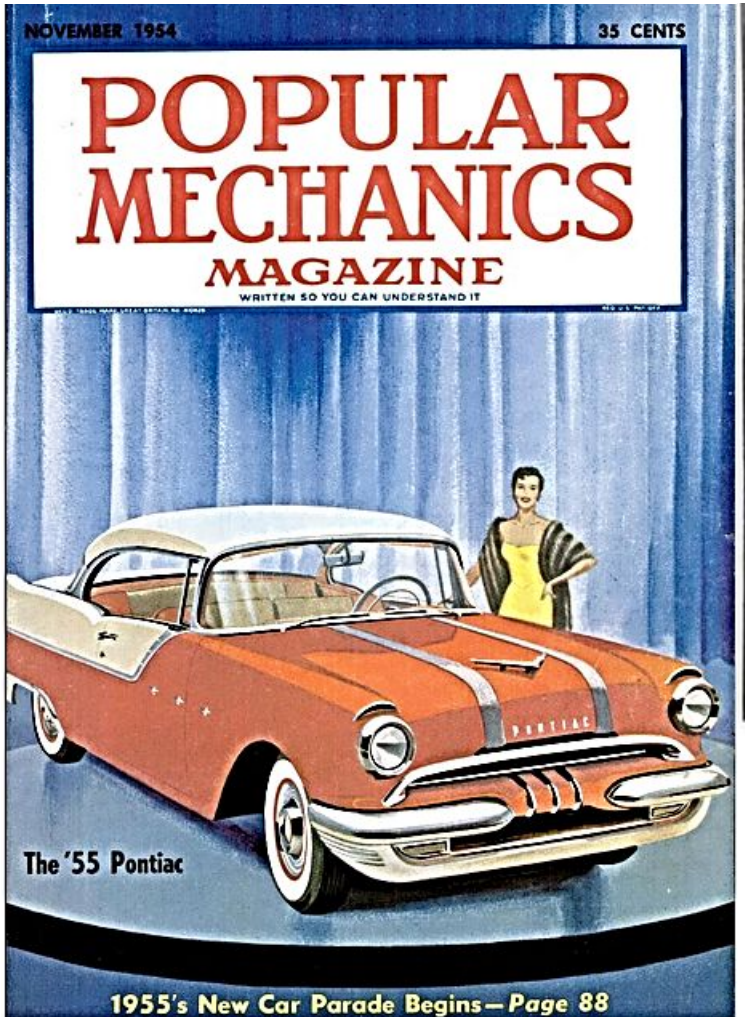
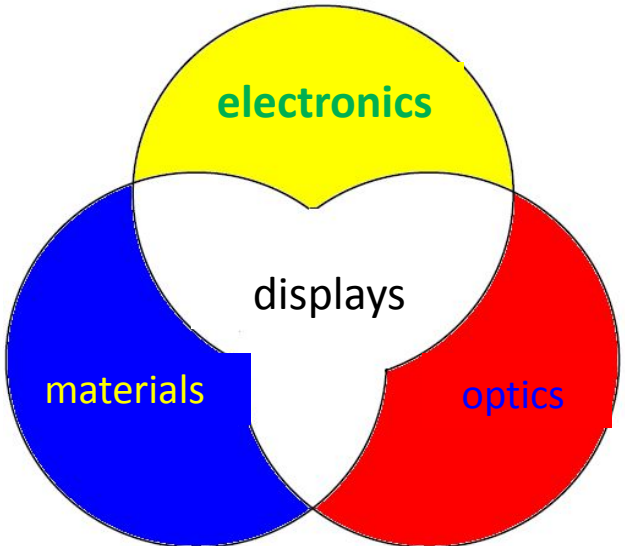
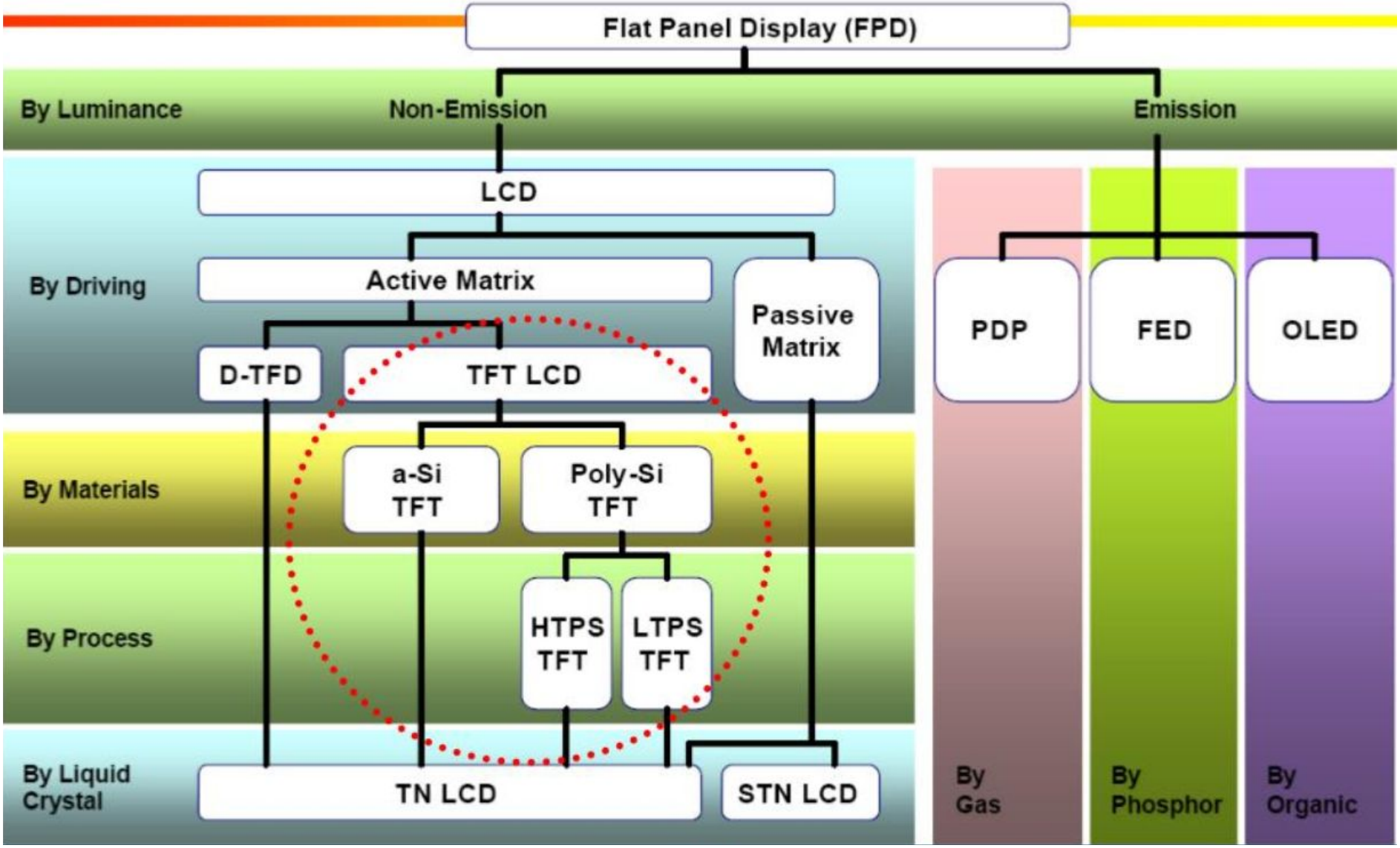
Displays require ideas and knowledge



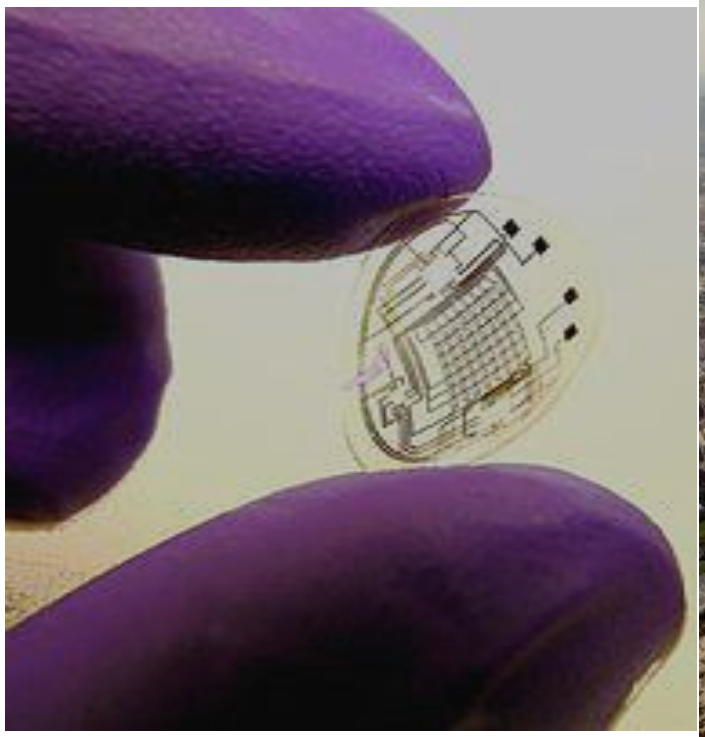
Would Feature Thin Screens

Your TV-picture screen in 1964 may be so thin that it can be hung like a painting on the wall or mounted like a vanity mirror in a table model. That's the prediction of General Electric scientists. The circuitry would be built into the picture frame and would use printed wiring and miniature components. Closely spaced wire grids would luminesce at their intersections to reproduce the transmitted picture. The futuristic TV set was suggested by work on an aircraft plotting system that will automatically transfer radar information to a picture screen.



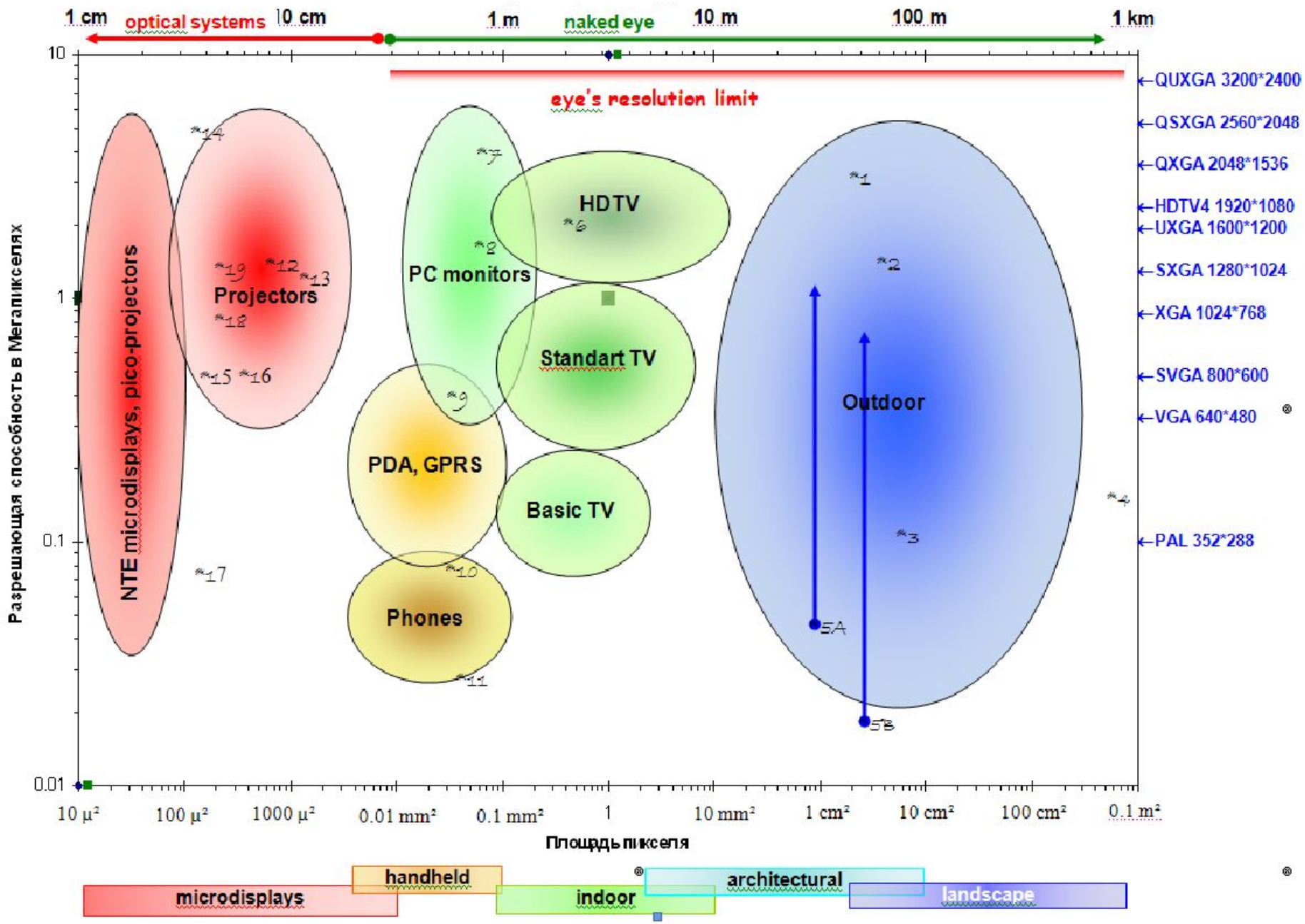

Flat Panel Display (FPD)
By Luminance
Non-Emission
Emission
By Driving
LCD
Active Matrix
Passive Matrix
D-TFD
TFT LCD
By Materials
a-Si TFT
Poly-Si TFT
By Process
HTPS TFT
LTPS TFT
By Liquid Crystal
TN LCD
STN LCD
PDP
FED
OLED
By Gas
By Phosphor
By Organic

… By size



Display built into the contact lens

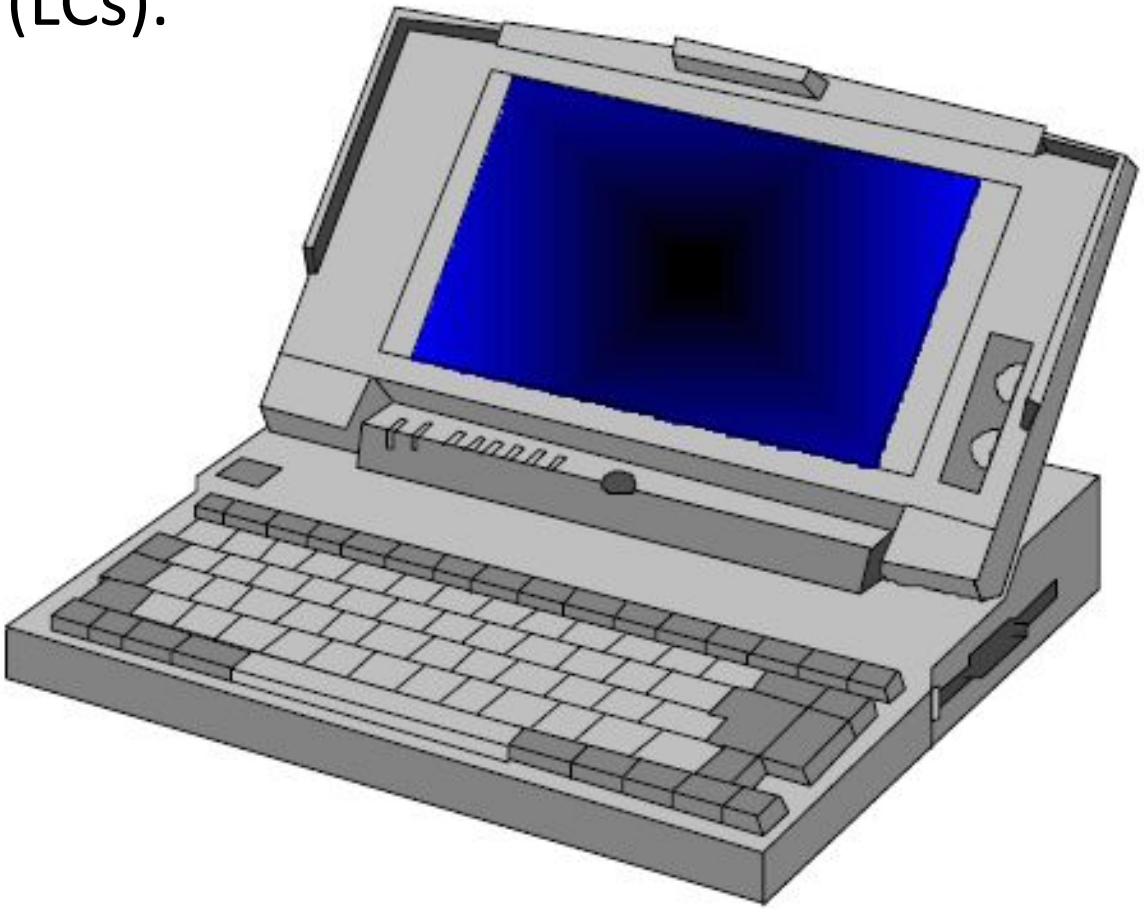
Aerial view of landscape display



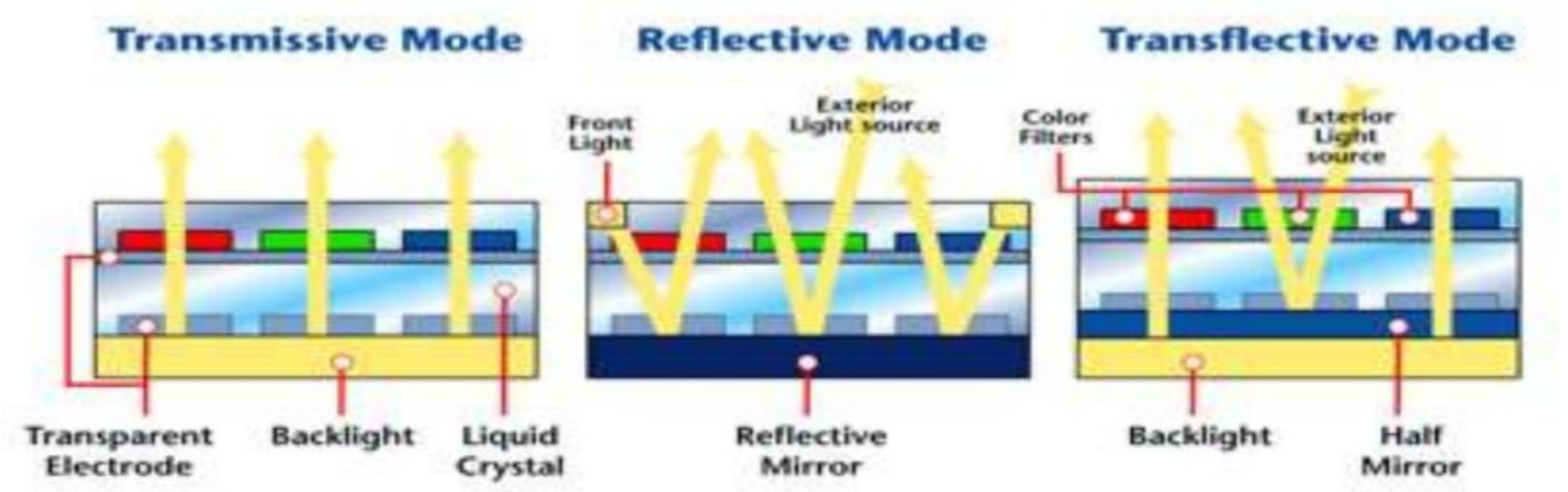
the observation distance *D* = 3500 * A, where A is the linear pixel size.

Liquid crystal display devices

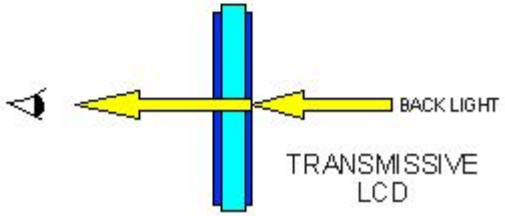
liquid crystal display (**LCD**) is a thin, flat electronic visual display that uses the light modulating properties of liquid crystals (LCs).



