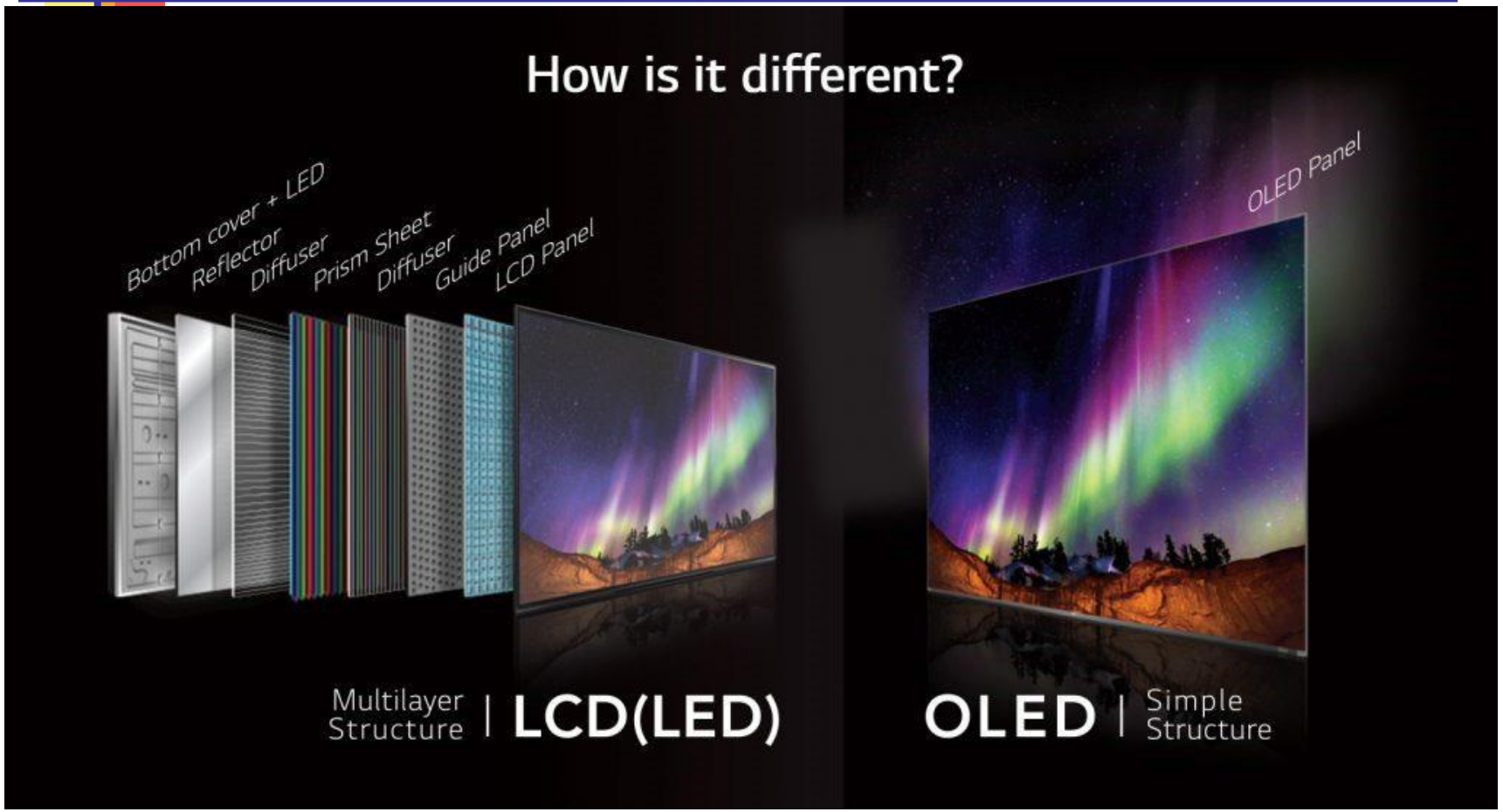
Introduction to System-on-Chip and its Applications