Ways of passing light through liquid crystal displays



Transmissive mode



Laptop

Monitor

LCD-TV

✓

- Good contrast
- Good color saturation
- High brightness

✗

- High power consumption (Use of Backlight)
- Poor readability in bright environment e.g. under sunlight

Reflective mode

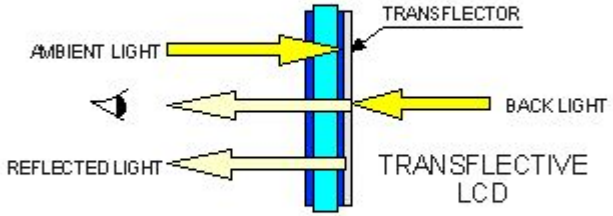
✓

- Very low power consumption
- Compact
- Light weight
- Sunlight readable

✗

- Poor readability in dark environment
- Low contrast
- Poor color saturation

Transflective mode



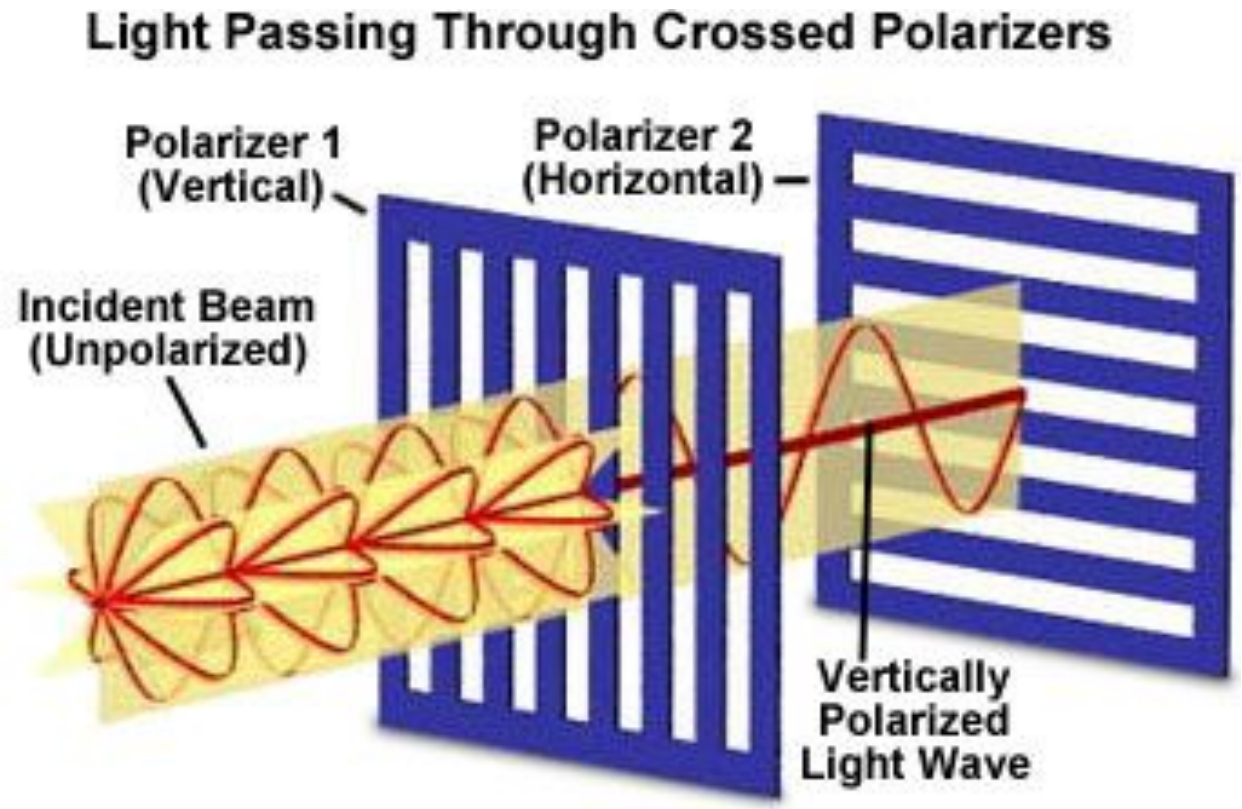
	Transmissive LCD	Reflective LCD
Dark Environment	ˇ	×
Bright Environment	×	ˇ

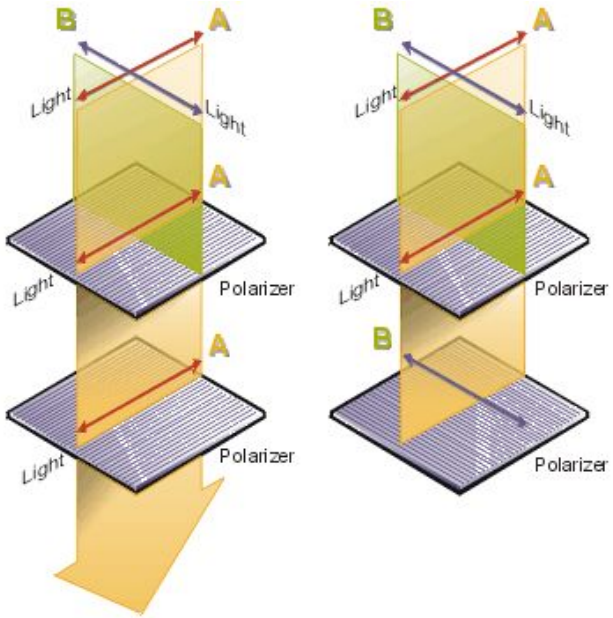
Combine together

	Transflective LCD
Dark Environment	ˇ
Bright Environment	ˇ

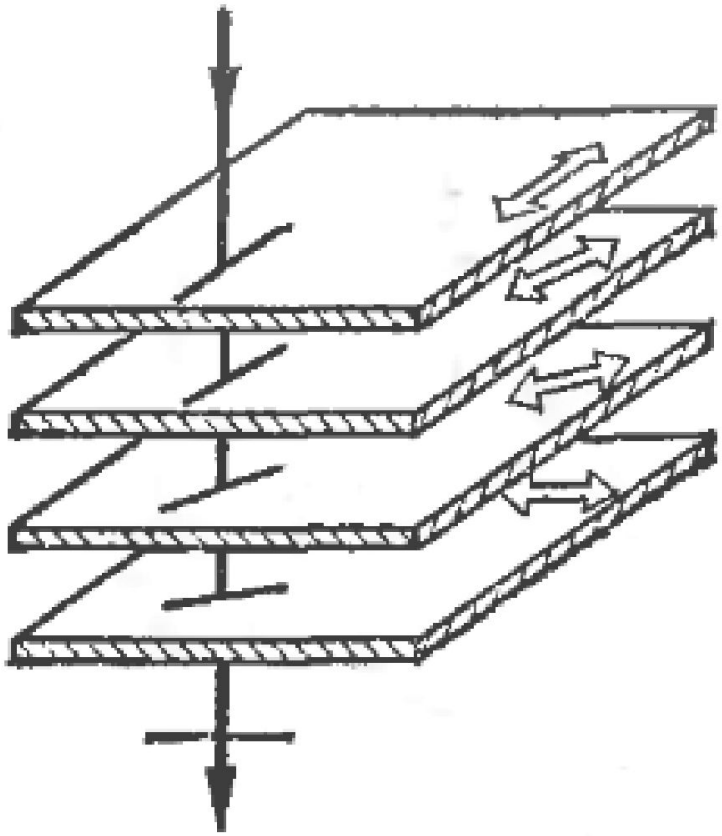
➢Good readability under **any** ambient light level !

Main properties of light: polarization

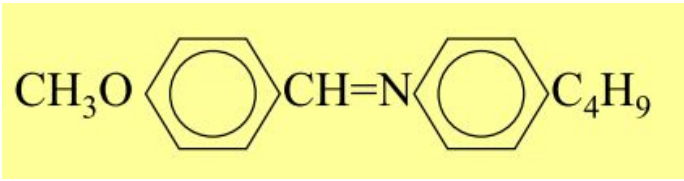


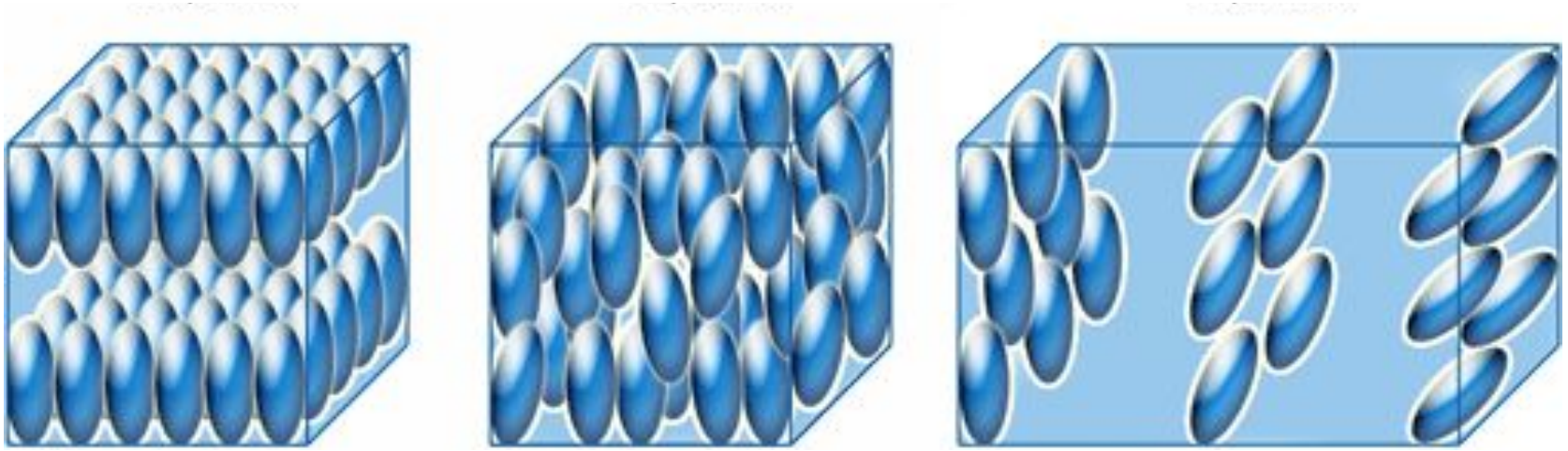


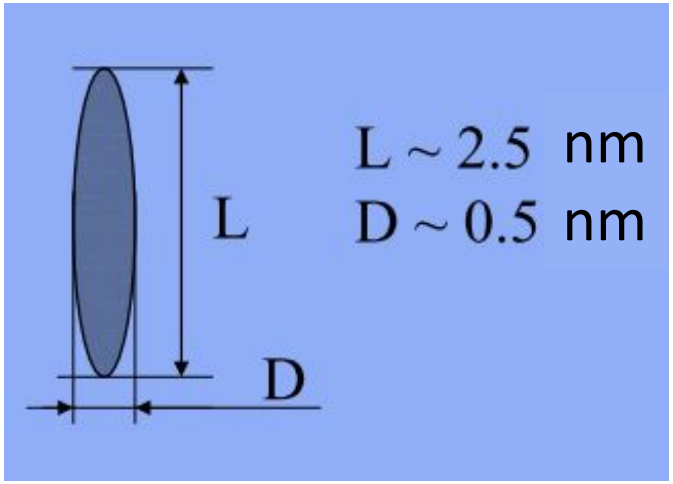
Crystal property: birefringence



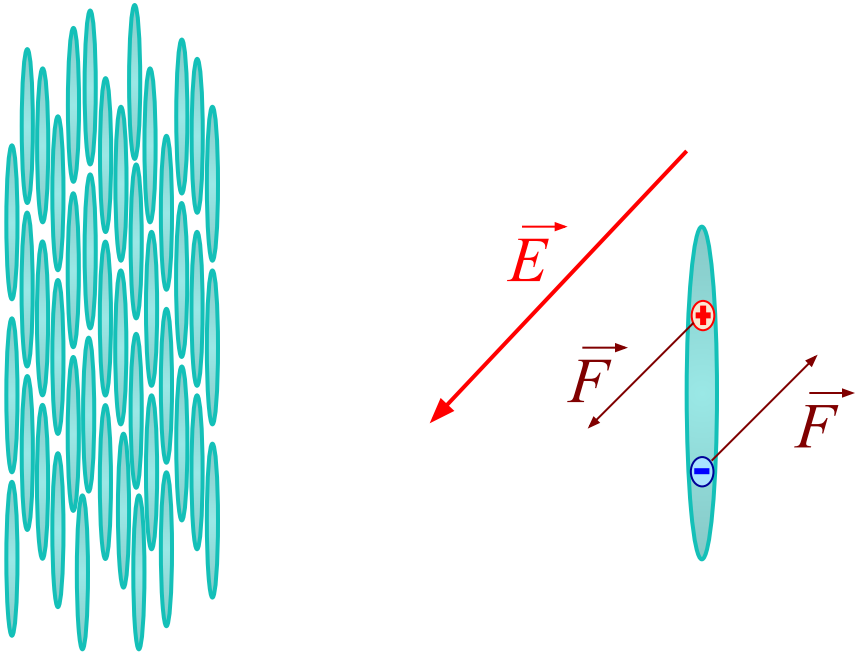
Liquid crystals



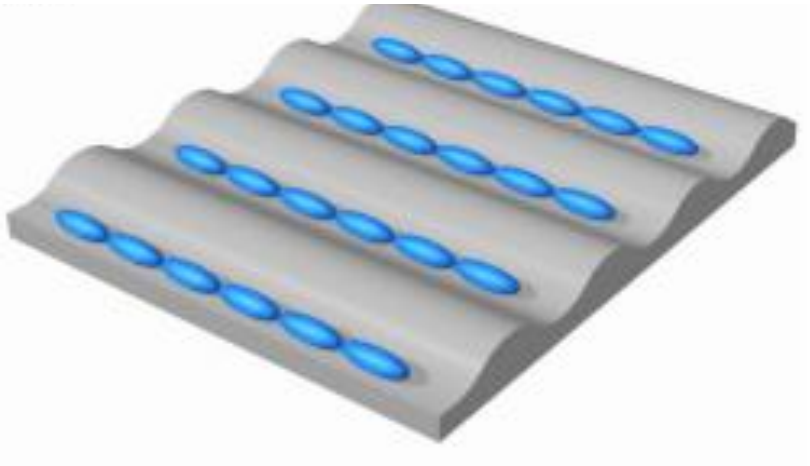


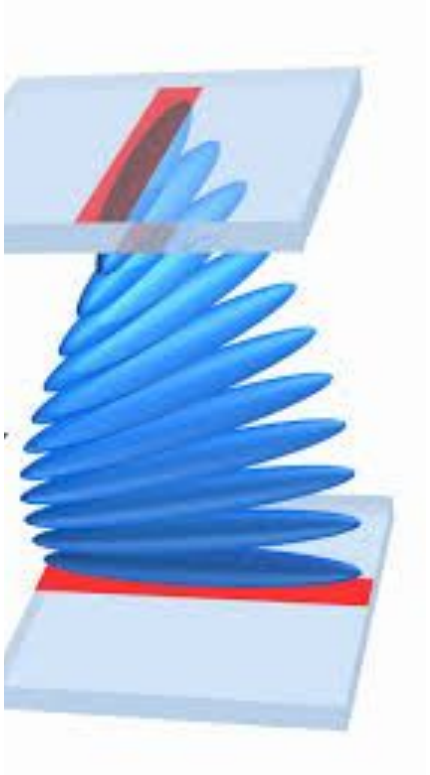


Fredericks effect in an electric field



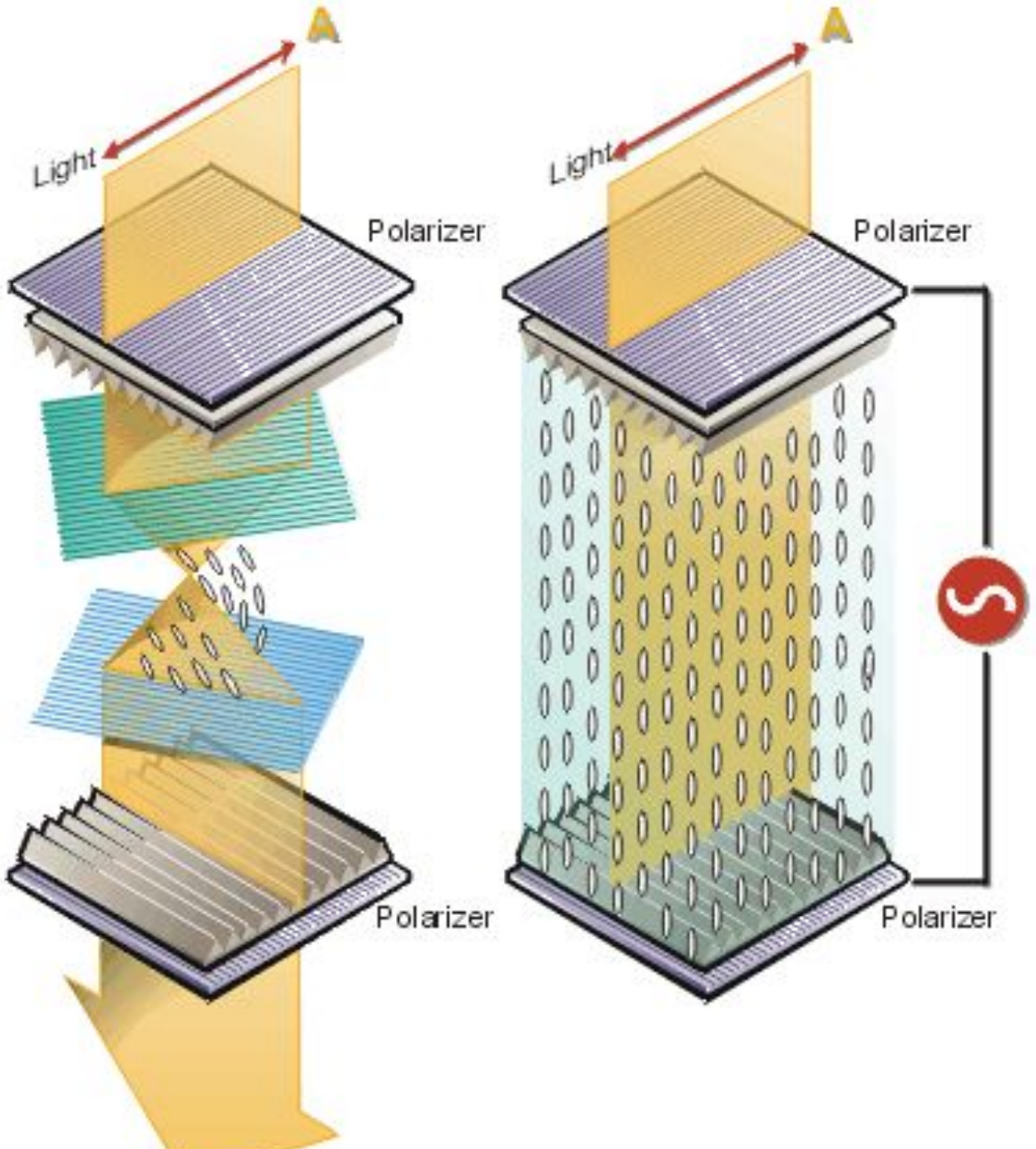
LC oriented without applying an electric field



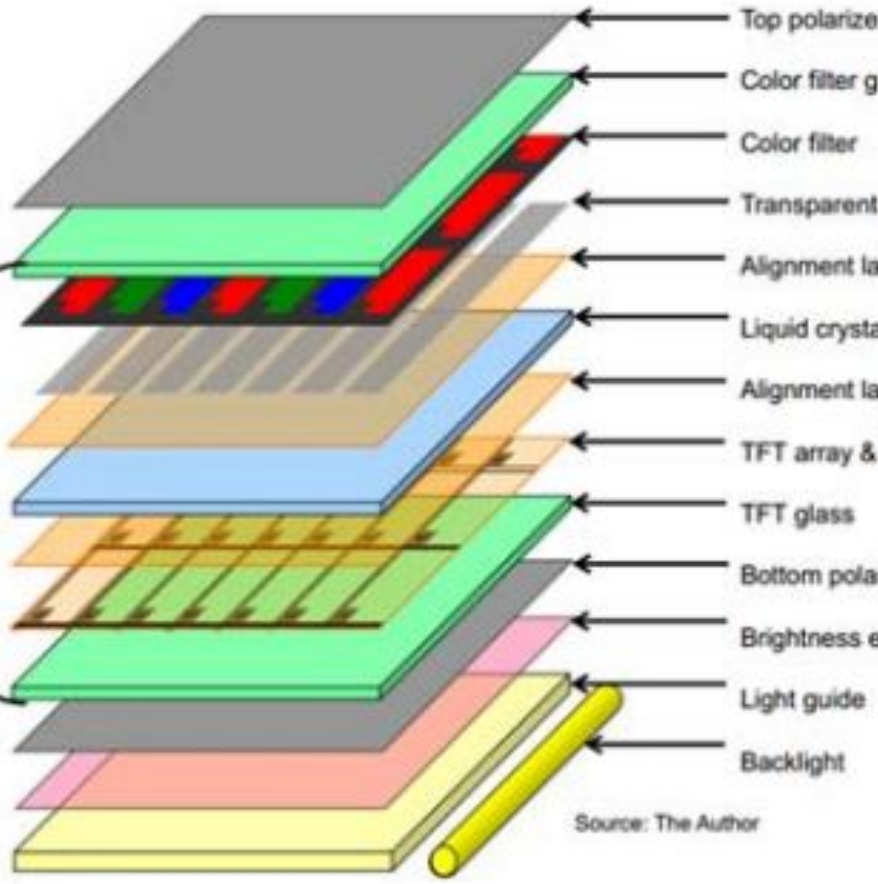


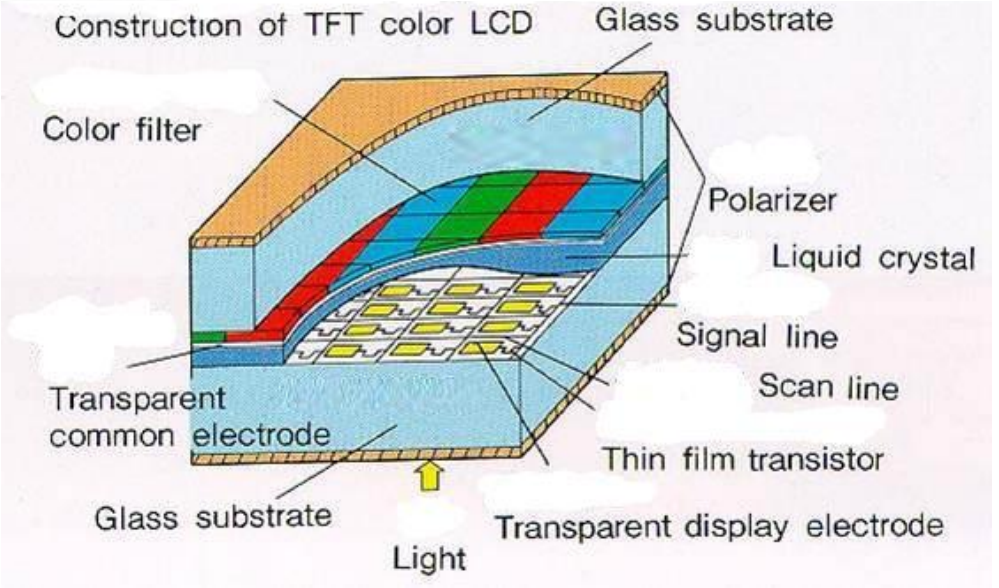
The parallel alignment of liquid crystal molecules along grooves

The basic structure of the liquid crystal cell

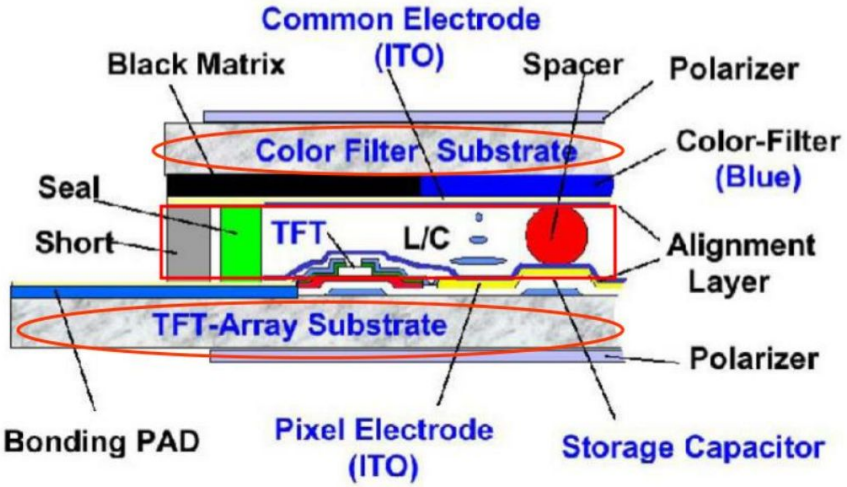


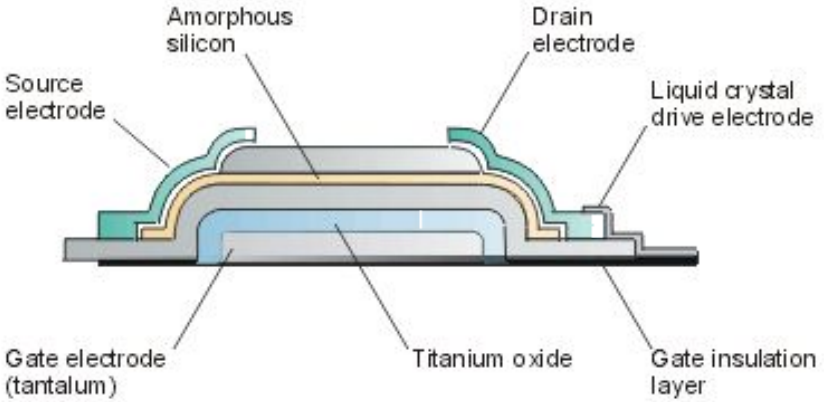
Creating an LCD

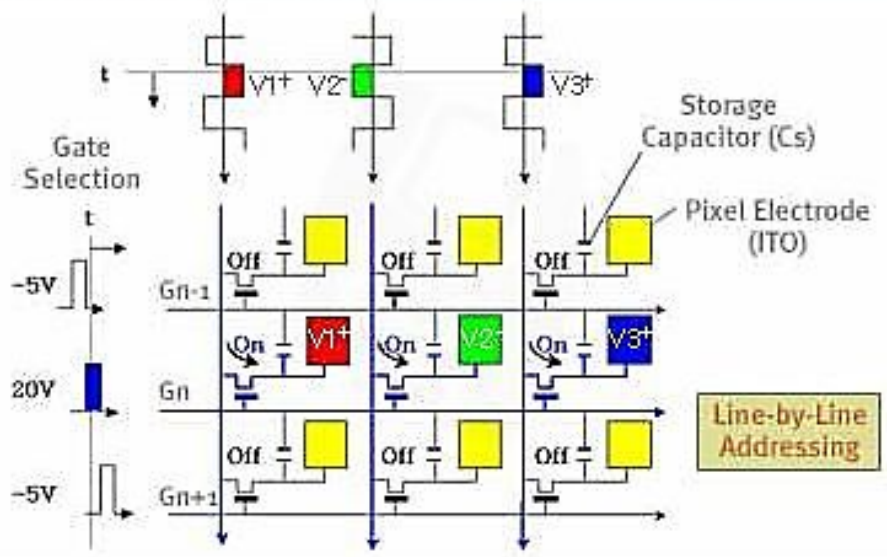




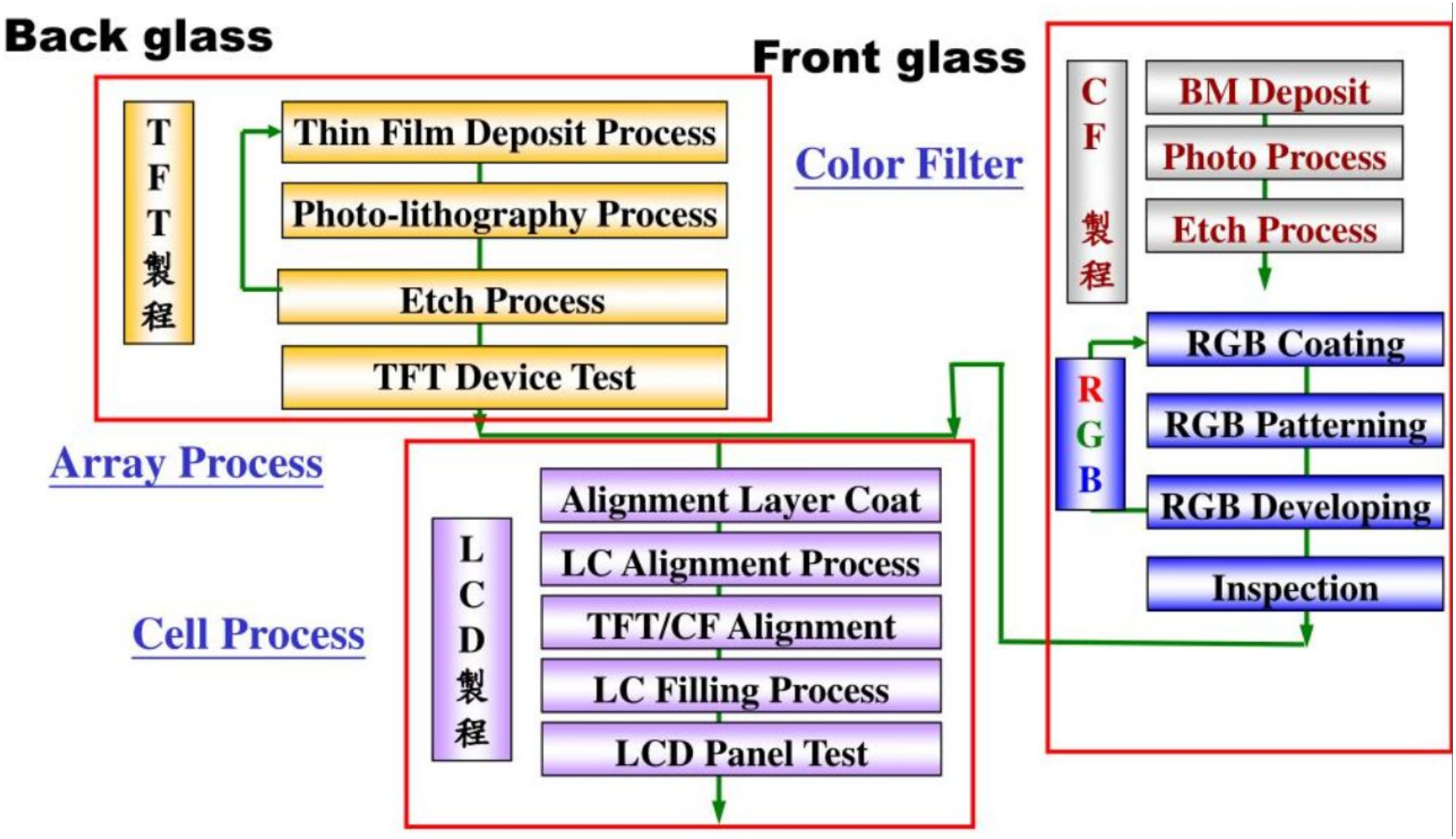
TFT LCD Configuration



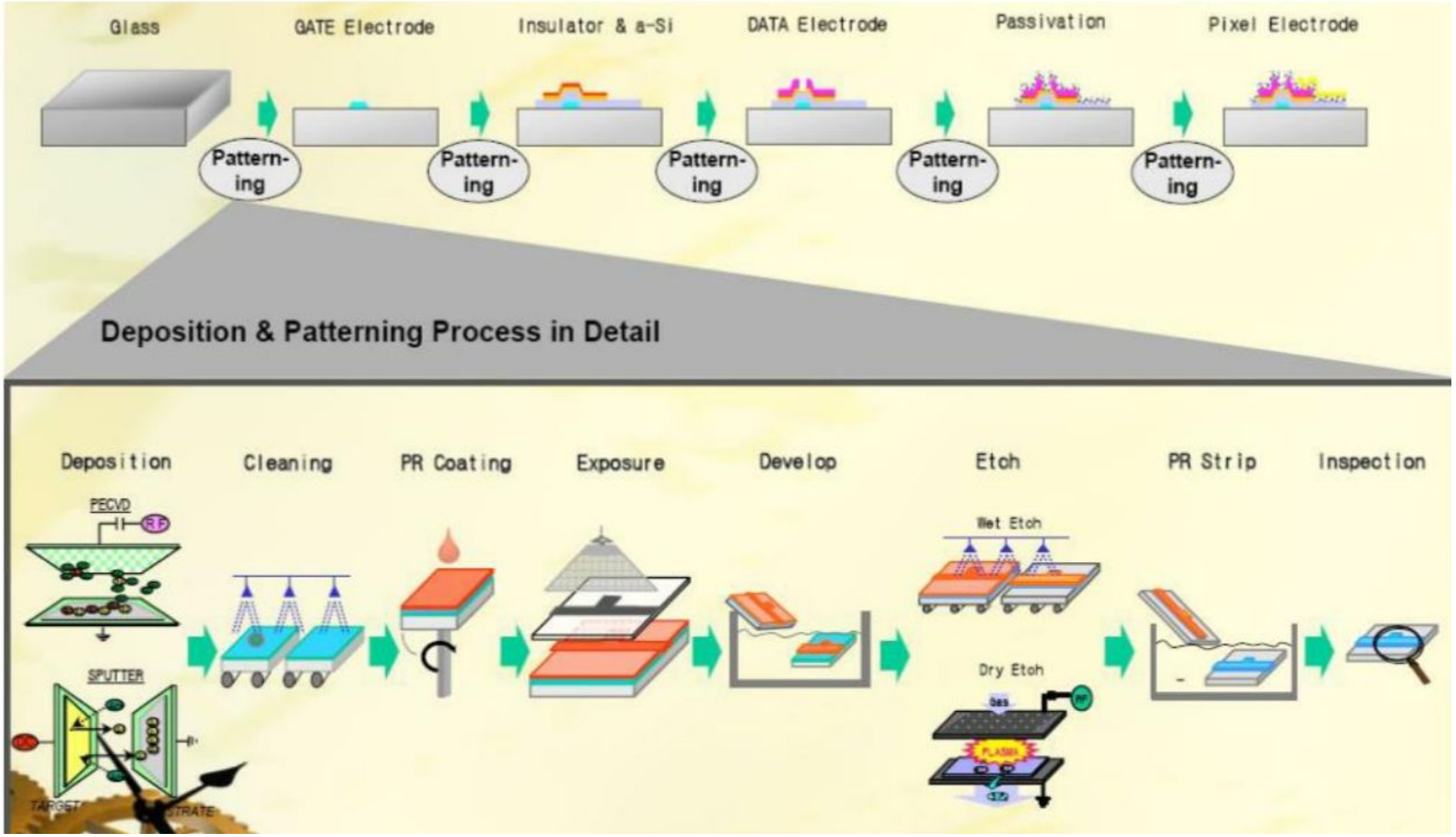




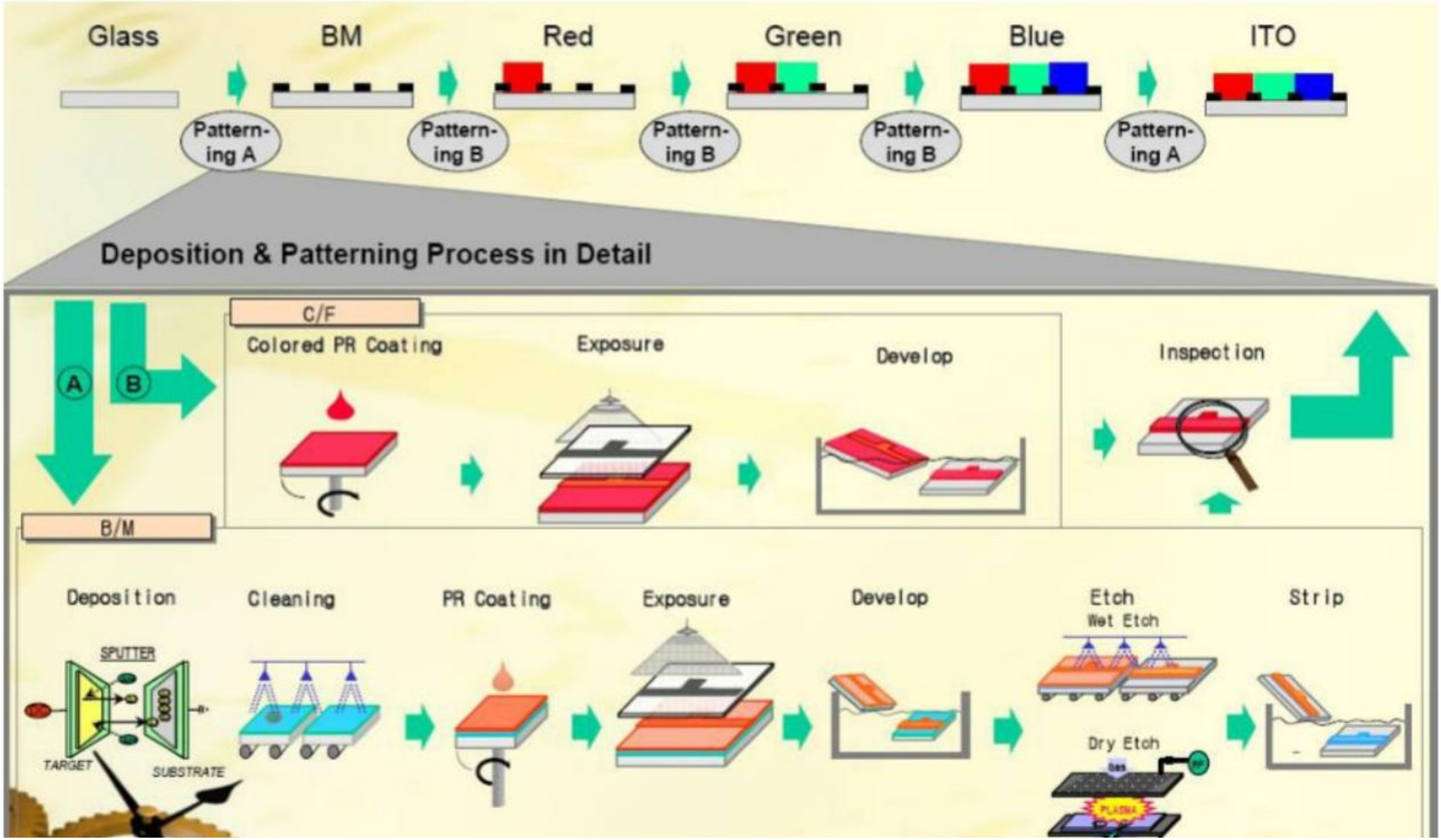
TFT LCD technology process



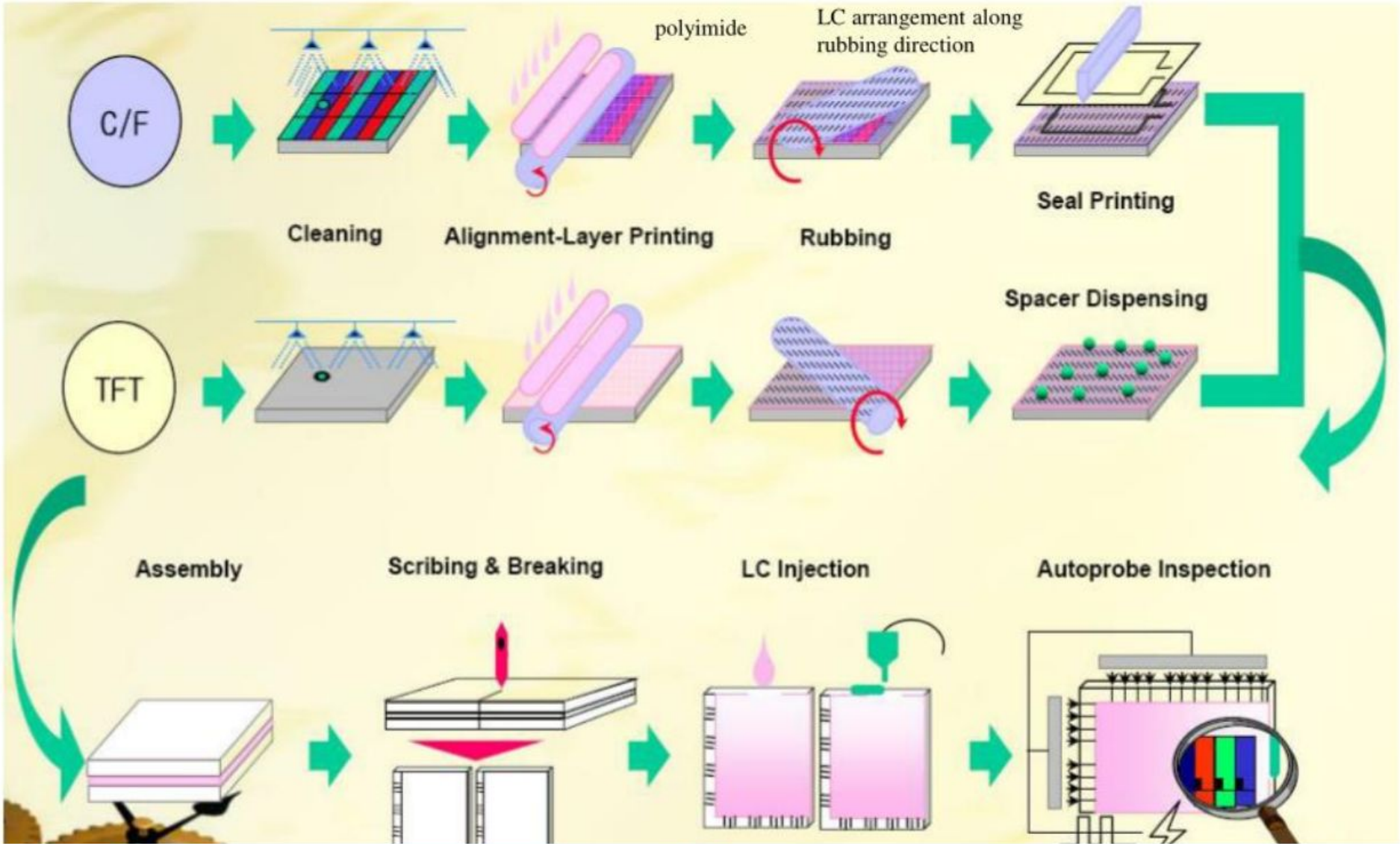
TFT Manufacturing Process



Color Filter Manufacturing Process



Cell Manufacturing Process

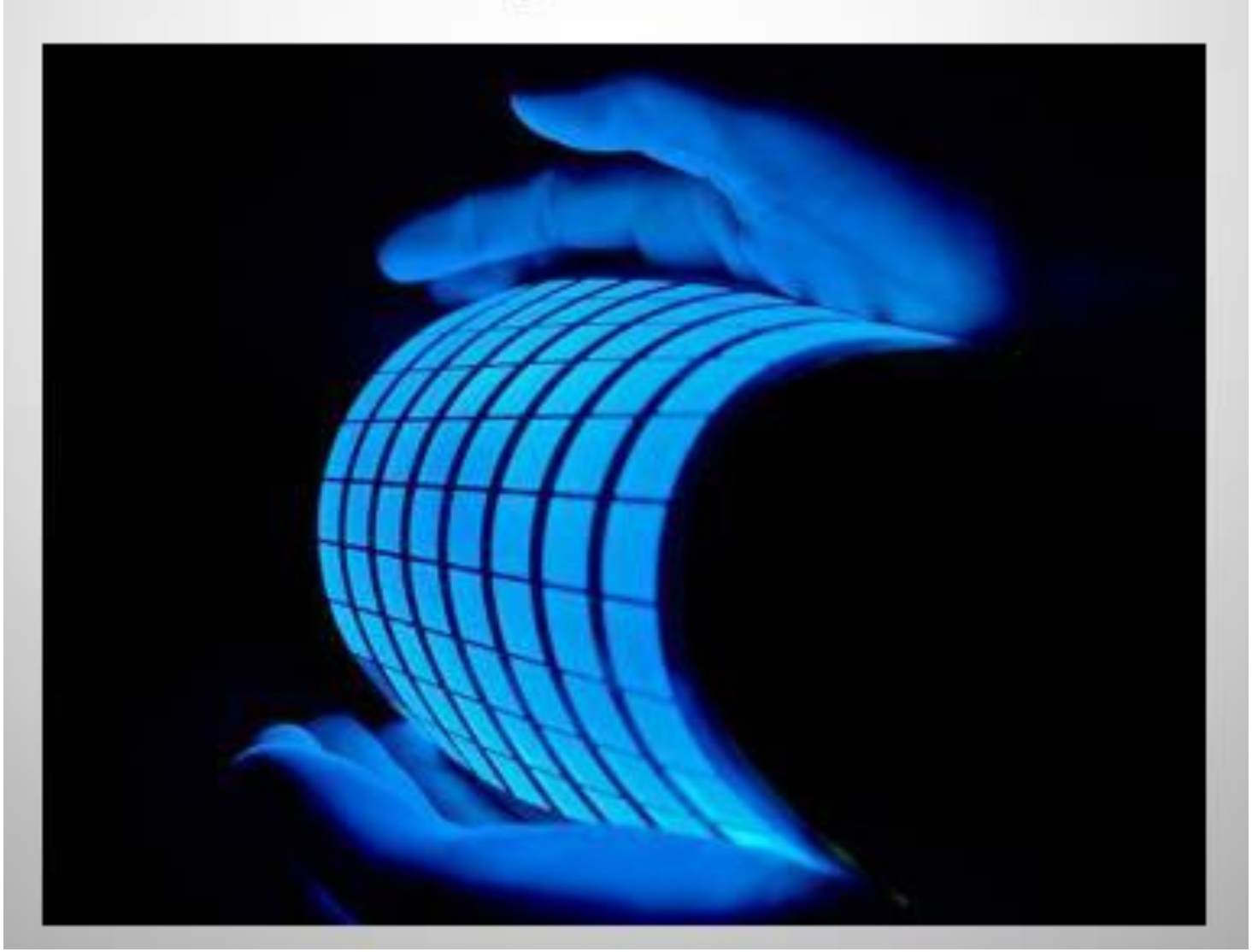


Targets applied in TFT-LCD manufacturing

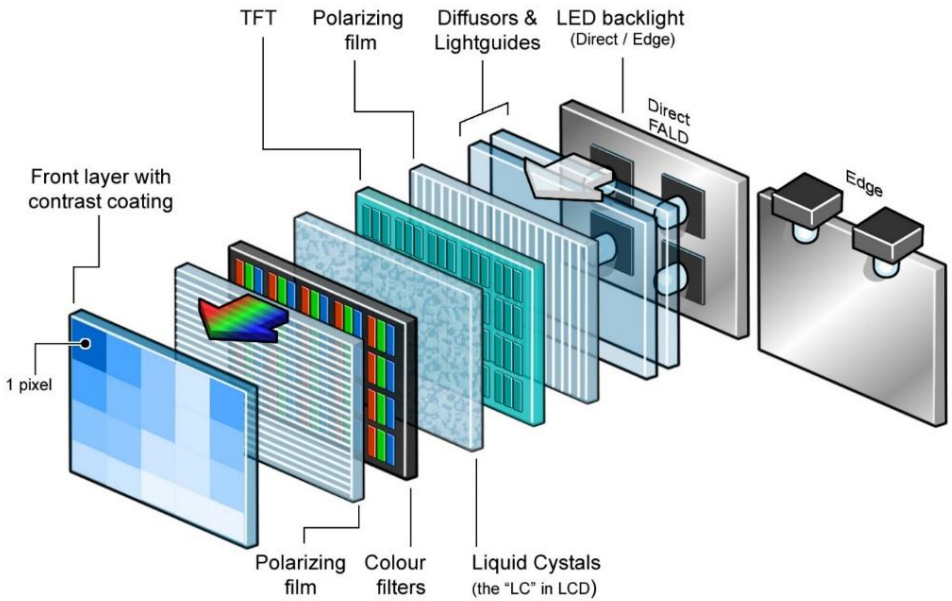
Target	Function
Al	electrode、conductive line
Mo	electrode 、conductive line
Cu	Electrode 、conductive line (next generation)
Cr	CF (black matrix)
ITO	CF and array electrode