Display System

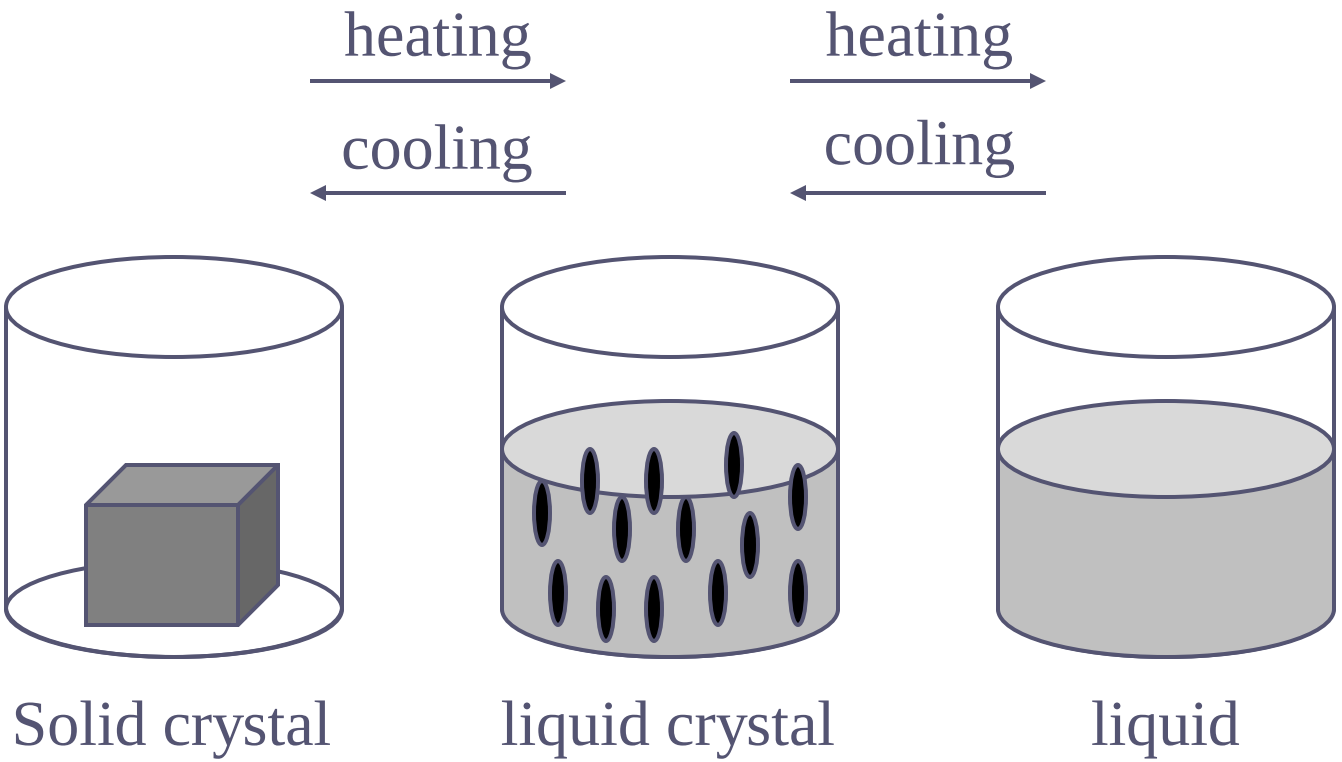
DISPLAY Systems

- Liquid Crystal Display LCD
- Light Emitting Diode LED
- Organic Light Emitting Diode OLED

LCD and OLED for TV

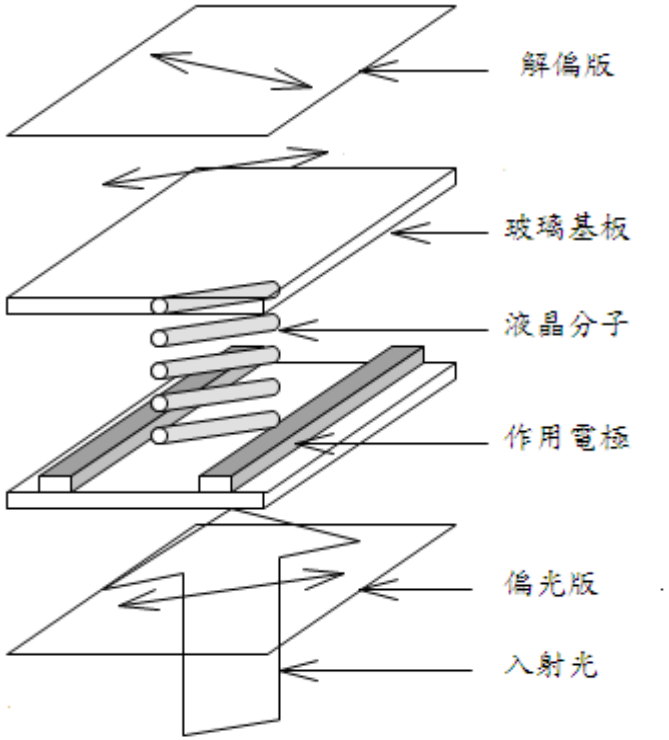


Phase change of liquid crystal



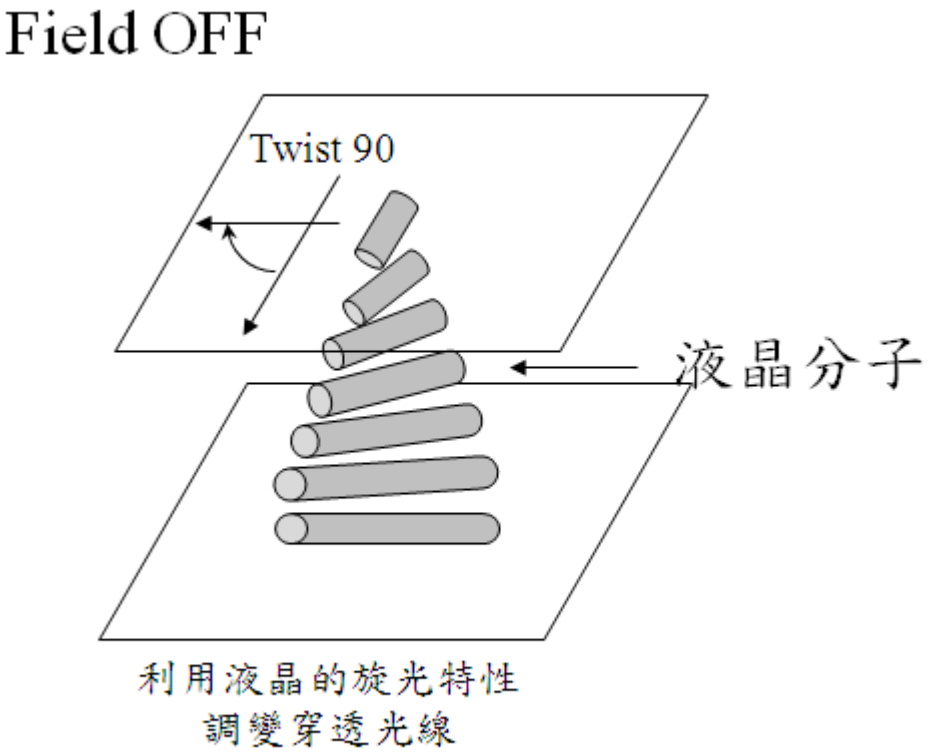
LCD(Liquid Crystal Display)

1. Light source (can’t display without light source)
2. Light polarization plate
3. Bottom glass
4. Liquid Crystal
5. Upper glass
6. Depolarization plate