Technology of Fabrication

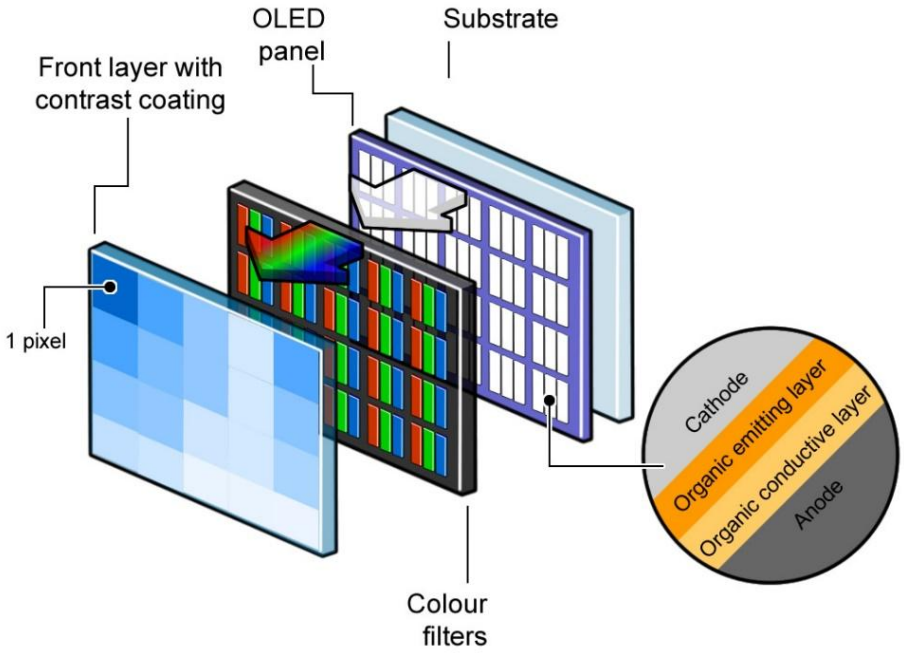
Organic Light Emitting Diodes (OLEDs)



LCD VS EMISSIVE DISPLAYS

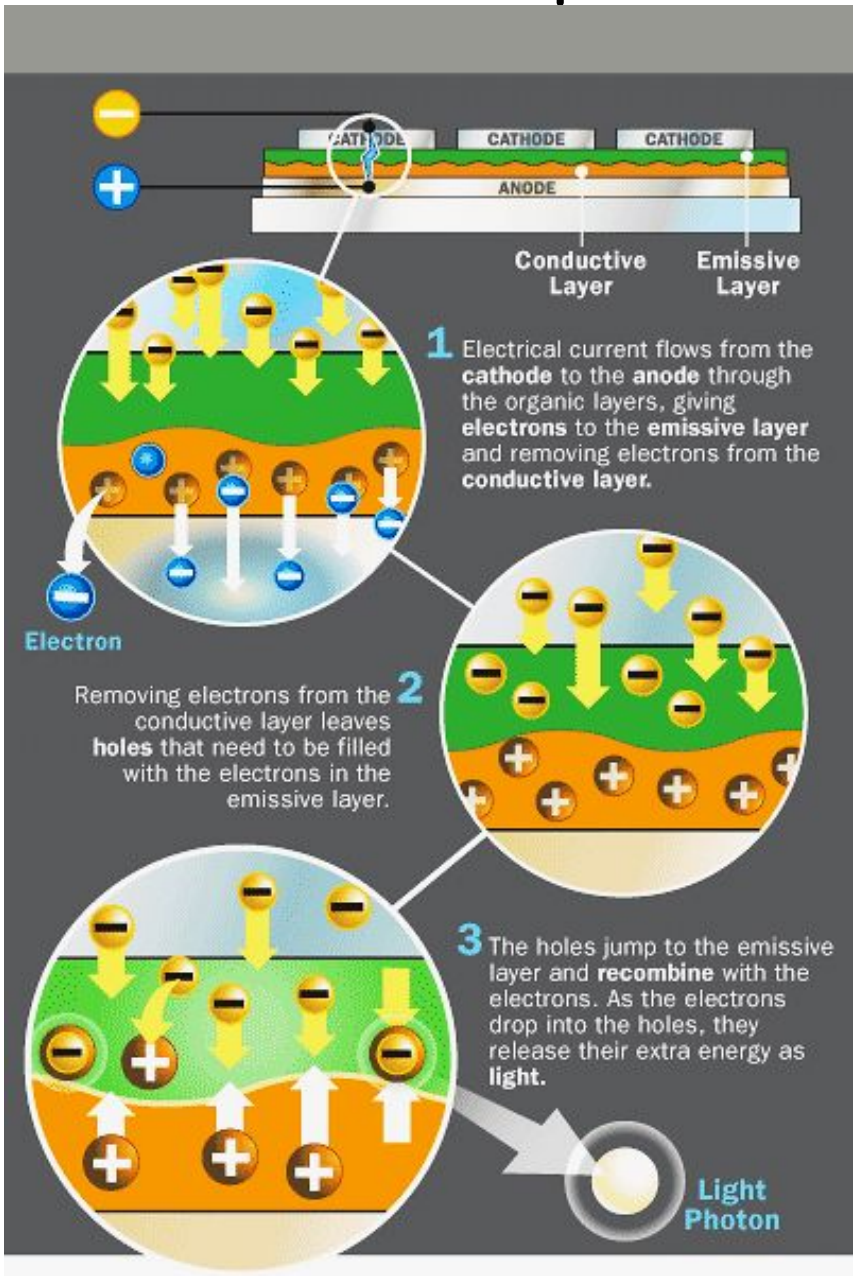


LCD

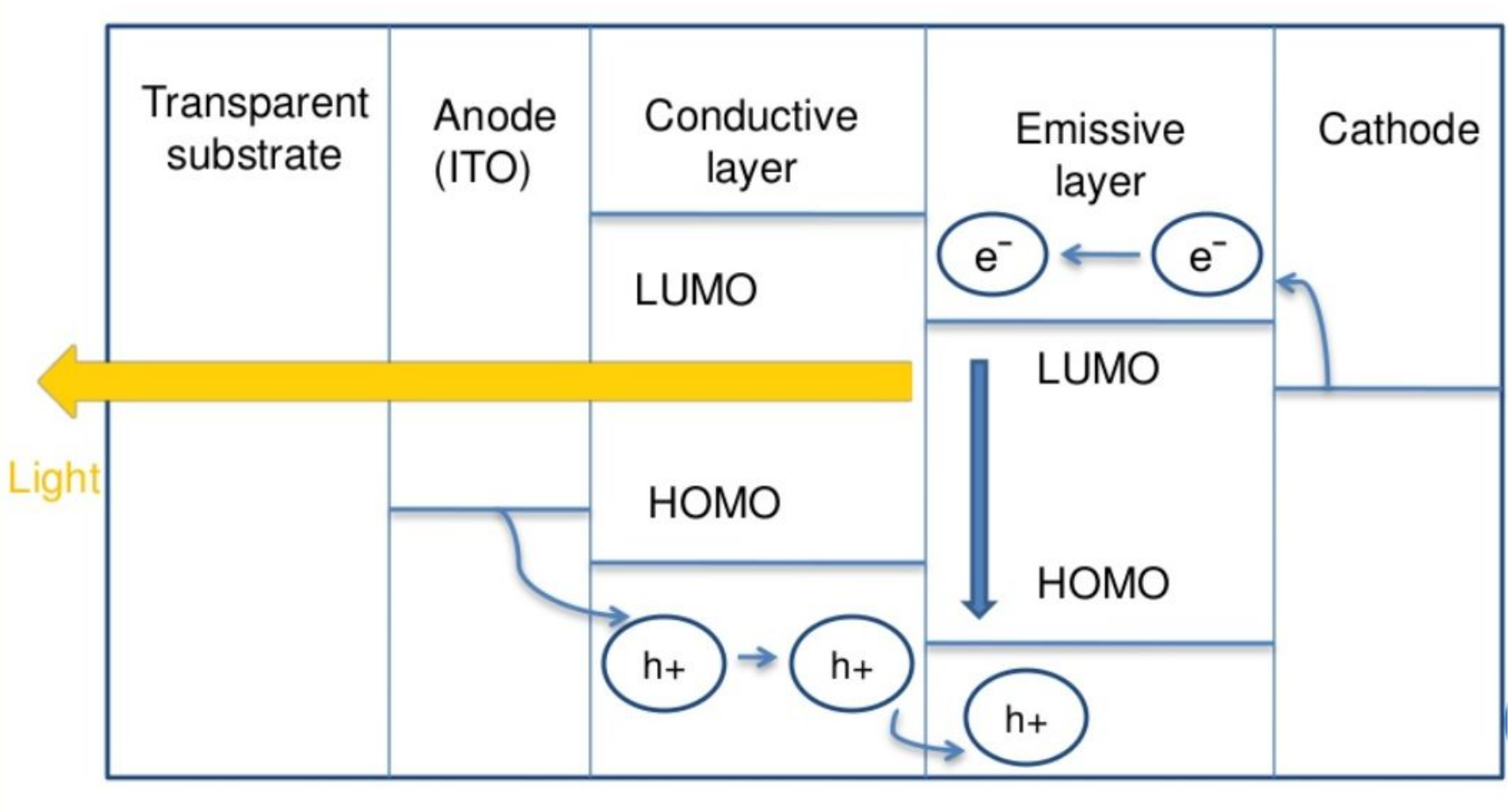


Emissive Displays

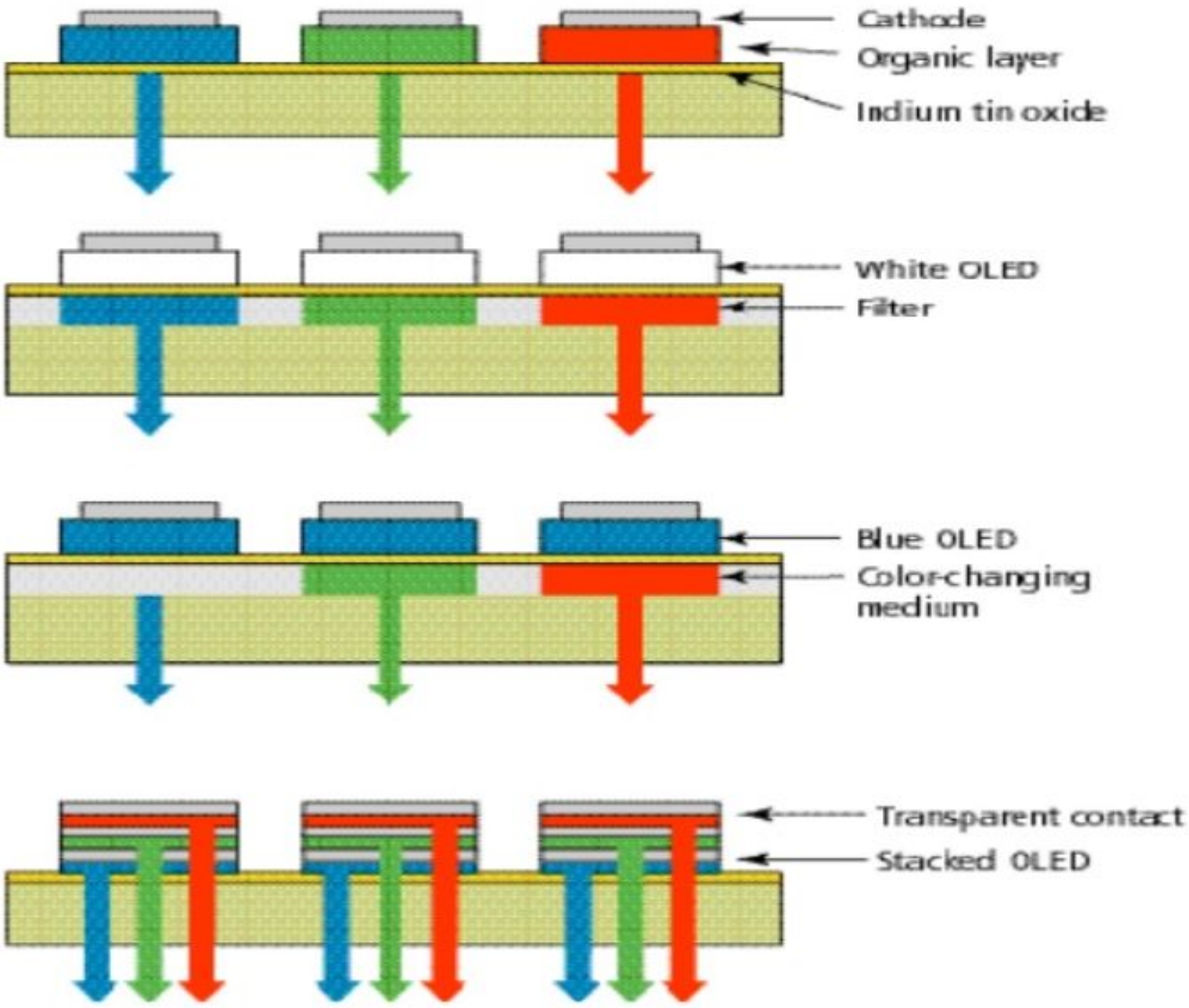
OLED Device Operation



OLED Diagram



OLED and Color



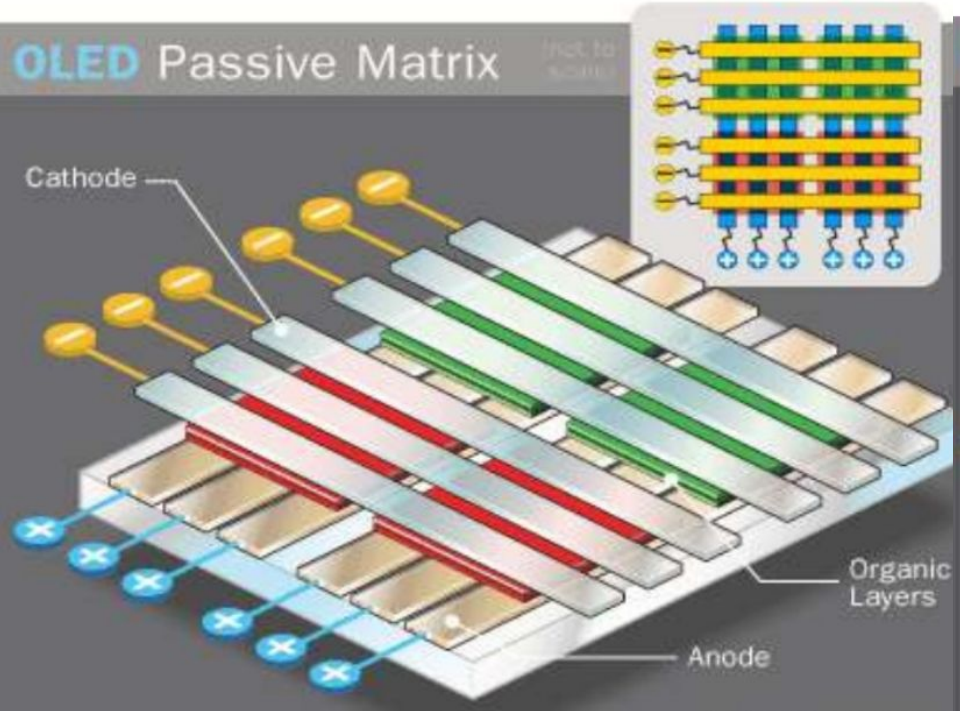
Types Of OLED

Six types of OLEDs

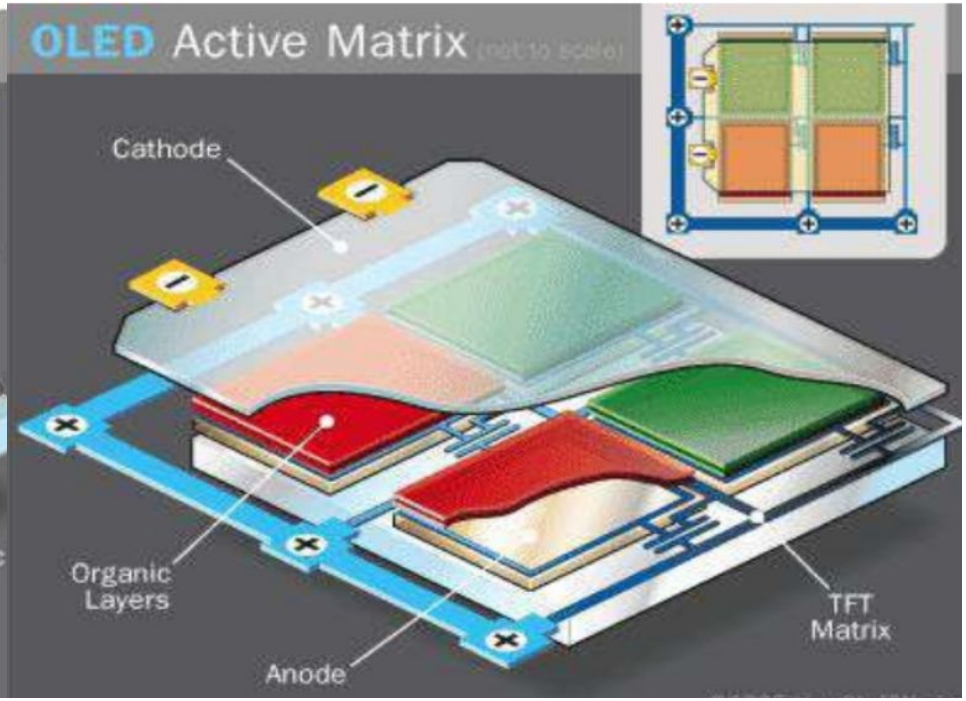
- Passive matrix OLED(PMOLED).
- Active matrix OLED(AMOLED).
- Transparent OLED(TOLED).
- Top emitting OLED.
- Flexible OLED(FOLED).
- White OLED(WOLED).

PMOLED and AMOLED

PASSIVE MATRIX OLED

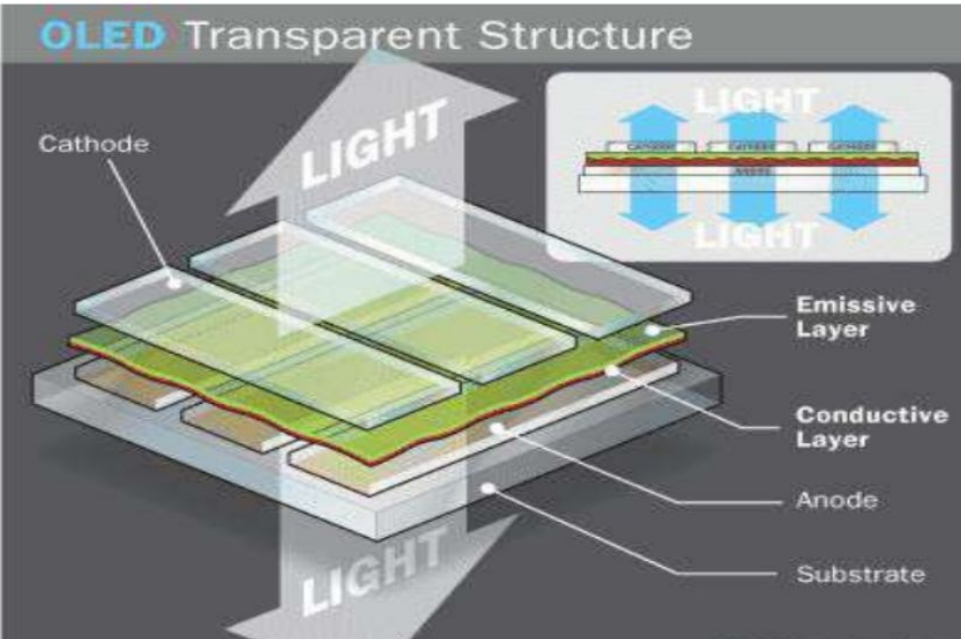


ACTIVE MATRIX OLED

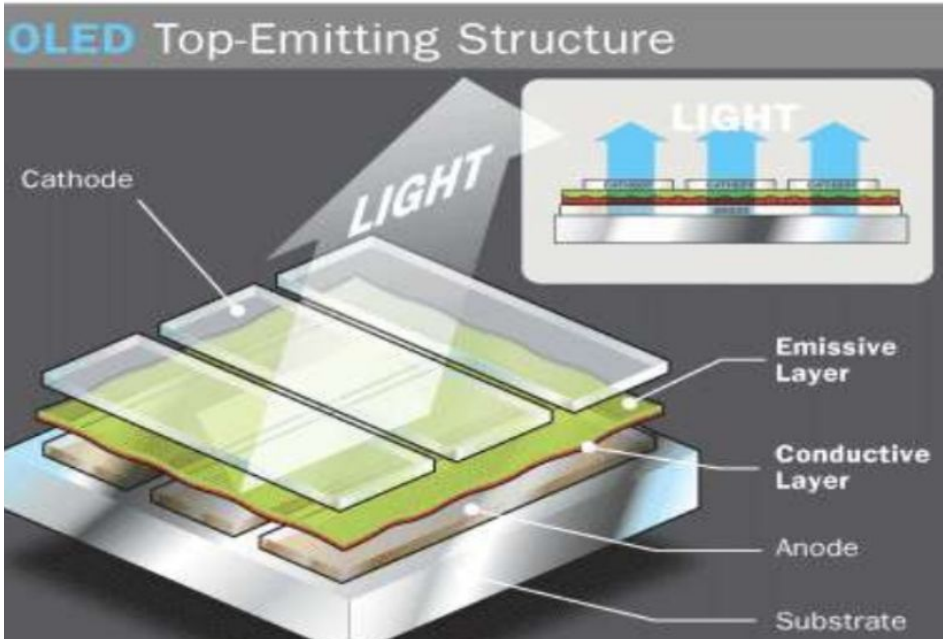


Transparent and Top Emitting OLED

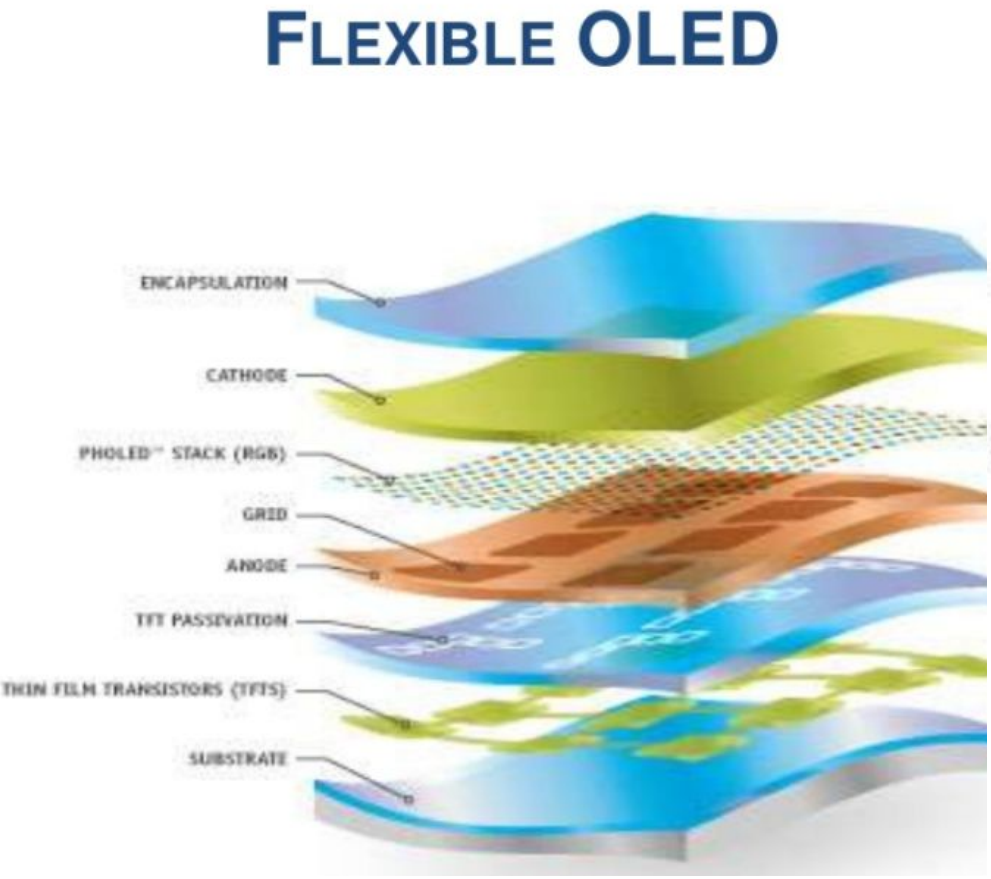
TRANSPARENT OLED

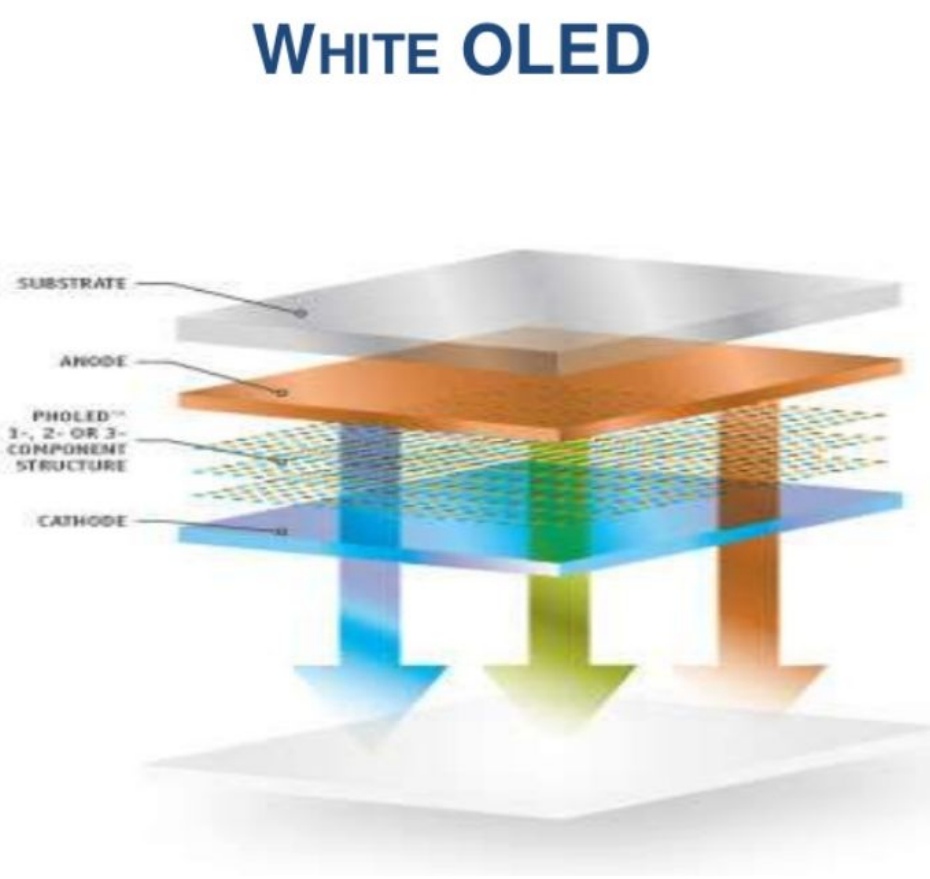


TOP EMITTING OLED



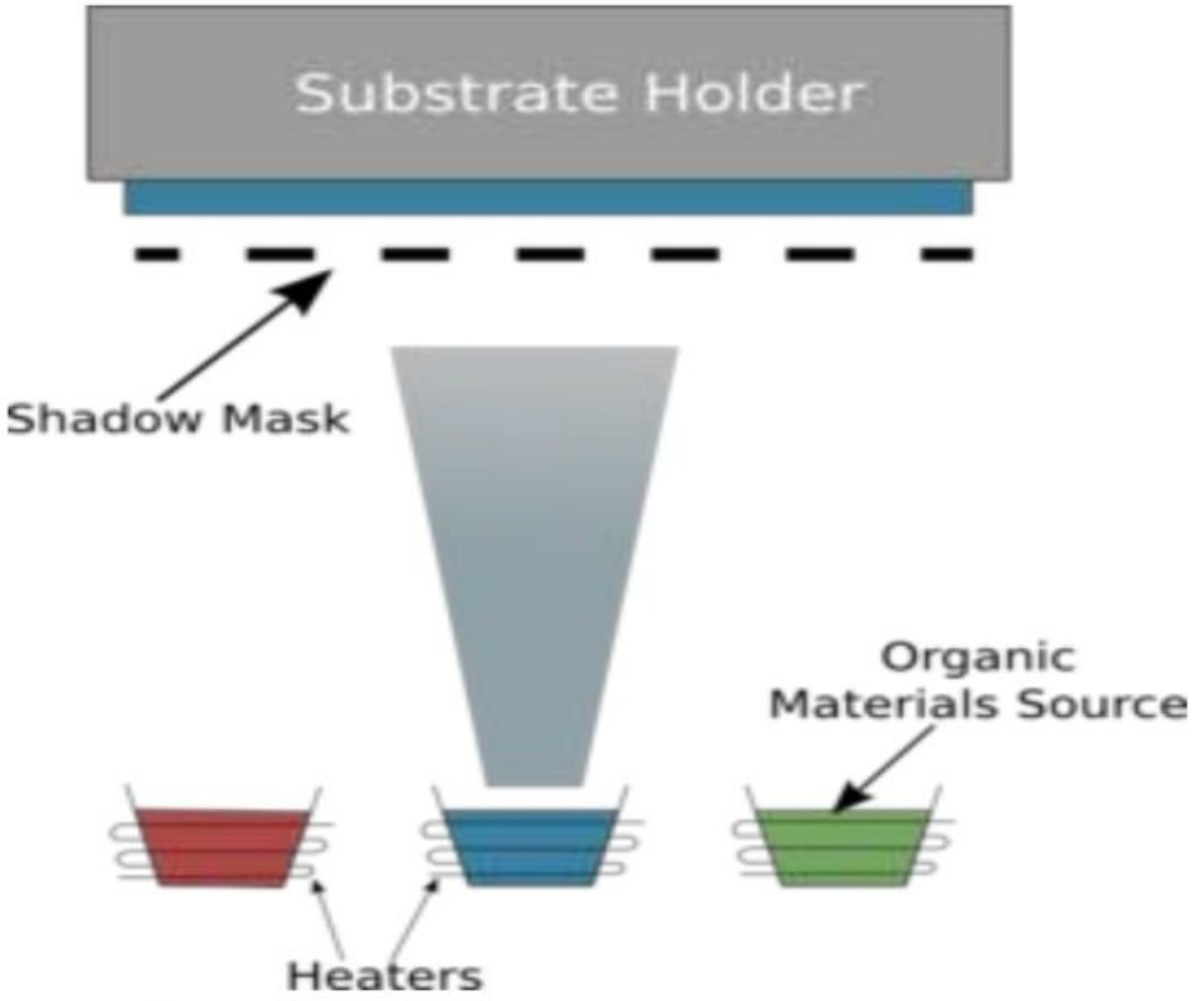
Flexible and White OLED





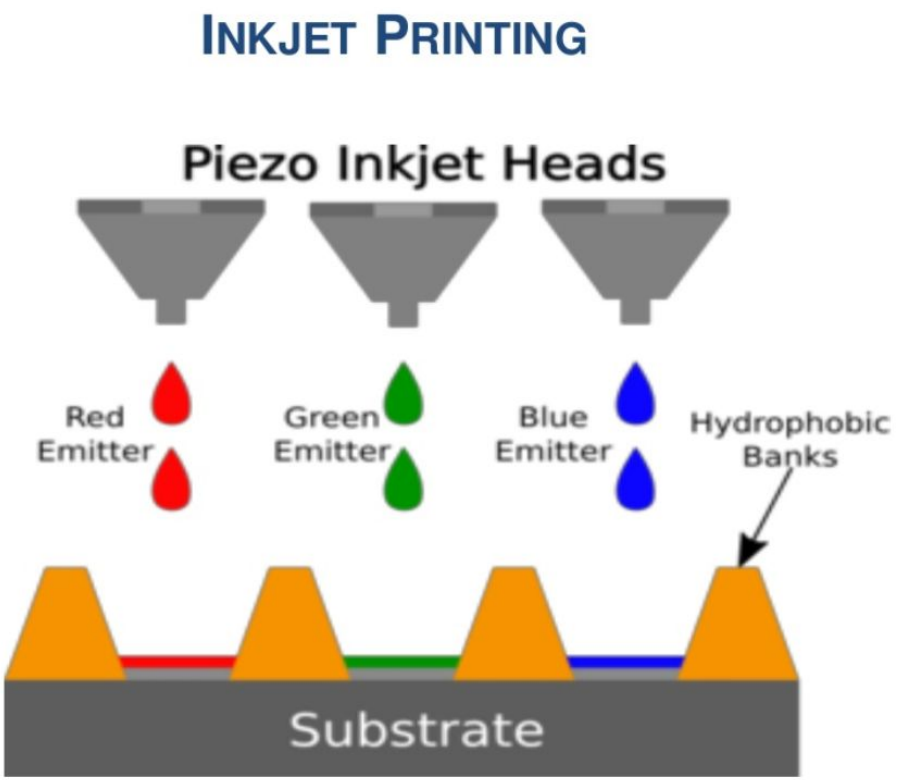
OLED Technology

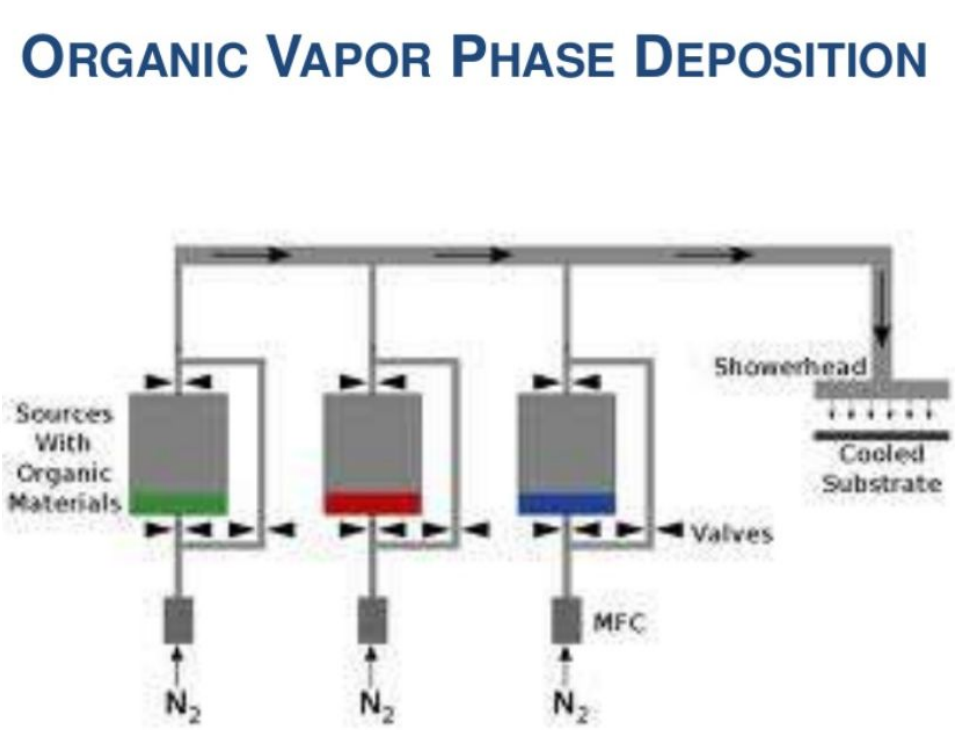
Evaporation and Shadow Masking



OLED Technology

Inkjet Printing and organic vapor phase deposition



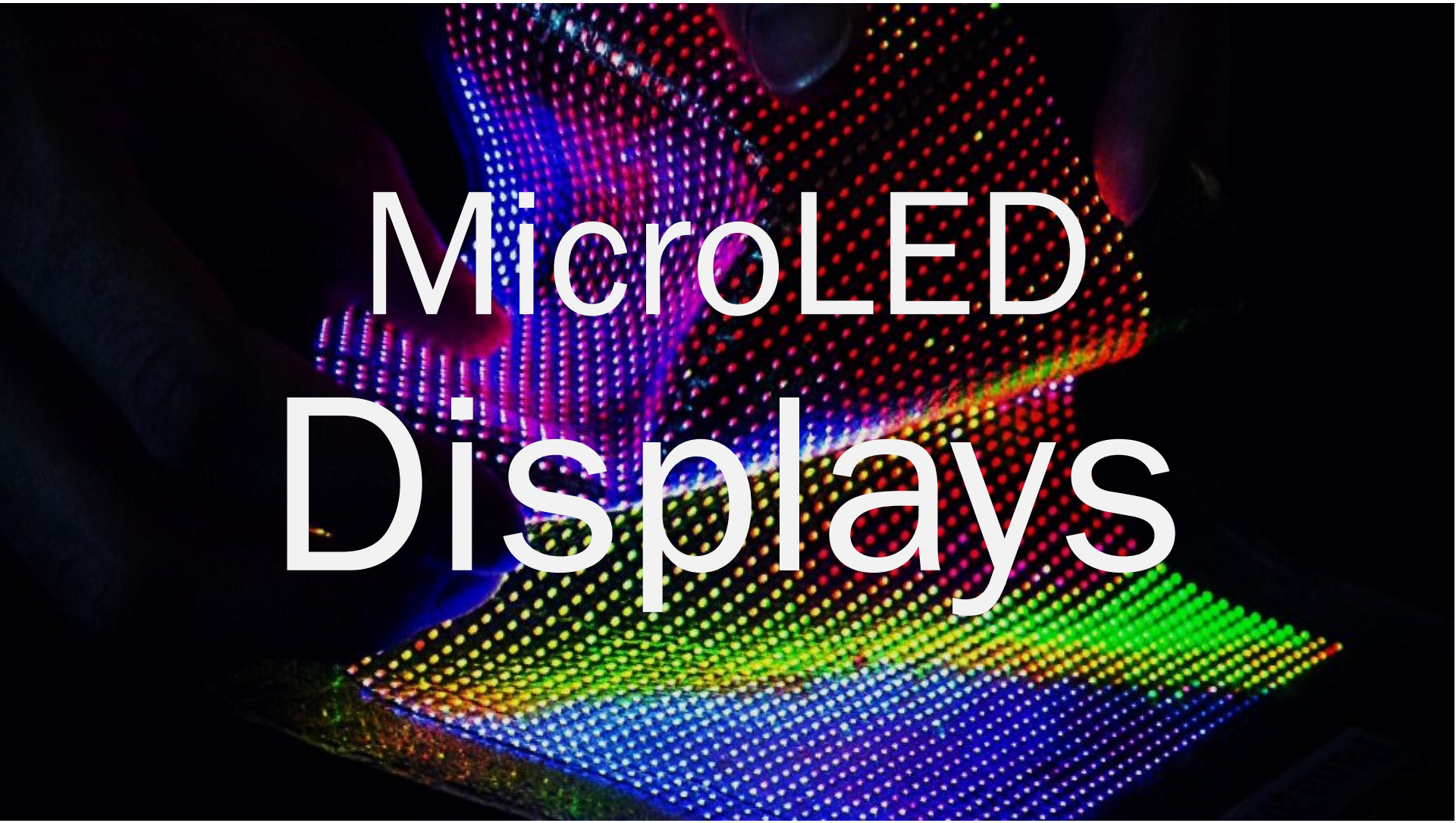


OLED Application

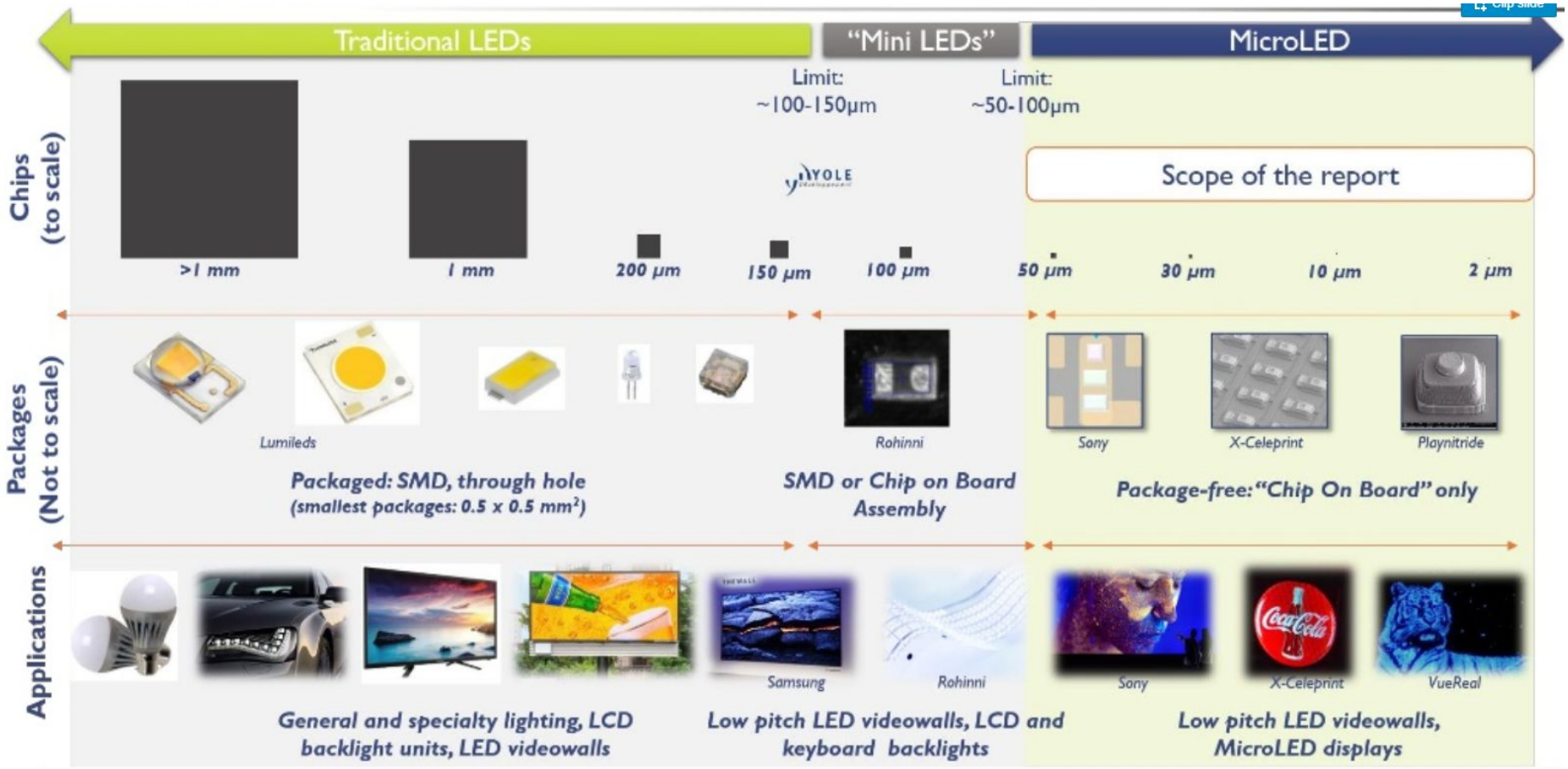
OLED TV

MOBILE PHONES WITH OLED SCREEN

ROLLTOP LAPTOP

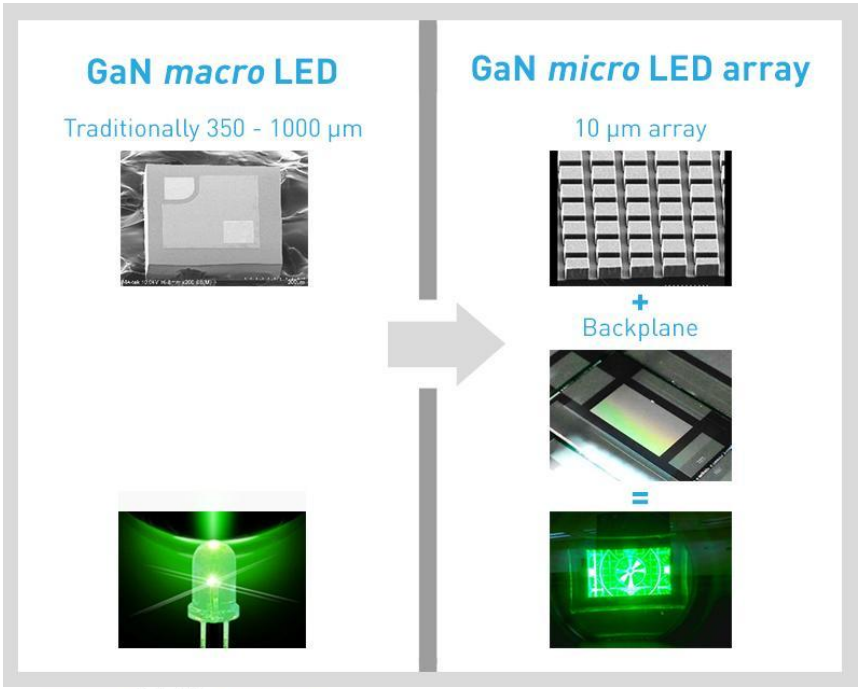

MicroLED
Displays

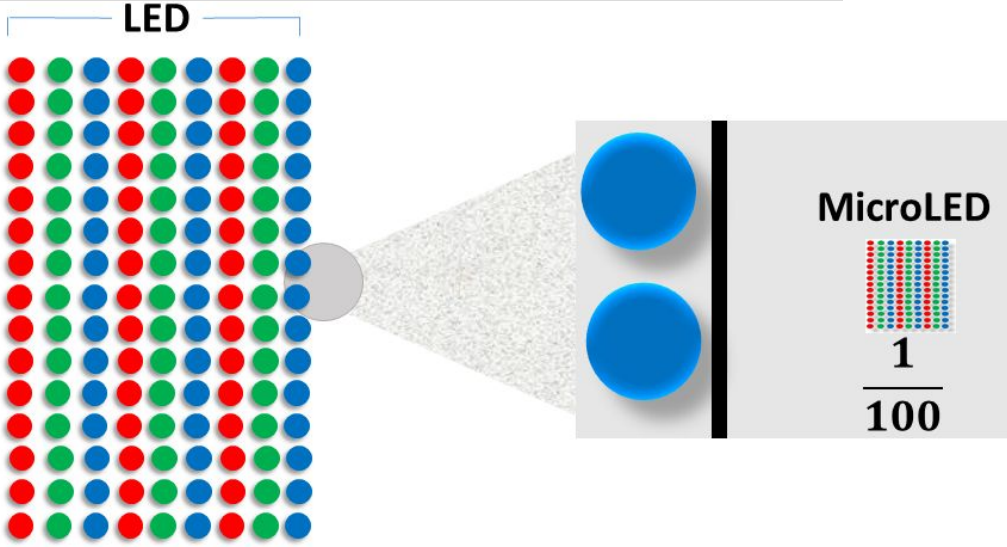
What is a MicroLED



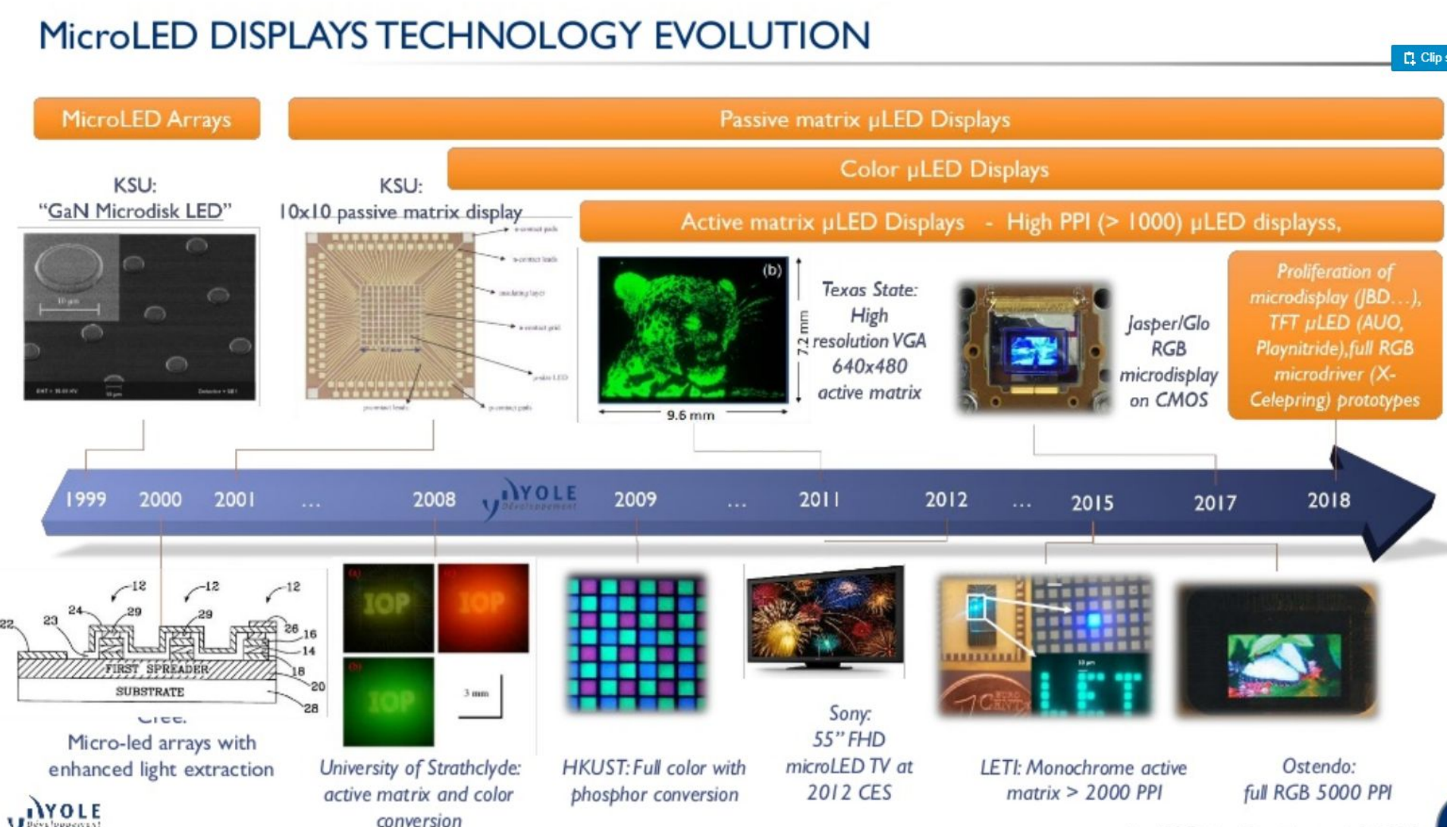
What is a MicroLED Display?

- Also known as micro-LED, mLED or µLED.
- MicroLED displays comprise several microscopic LEDs, which self-illuminate per display pixel - just like an OLED (Organic Light Emitting Diode) panel would, only MicroLED uses inorganic material.
- MicroLED features miniature length less than 100 µm. Via mass transfer technology µm–level trio-color RGB MicroLEDs are moved onto substrate , creating MicroLED display in various size.





Timeline

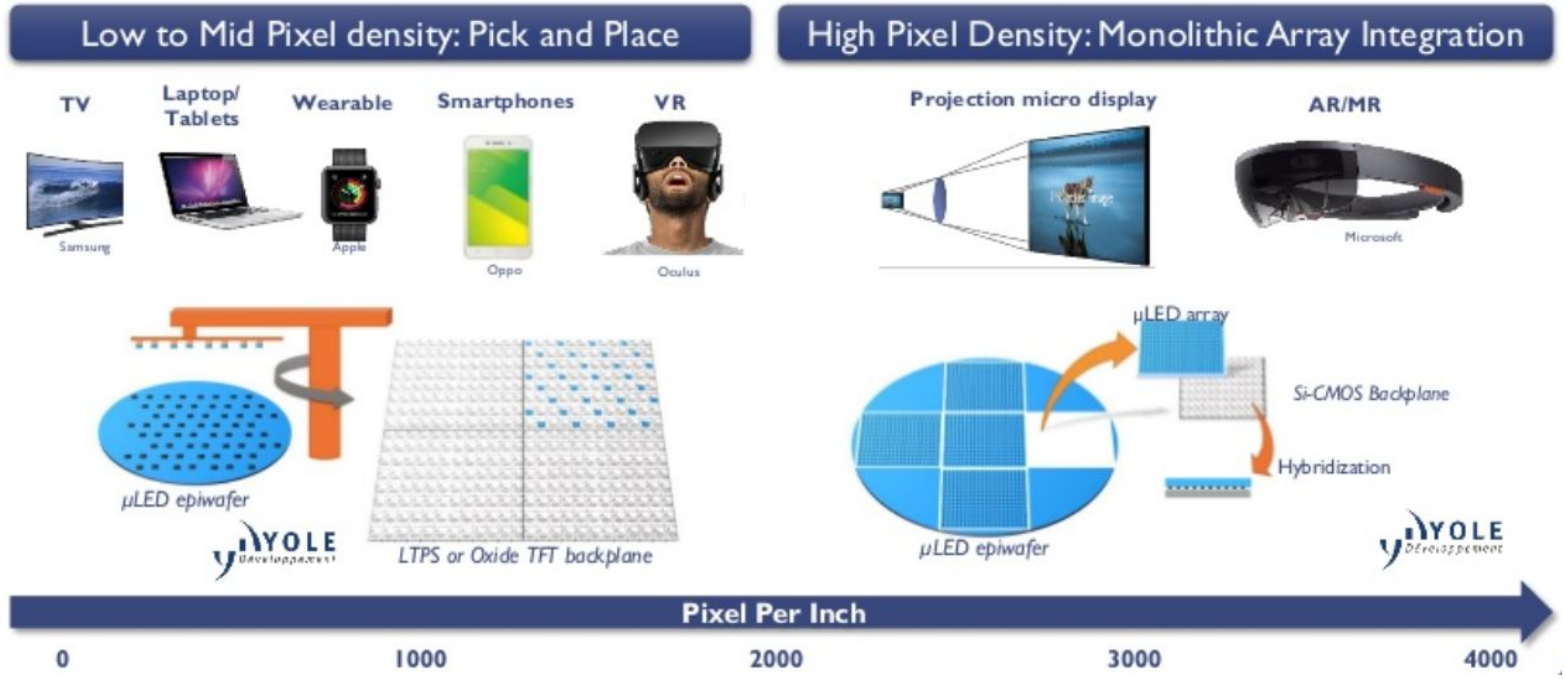

MicroLED DISPLAYS TECHNOLOGY EVOLUTION
MicroLED Arrays