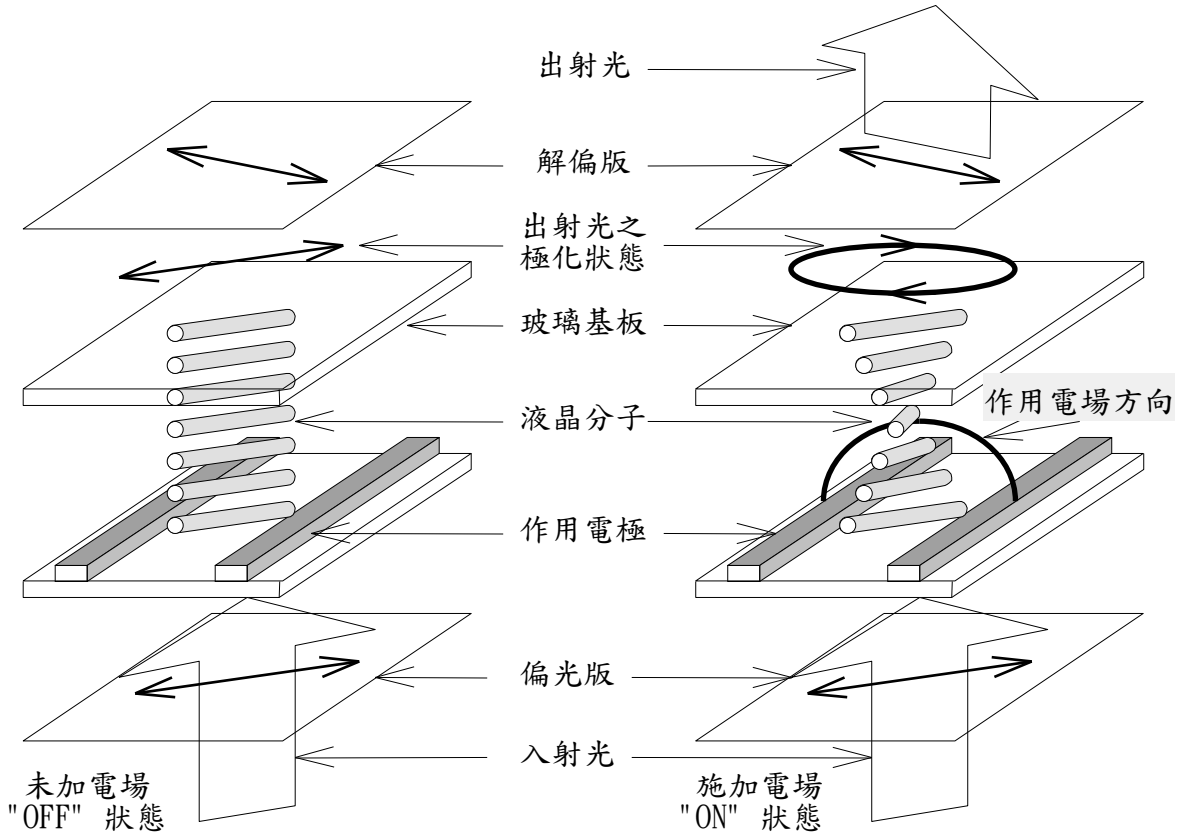
Twist Nematic (TN)

- **How Liquid Crystal Bring Light to top of the display?**
  Twist of liquid crystal of 90 degree to bring light to top polarity plane



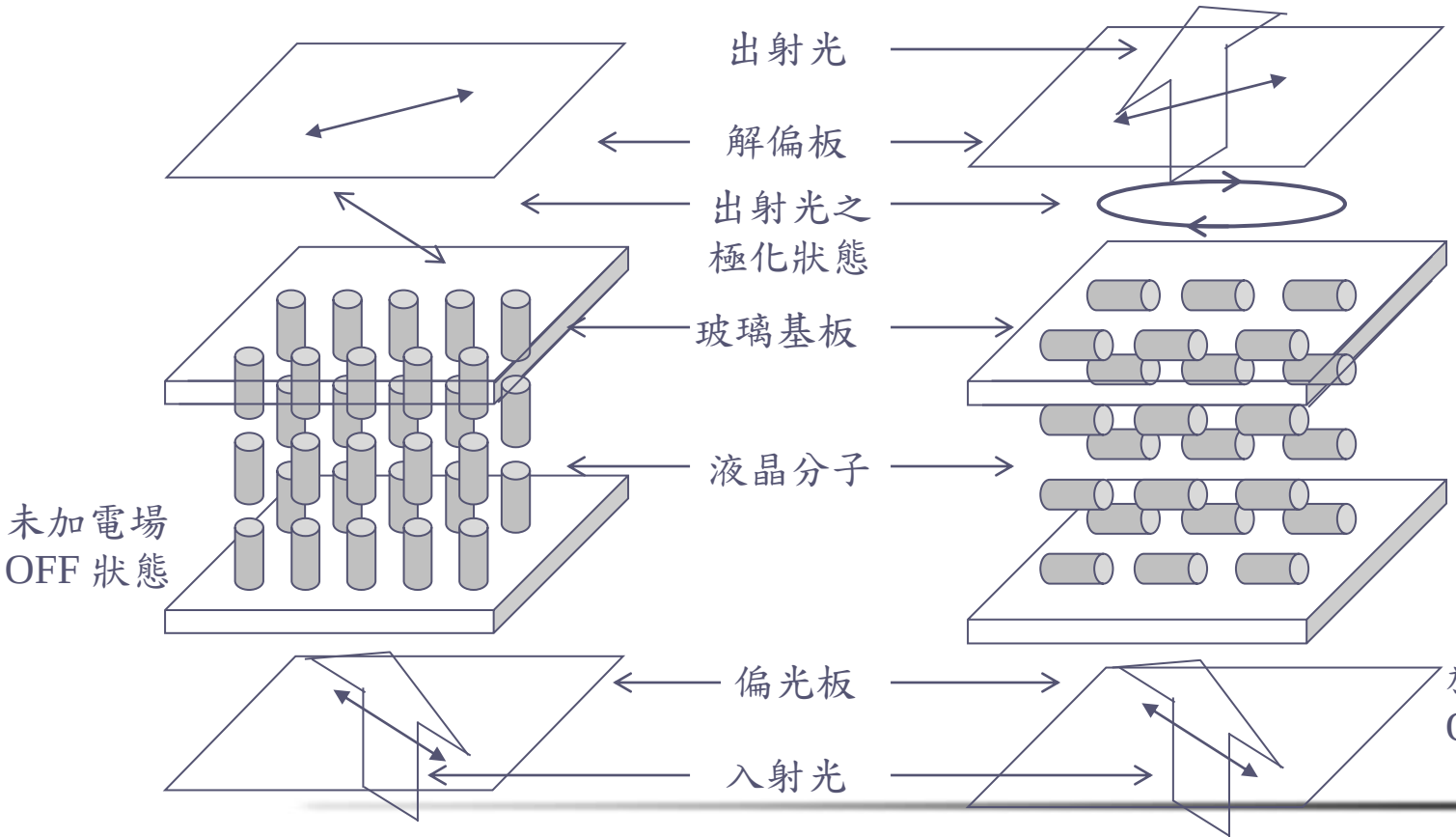
In-Plane-Switch(IPS) Mode LCDs

- LD remains flat steady when field is off
- LD twists in flat when field is on(using voltage to control rotate angle)
- Good Viewing angle



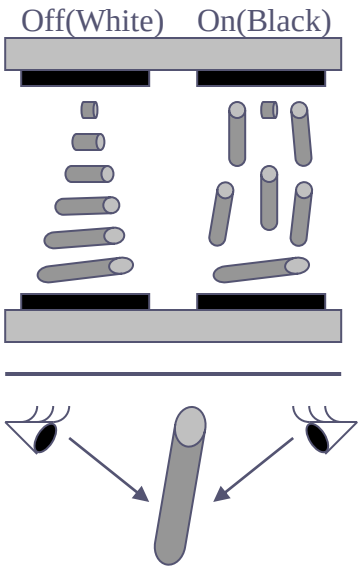
Vertical Alignment (VA) Mode LCDs

- LD remains steady up when field is off
- LD twists in flat when field is on(using voltage to control rotate angle)
- Good Viewing angle



Comparison of Liquid Crystal Modes

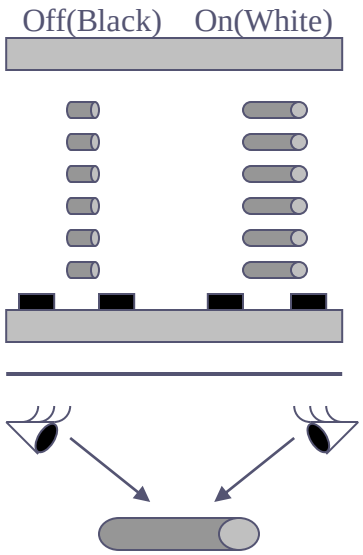
TN



Strongly dependent
on viewing angle

- ○ 低驅動電壓
- ✕ 視角窄小(low-end display)

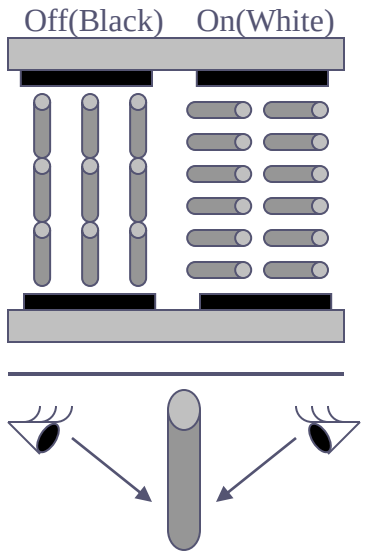
IPS



Slightly dependent
on viewing angle

- ○ 廣視角(High end display)
- ✕ 液晶反應速度慢
- ✕ 畫面對比低
- ✕ 畫面品質差

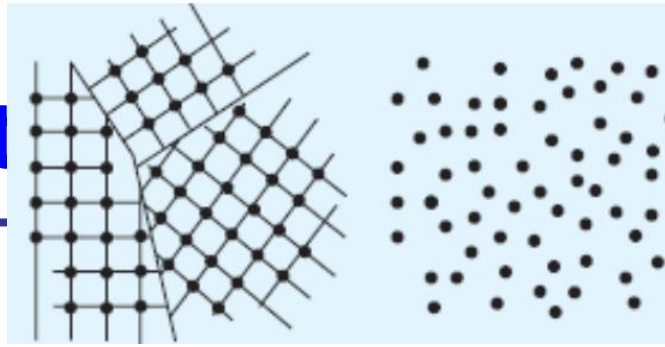
VA



Slightly dependent
on viewing angle

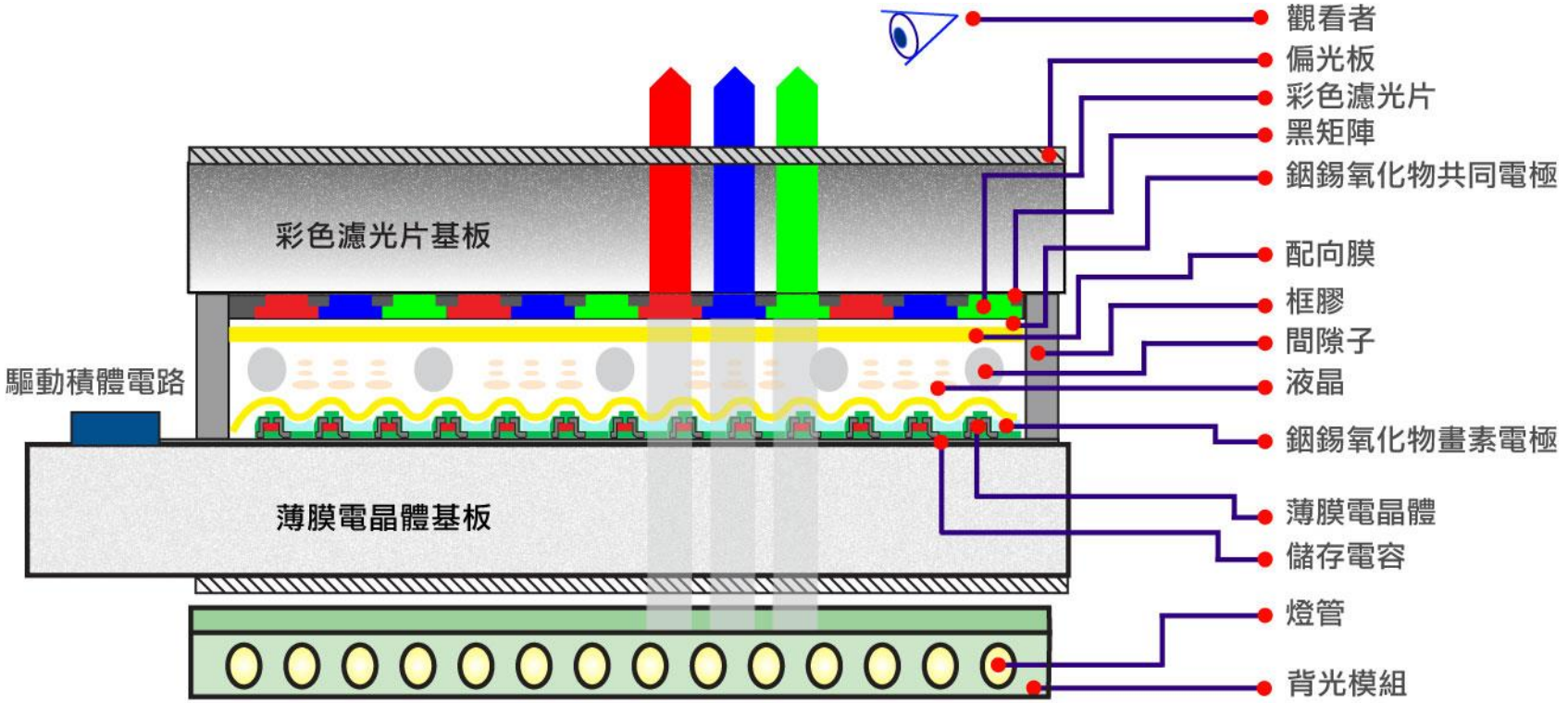
- ○ 畫面對比高(high end display)
- ○ 廣視角
- ○ 液晶反應速度快
- ○ 彩色畫面顯像佳