Passive matrix µLED Displays
Color µLED Displays
Active matrix µLED Displays - High PPI (> 1000) µLED displayss,
KSU:
"GaN Microdisk LED"
KSU:
10x10 passive matrix display
Texas State:
High
resolution VGA
640x480
active matrix
9.6 mm
7.2 mm
Jasper/Glo
RGB
microdisplay
on CMOS
Proliferation of
microdisplay (JBD…),
TFT µLED (AUO,
Playnitride),full RGB
microdriver (X-
Celepring) prototypes
1999
2000
2001
…
2008
2009
…
2011
2012
…
2015
2017
2018
FIRST SPREADER
SUBSTRATE
Micro-led arrays with
enhanced light extraction
University of Strathclyde:
active matrix and color
conversion
HKUST: Full color with
phosphor conversion
Sony:
55" FHD
microLED TV at
2012 CES
LETI: Monochrome active
matrix > 2000 PPI
Ostendo:
full RGB 5000 PPI

Production methods for micro-LEDs

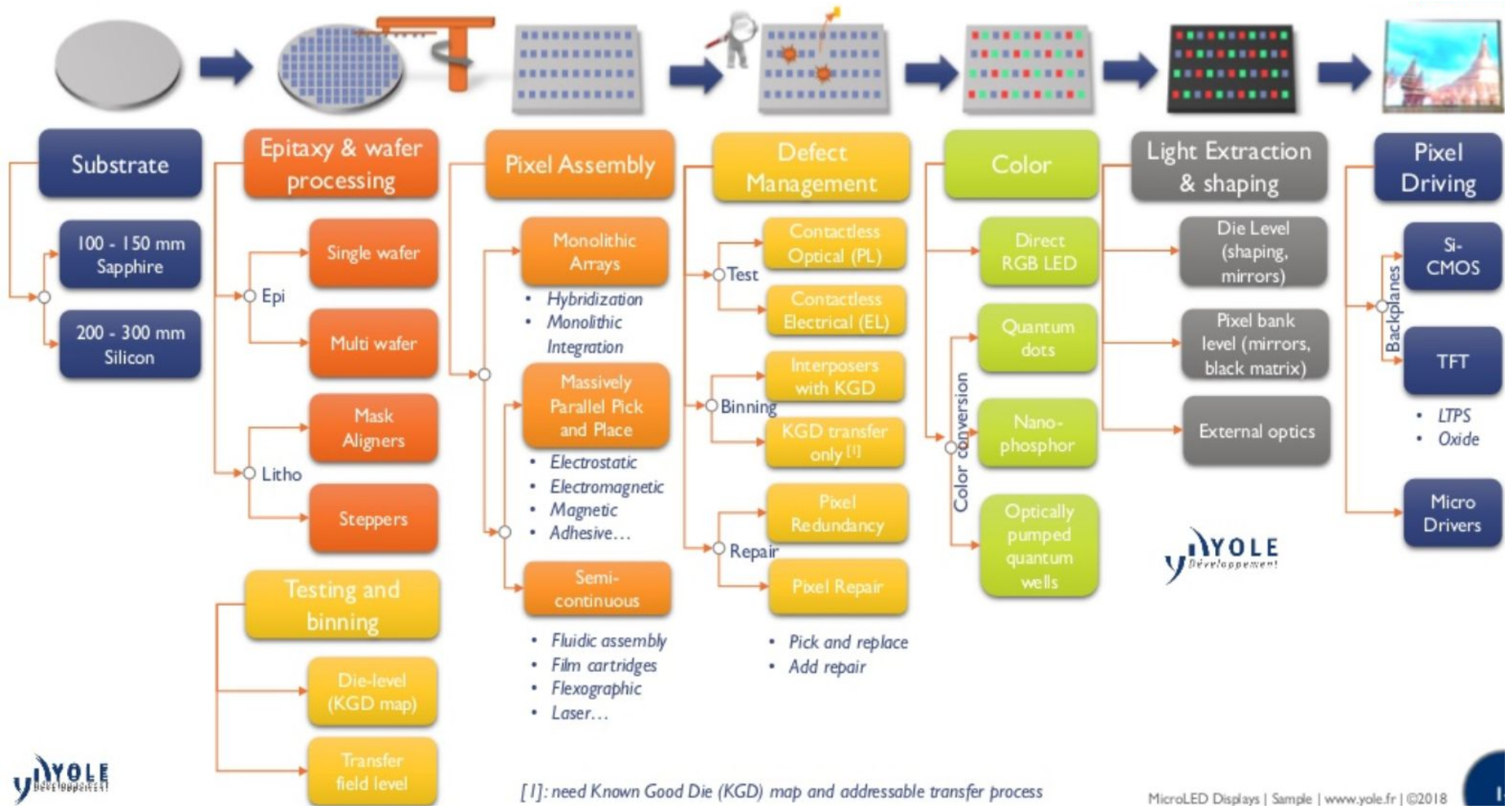
ASSEMBLY

- The art of making µLED displays consists in processing a bulk LED substrate into an array of micro-LEDs which are poised for pick up and transfer to a receiving substrate for integration into heterogeneously integrated system: the display (which integrates, LEDs, transistors, optics, etc.). Epiwafers can accommodate 100's of millions of µLED chips compared to 1000's with traditional LEDs.
- The micro-LEDs can be picked up and transferred individually, in groups, or as the entire array of 100,000's of µLEDs:

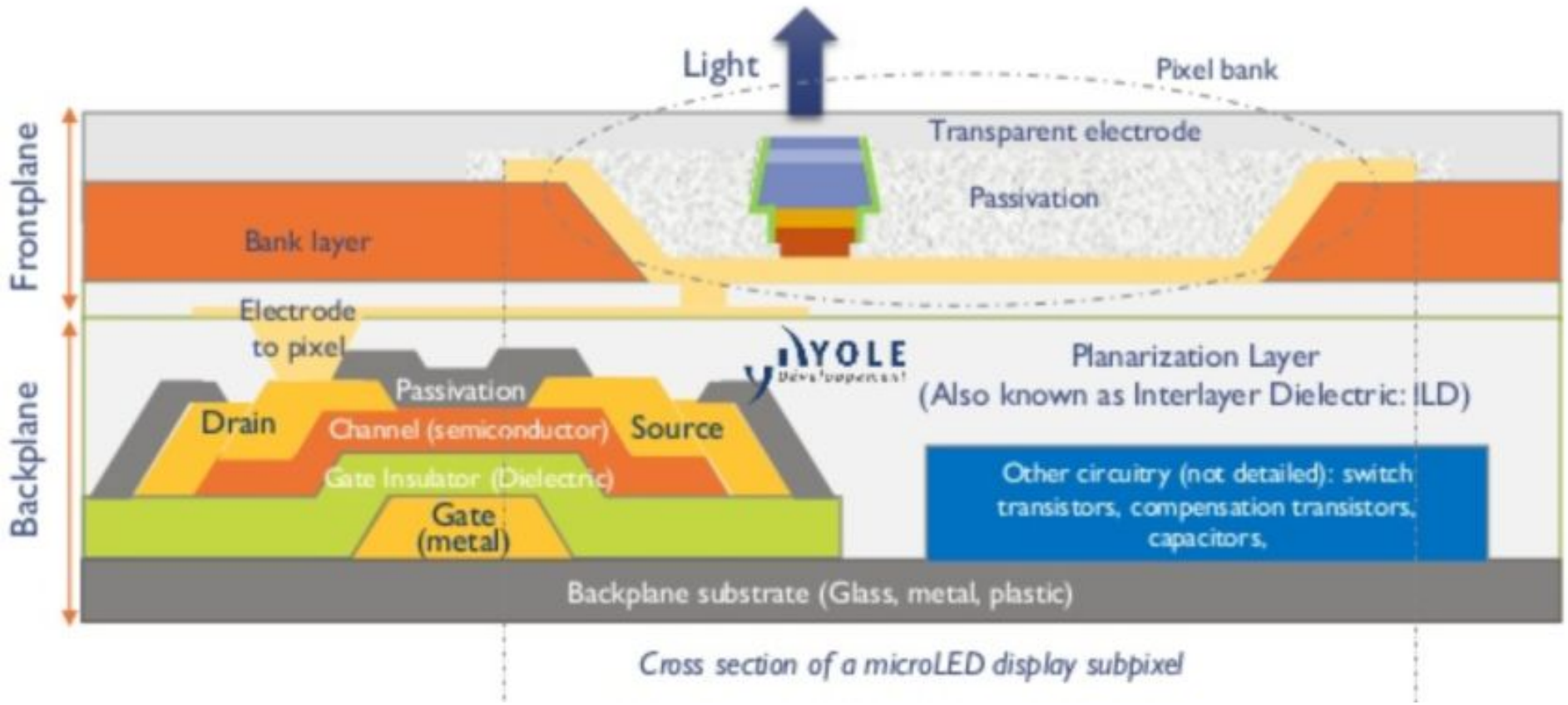
Monolithic integration of µLED arrays is preferred for the realization of displays with high pixel densities.