TFT(Thin Film Transist



Thin film transistor (MOSFET)

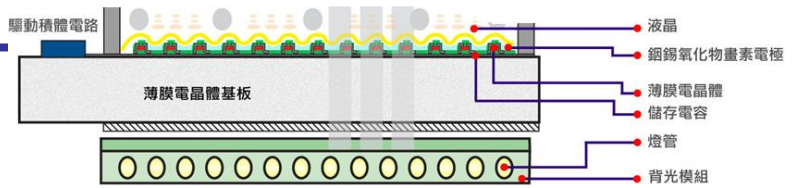
- Relatively thin compared to the plane of the device
- A FET on non-conducting substrate such as glass
- Semiconductor is amorphous (low mobility) or polysilicon
- (large device to device variation)
- transparent electrodes, such as indium tin oxide (ITO)



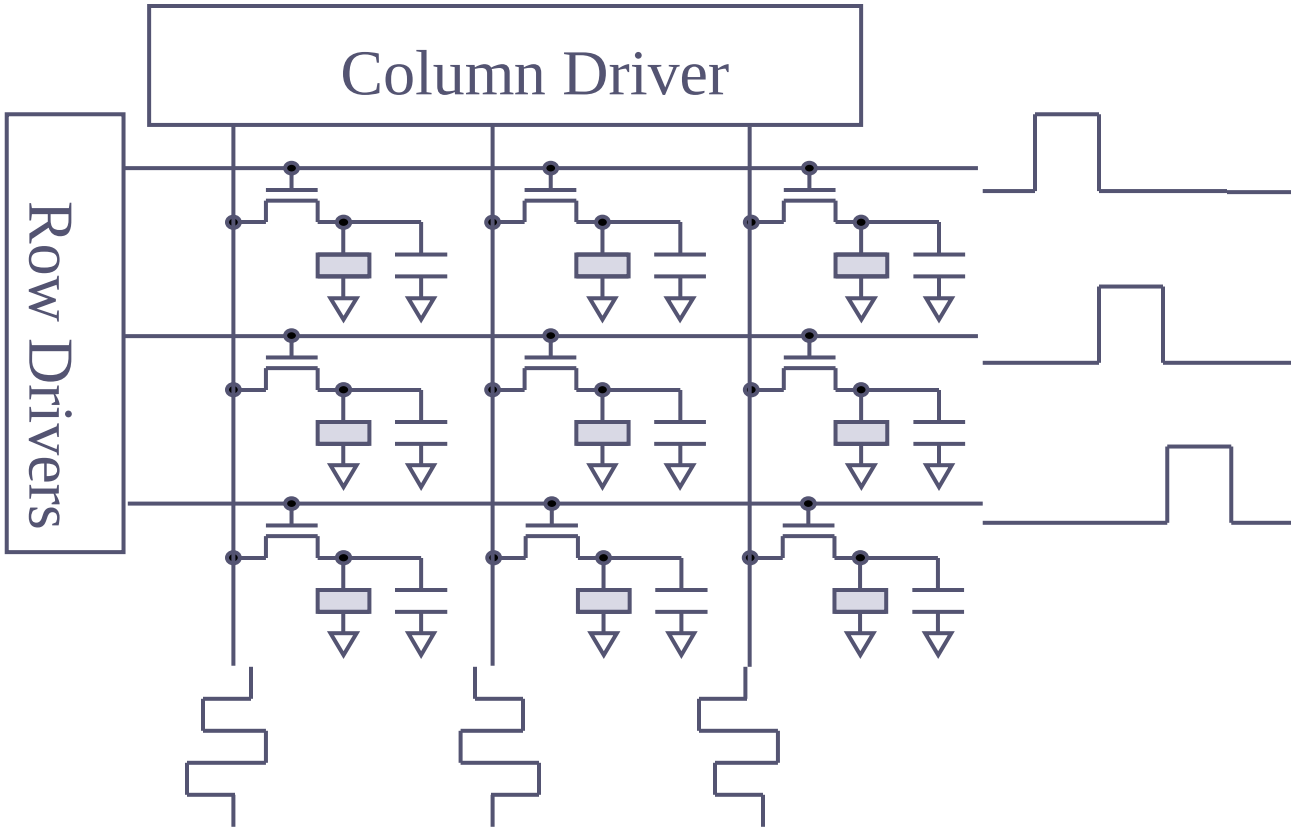
【圖一】 薄膜電晶體-液晶顯示器結構

TFT LCDs Equivale

LCD Driver IC

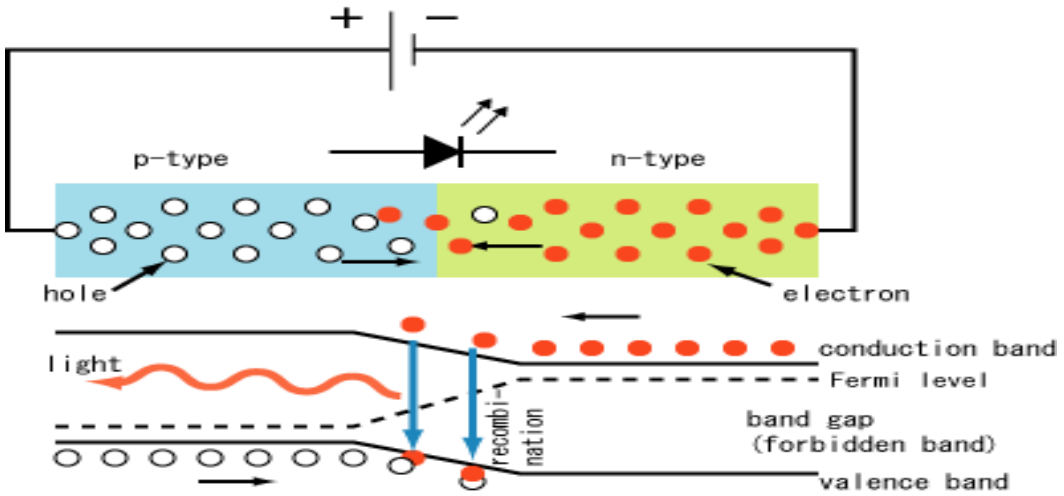


【圖一】 薄膜電晶體-液晶顯示器結構



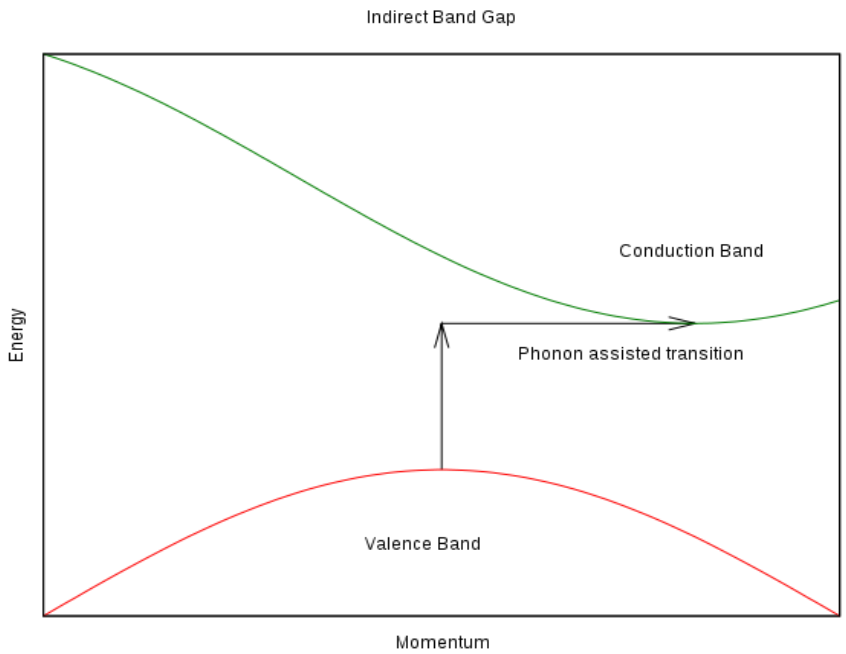
LED(light emitting diode)

- Semiconductor light source (Self-luminous)
- Red, Green and Blue LED
- Electrons combine within holes(forward bias)
- Indirect bandgap can't emit light (Silicon)
- Direct bandgap-Release energy in the form of photons (Gallium Arsenide)
- Color depends on the energy gap of the semiconductor

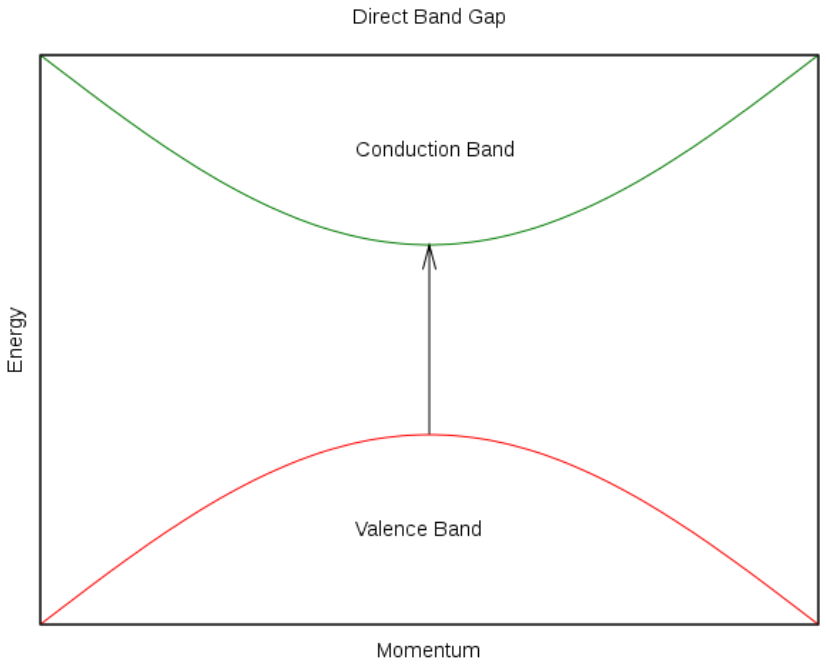


LED(light emitting diode)