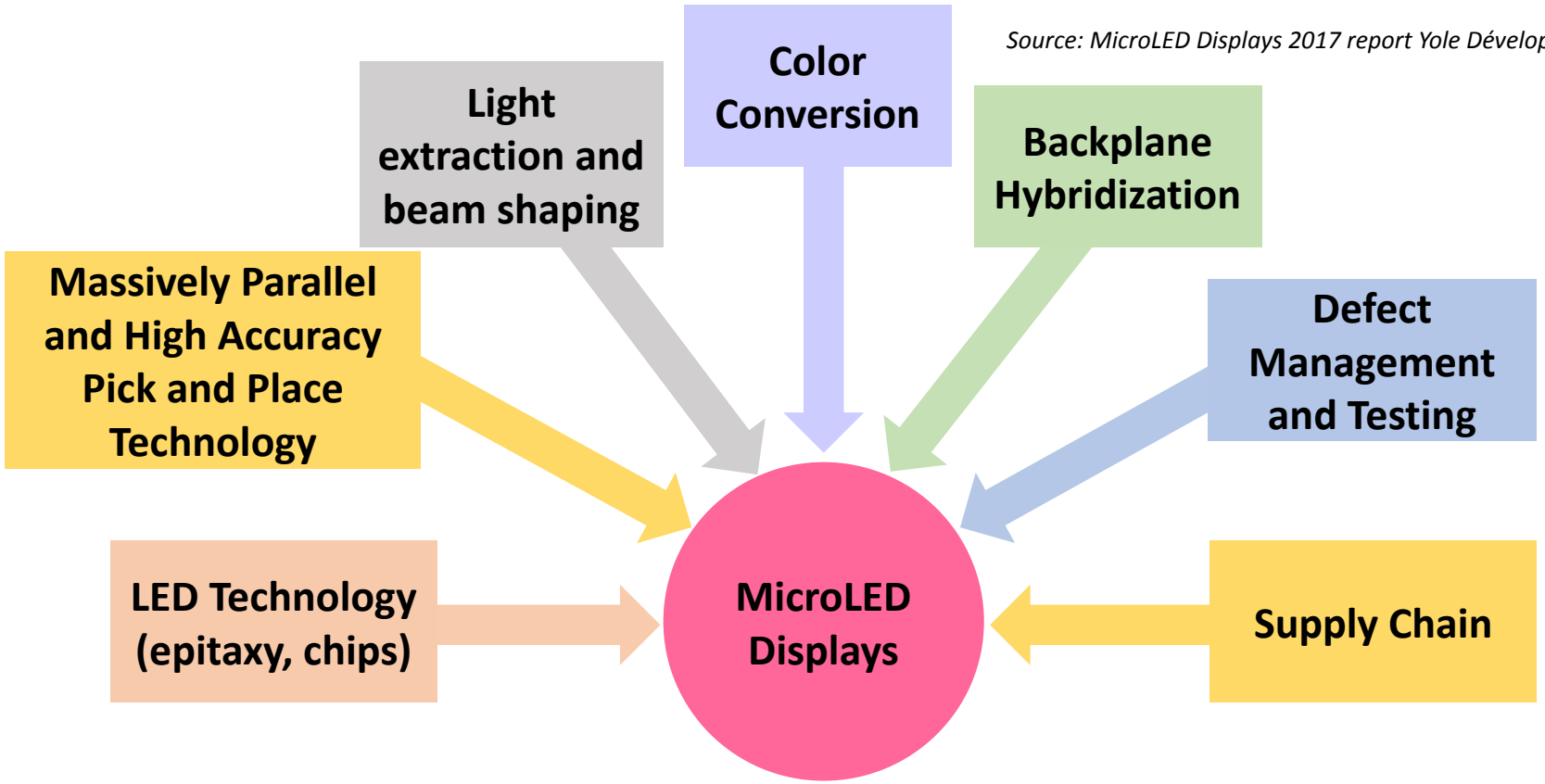
Major manufacturing technology bricks



MicroLED and addressing structure



MicroLed Display Manufacturing Challenges

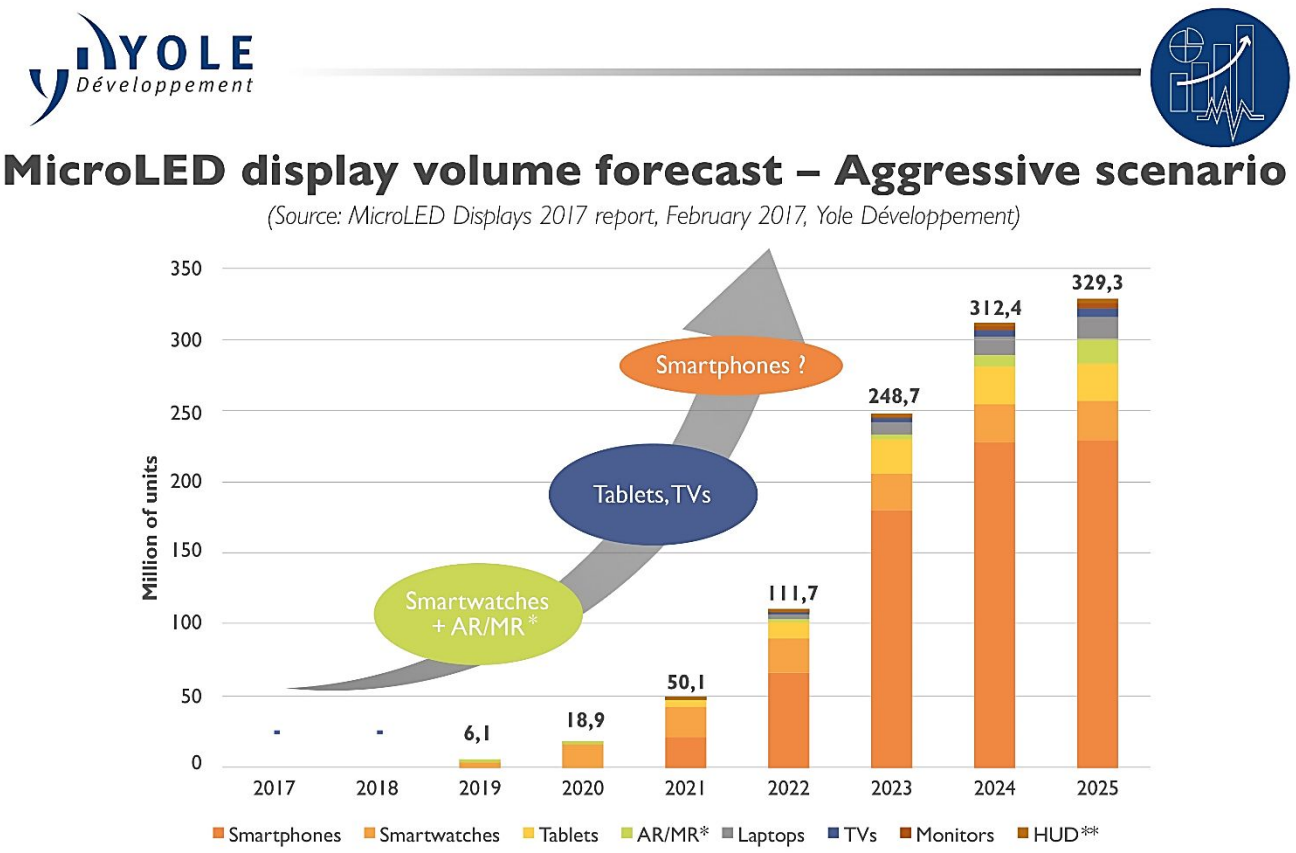


TFT-LCD vs OLED vs MicroLED

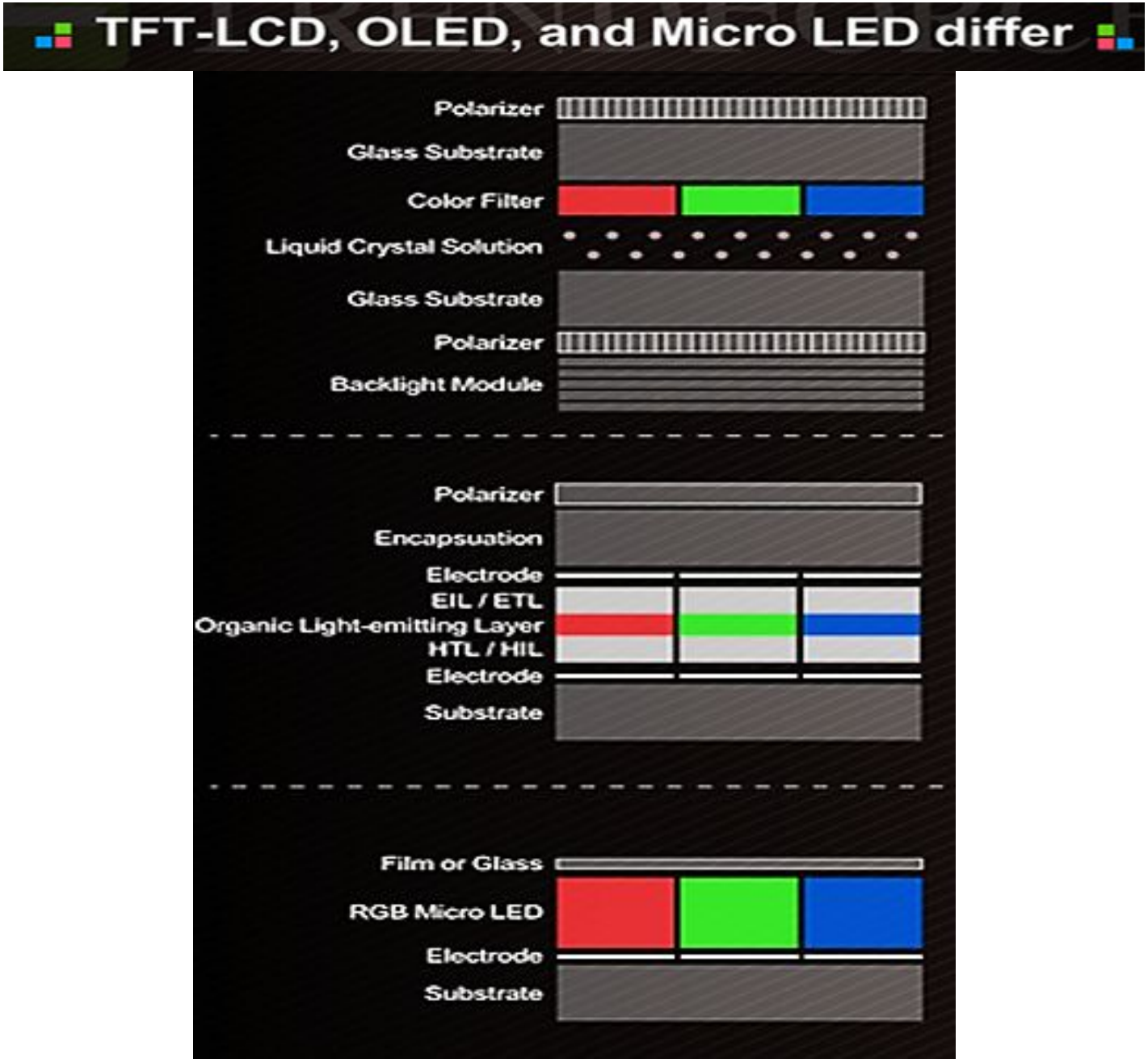
Display technique	LCD	OLED	Micro LED
Technological type	Back light/LED	Self-Illumination	Self-Illumination
Contrast ratio	5,000:1	∞	∞
Lifetime	Medium	Medium	Long
Response time	ms	μs	ns
Operating temperature	-40 to 100℃	-30 to 85℃	-100 to 120℃
Cost	Low	Medium	High
Energy consumption	High	Medium	Low
Viewing Angle	Low	Medium	High
PPI（Wearables）	Max 250 ppi	Max 300 ppi	Above 1500 ppi
PPI(VR)	Max 500 ppi	Max 600 ppi	Above 1500 ppi

Applications of MicroLED

- Smart Watches and Wearables
- Virtual reality
- Augmented/Mixed Reality
- Automotive Head-Up Display
- Large Video Displays
- 8K UHD TVs
- Smartphones
- Laptop/Tablets

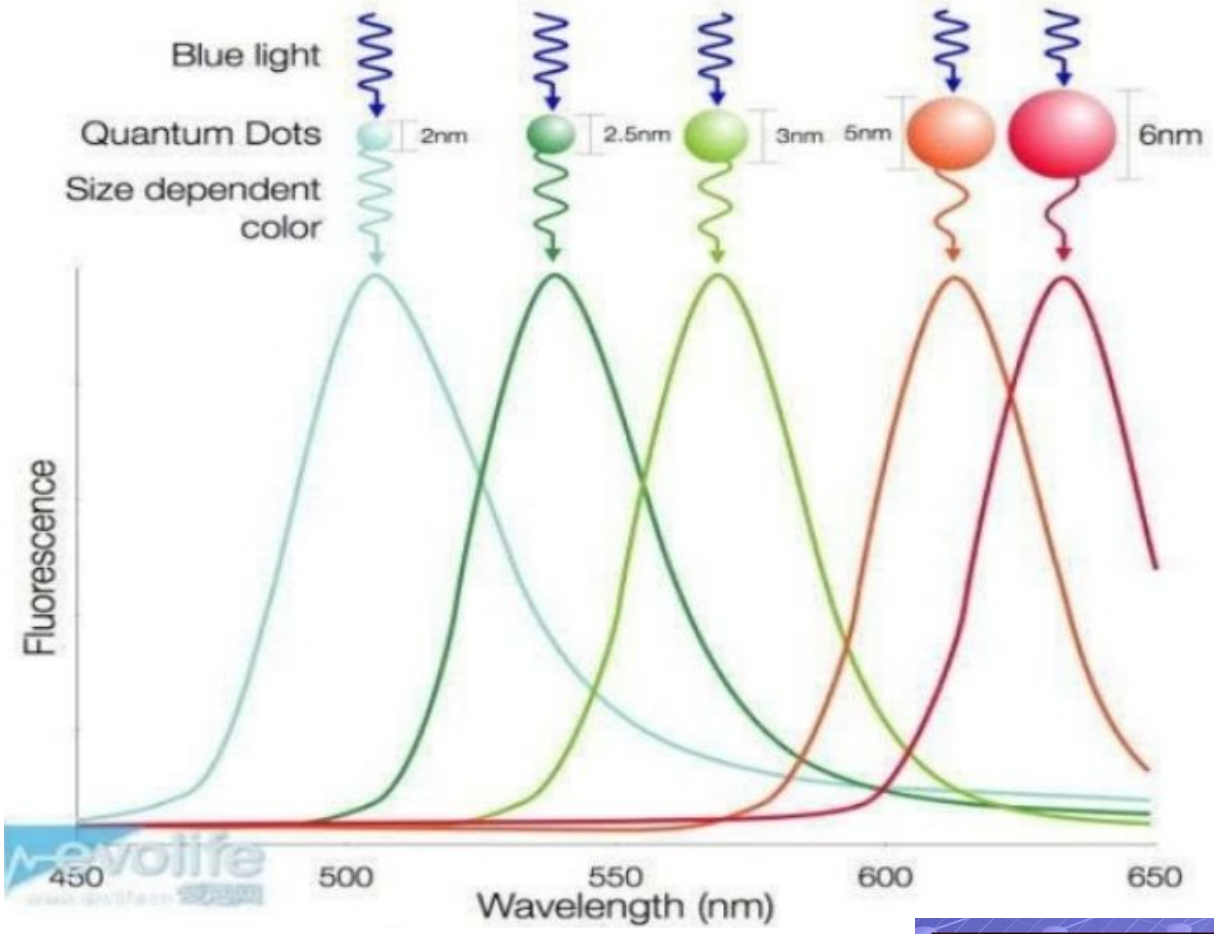


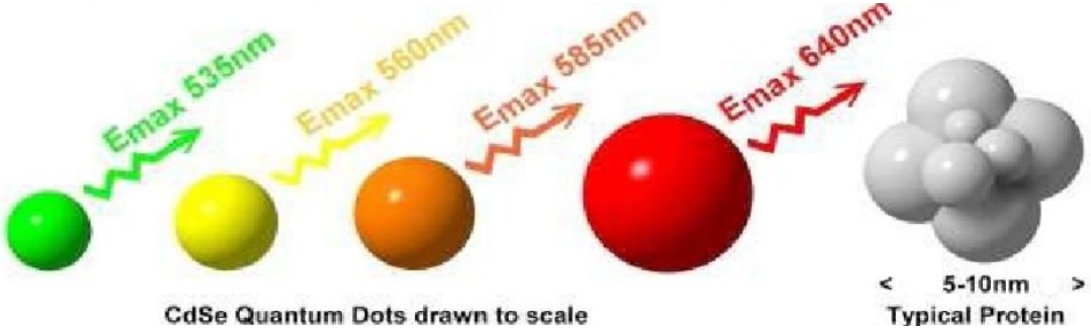
Conclusion

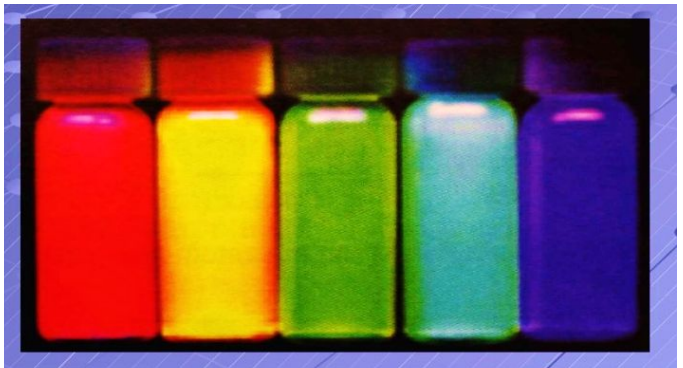

TFT-LCD, OLED, and Micro LED differ
Polarizer
Glass Substrate
Color Filter
Liquid Crystal Solution
Glass Substrate
Polarizer
Backlight Module
Polarizer
Encapsuation
Electrode
EIL / ETL
Organic Light-emitting Layer
HTL / HIL
Electrode
Substrate
Film or Glass
RGB Micro LED
Electrode
Substrate