- **Indirect/Direct Bandgap**

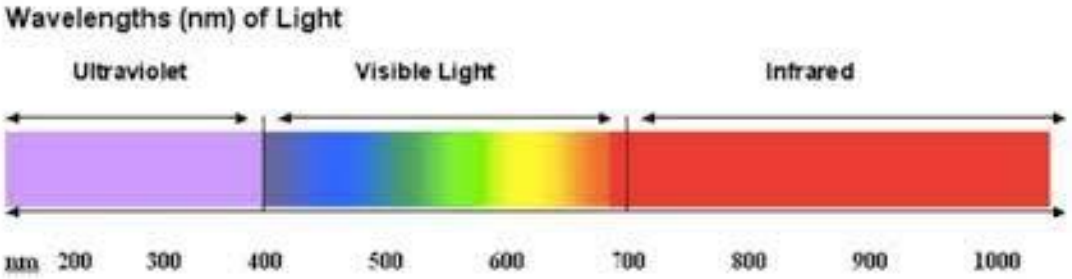


Indirect bandgap

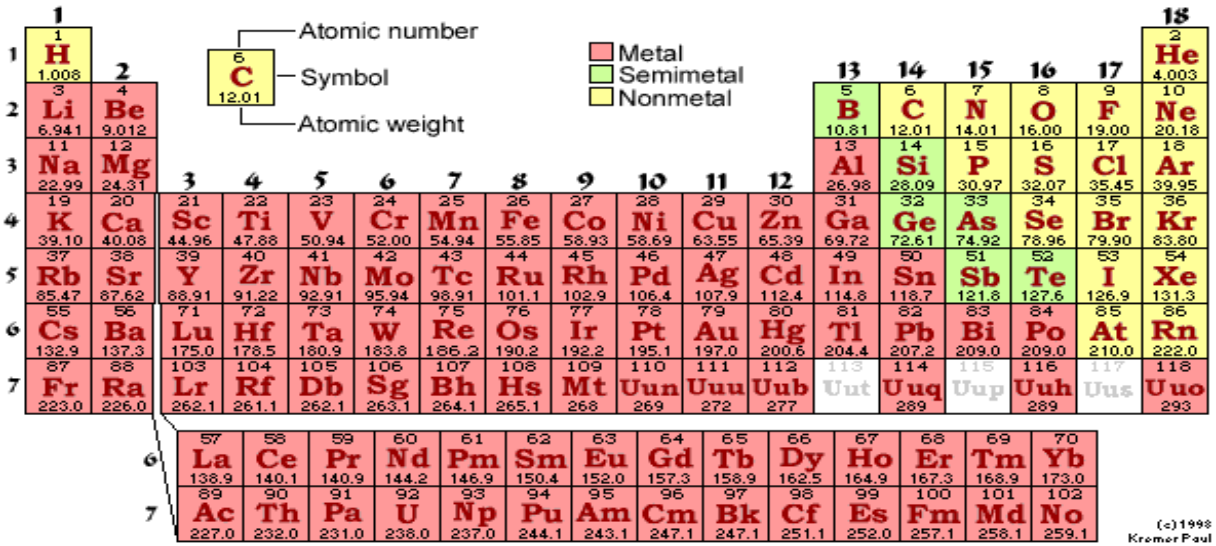


Direct bandgap

LED Materia

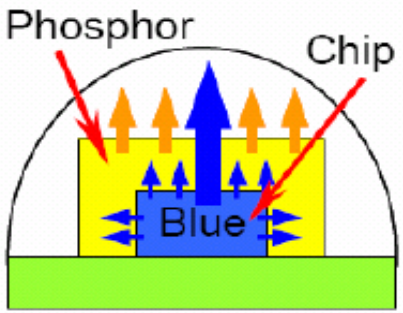
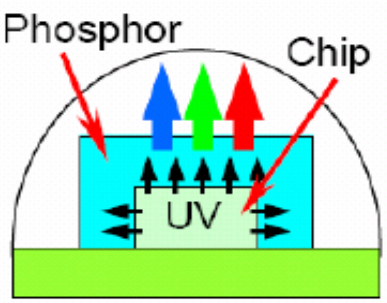
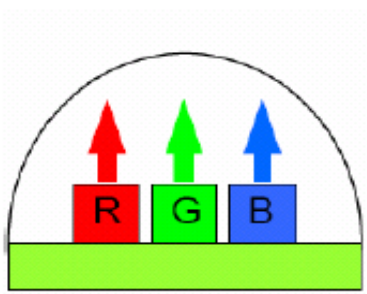


- Red – Aluminium Gallium arsenide(AlGaAs)
- Green - Gallium Phosphide(GaP)
- Blue - Zinc selenide (ZnSe) or Indium Gallium Nitride (InGaN)
- White - mix R,B,G three lights
- Phosphor-based white LED
  - Coating blue LED with phosphor of different colors



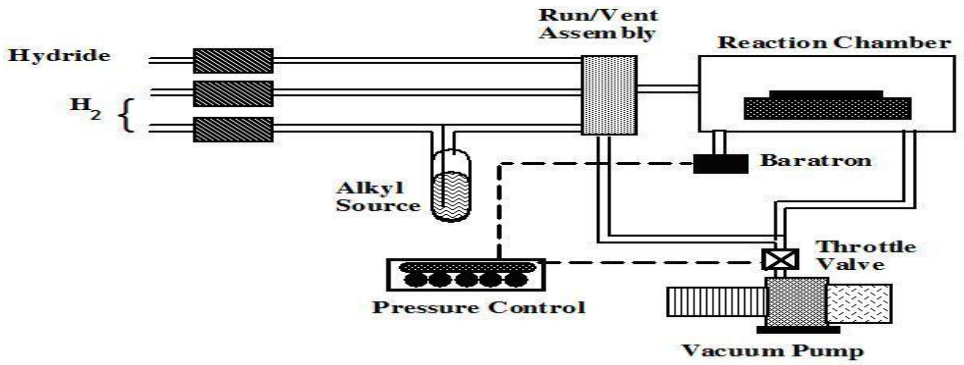
White LED types

- White LED
- White - mix R,B,G three lights
- Phosphor-based white LED
  - coating blue LED with phosphor of different colors.