Quantum Dot Display

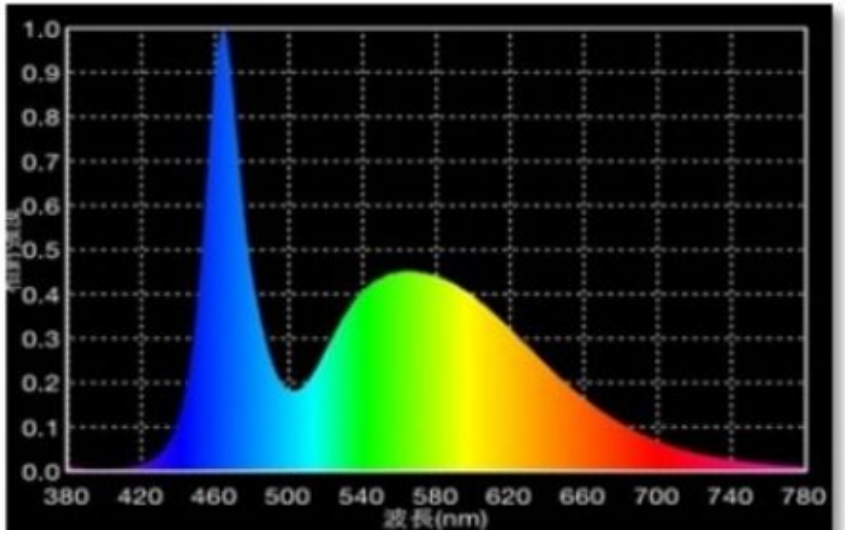
Quantum Dot Size and Color

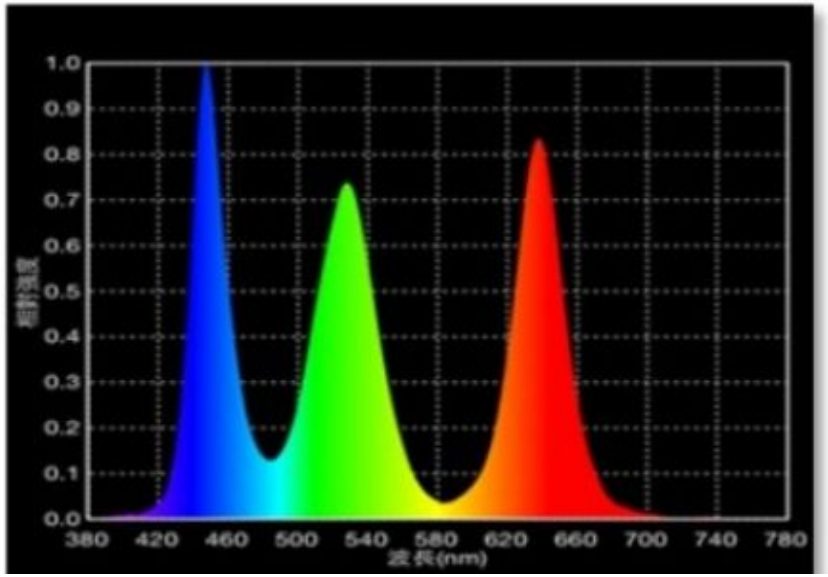




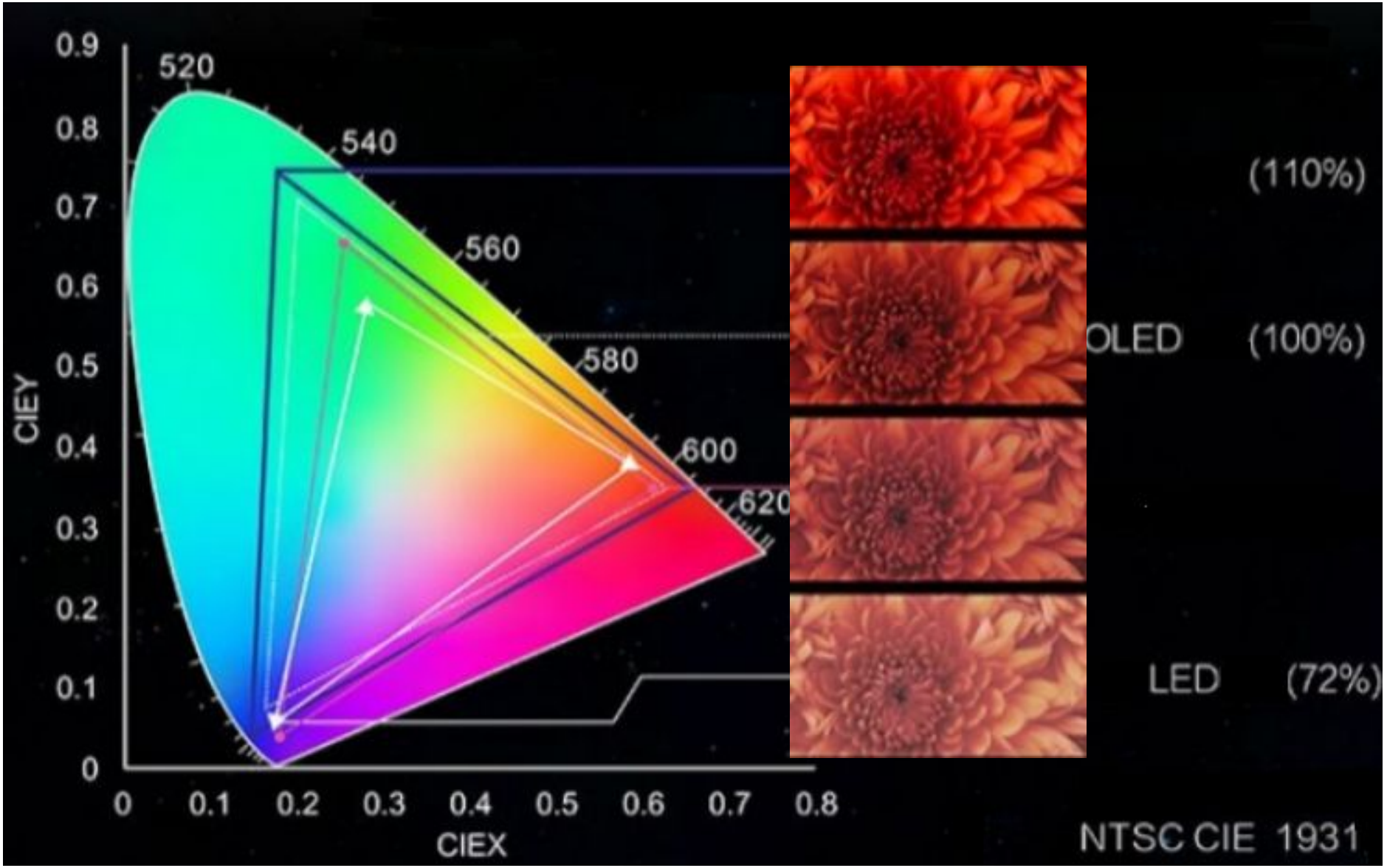


White LED vs Quantum Dot

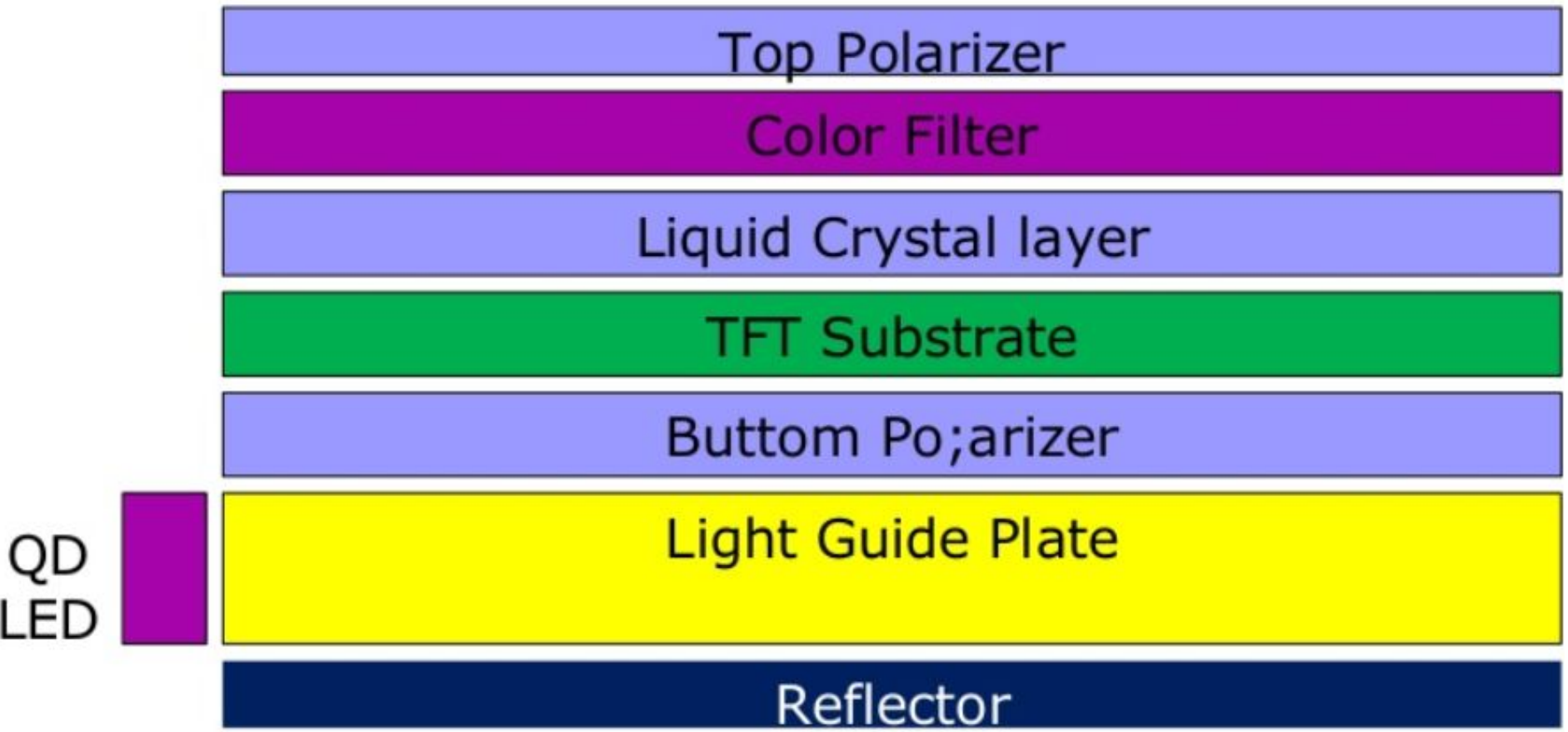




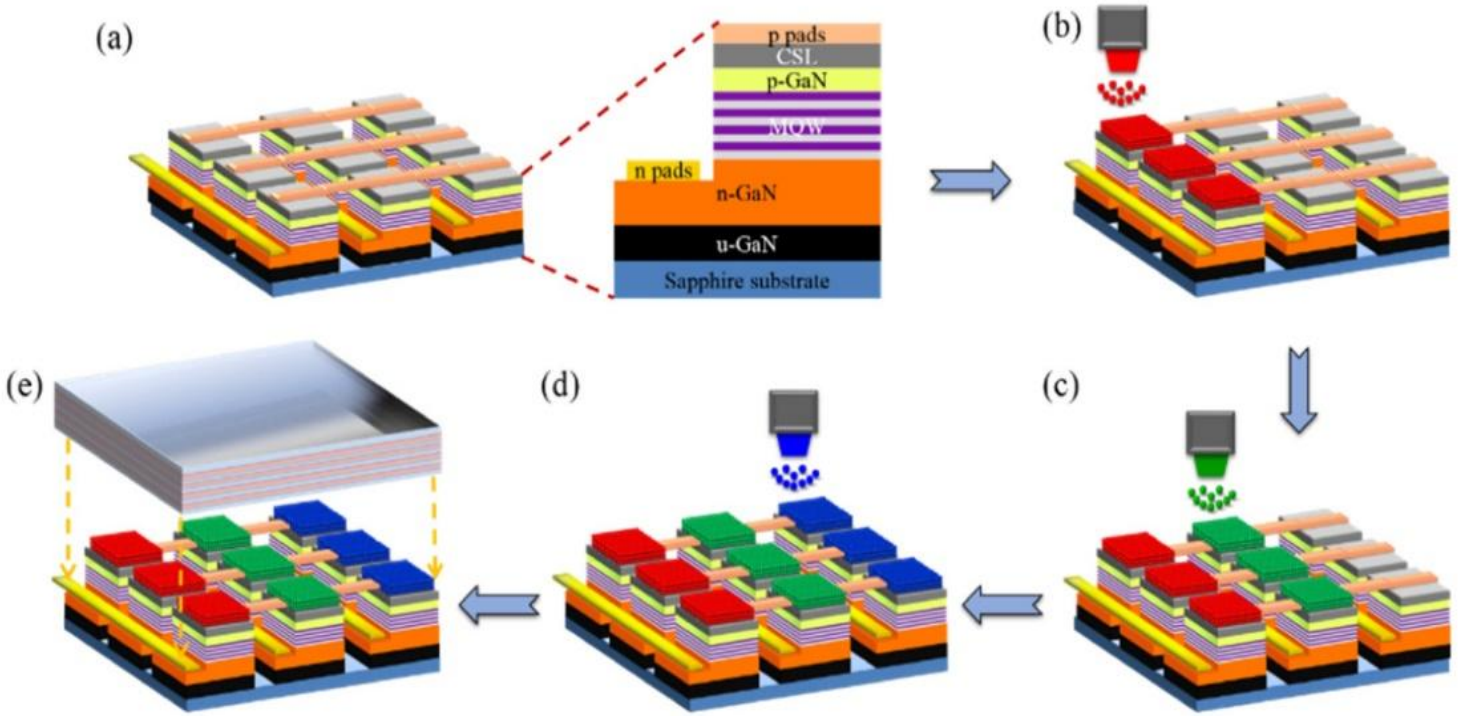
High Color GAMUT



On-& In-Chip type of Quantum dot

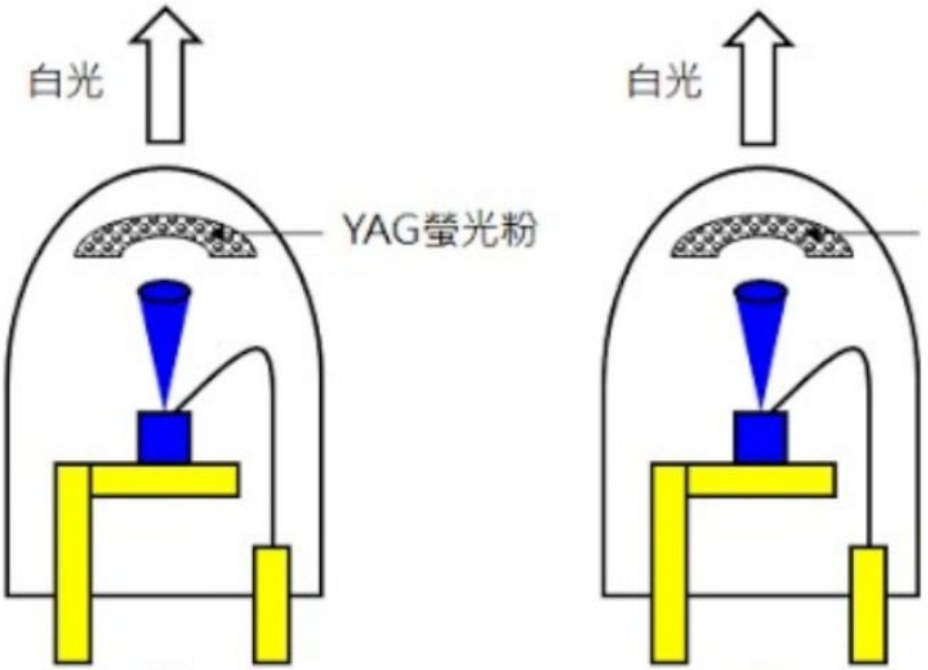


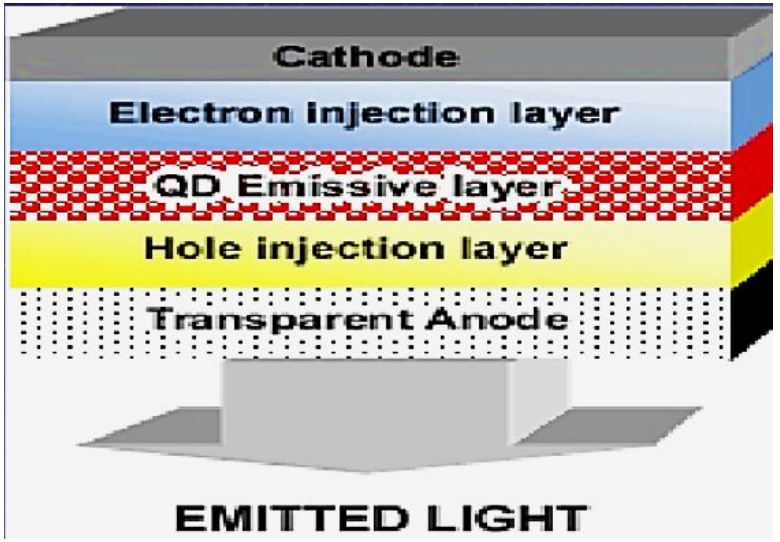
MicroLED + Quantum dots



The process flow of the full-color emission of quantum-dot-based micro LED display.

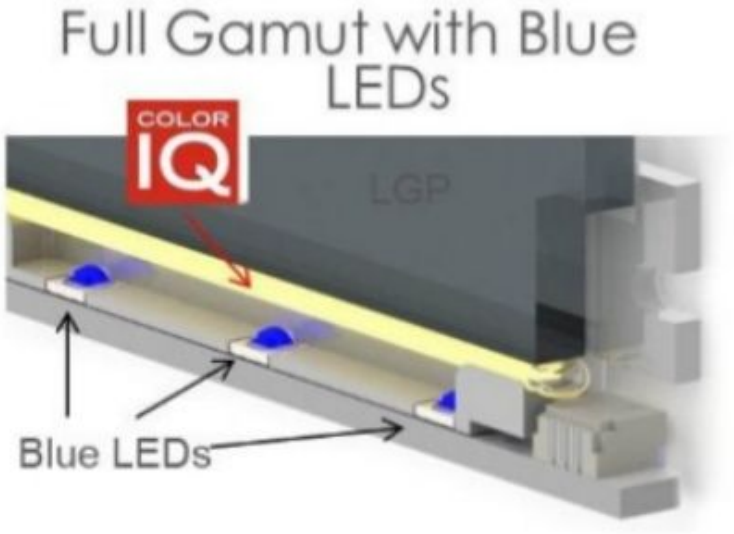
White LED vs Quantum Dot-LED

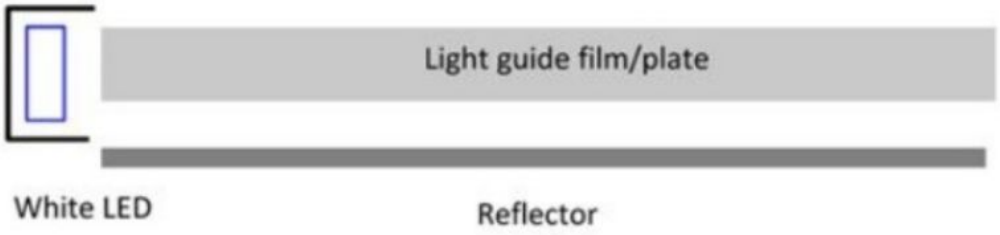




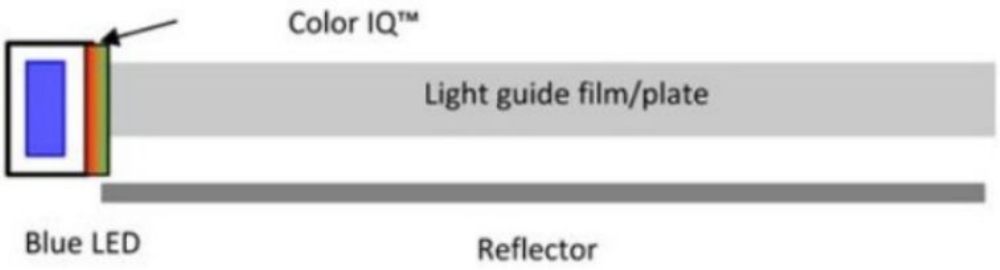
On-Edge type of Quantum dot

Types of realization

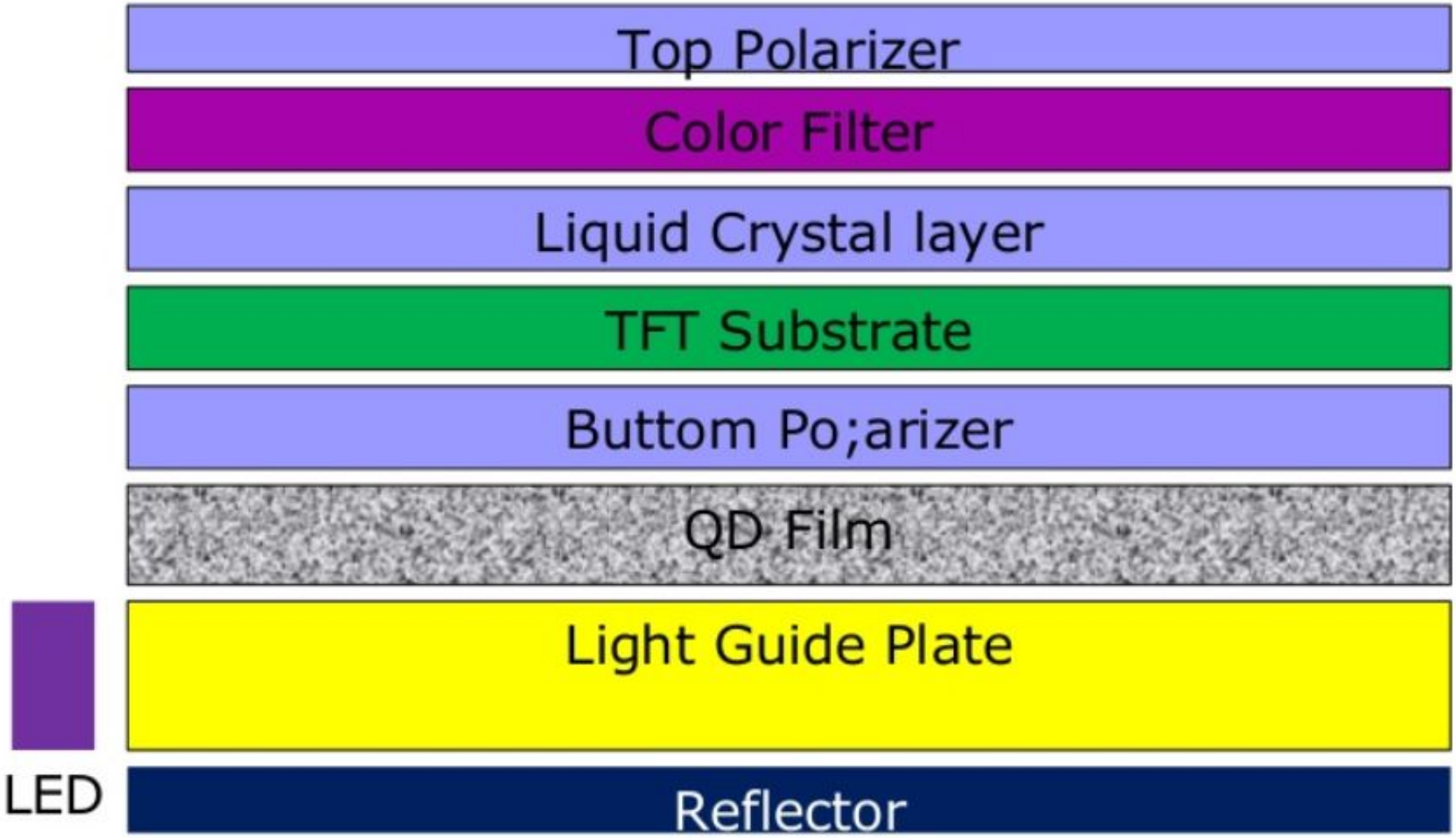




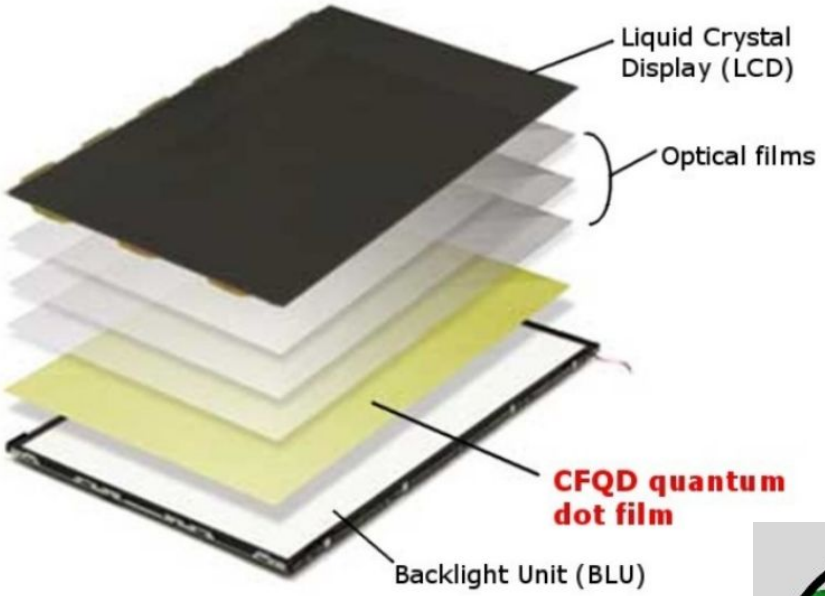
Color IQ™ Solution

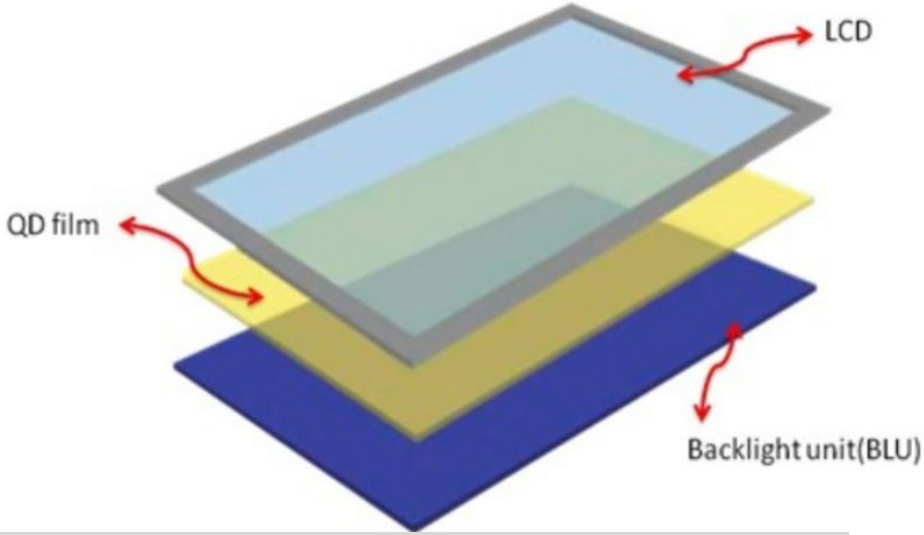


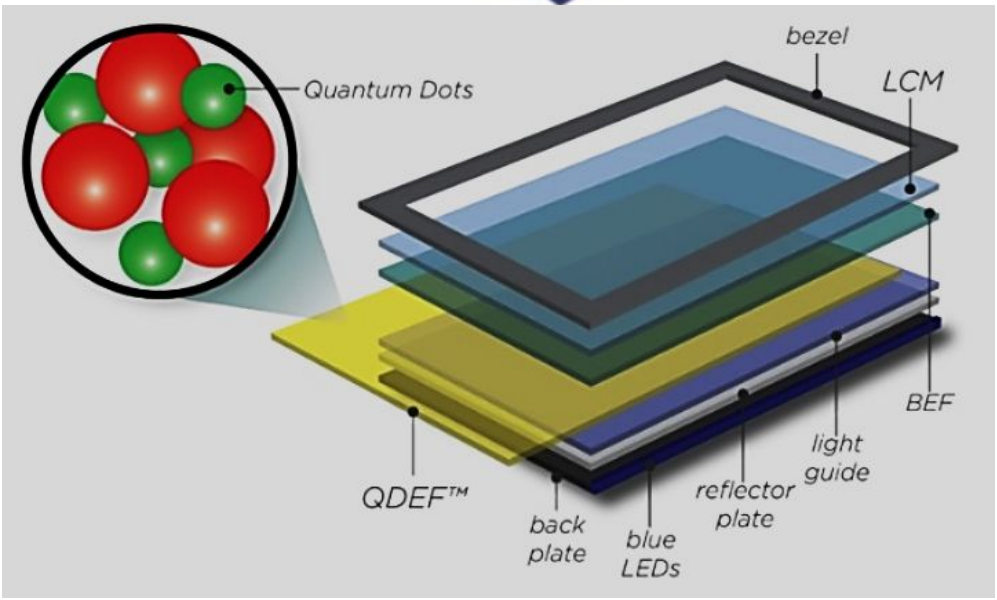
On-Surface type of Quantum dot



Types of realization







Comparison of Quantum Dot Display

Type	Conventional	On-Chip	On-Edge	On-Surface
Structure	WLED+LGP	QD-LED+LGP	LED+QD Optics+LGP	LED+QD Film+LGP
Players	All	--	QD Vision	Nanosys, Nanoco
TV makers	All	--	TCL, Hisense	Samsung

Conclusion

- A new nano crystal material
- High efficiency, low power
- High Color Gamut
- Do not change conventional LCD Manufacture process
- Superior to WLED light source
- Wide adoption in TV and monitor market