	Blue LED + Yellow Phosphor	UVLED + RGB Phosphor	RGB 3 Chip
架構			
晶片	Blue: InGaN	UV: InGaN	R,G: AlInGaP B: InGaN
演色性	80	90	90

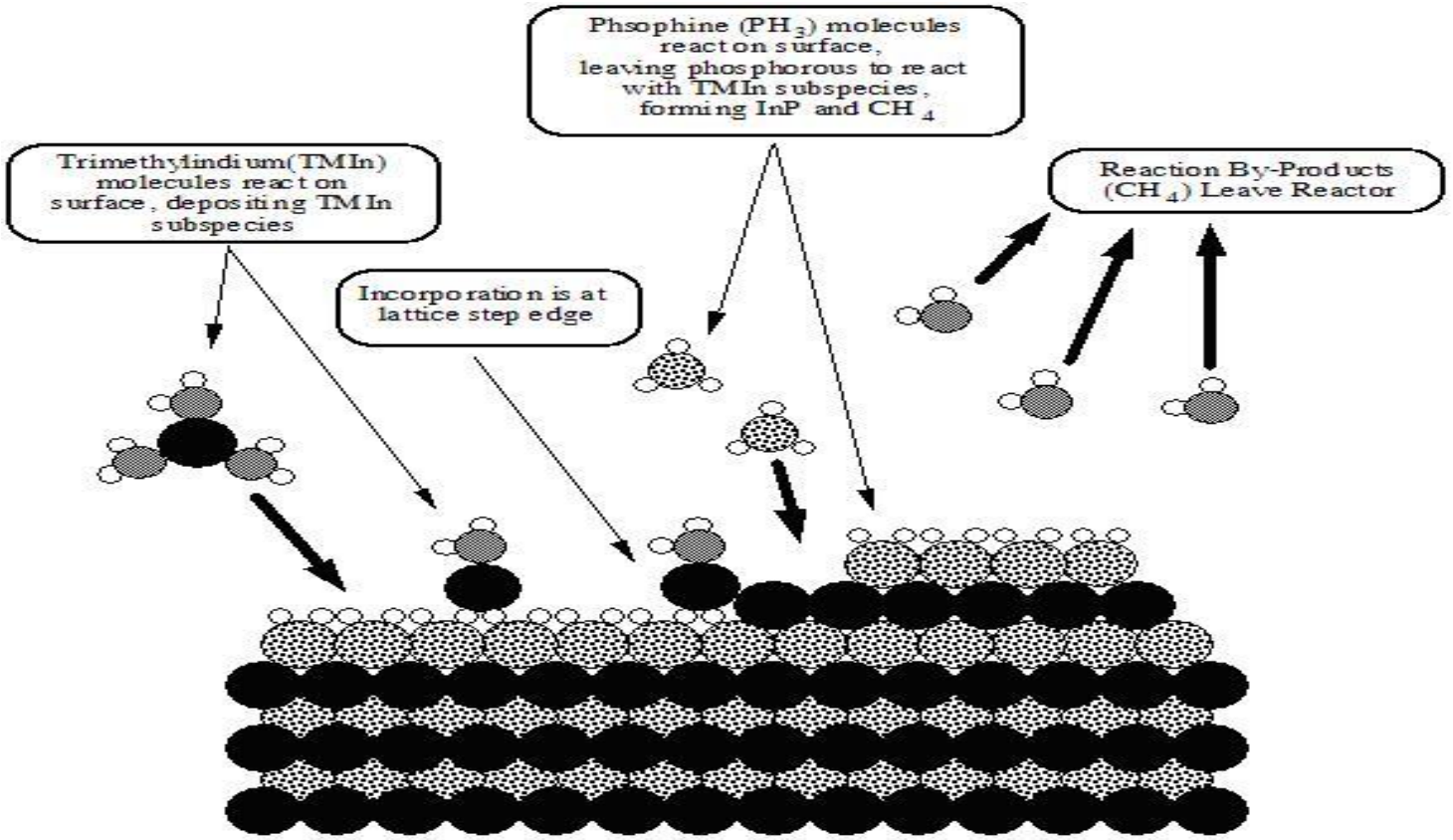
MOCVD
metalorganic chemical vapor deposition

- Epitaxial growth of materials-from the surface reaction of organic and metal hydrides containing the required chemical elements.
- MOCVD- the growth of crystals is by chemical reaction
- Not in a vacuum, but from the gas phase at moderate pressures (2 to 100 kPa).
- The dominant process for the manufacture of laser diodes, solar cells, and LEDs.



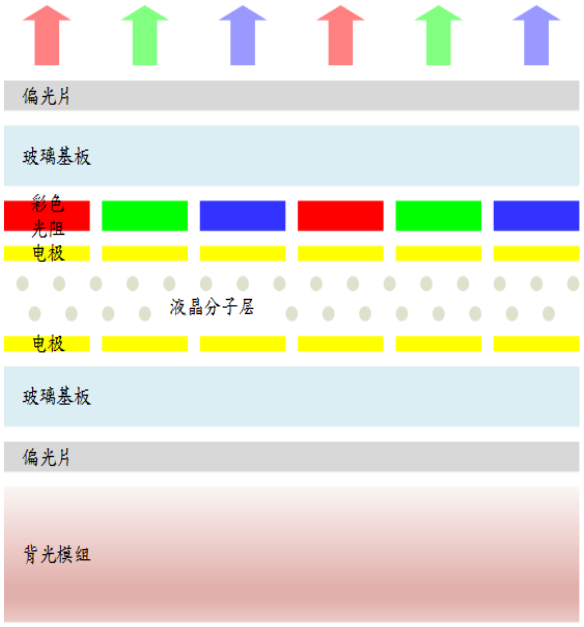
MOCVD
metalorganic chemical vapor deposition

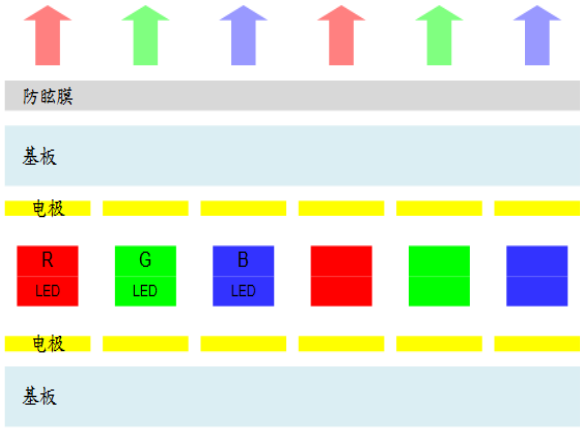
- indium phosphide could be grown in a reactor on a substrate by introducing Trimethylindium ($(CH_3)_3In$) and phosphine (PH_3).



MicroLED

- **Combine Thin Film Transistor and LED**
  - Size around1~10μm
  - Fabricate direct bandgap semiconductor
- **Comparison**

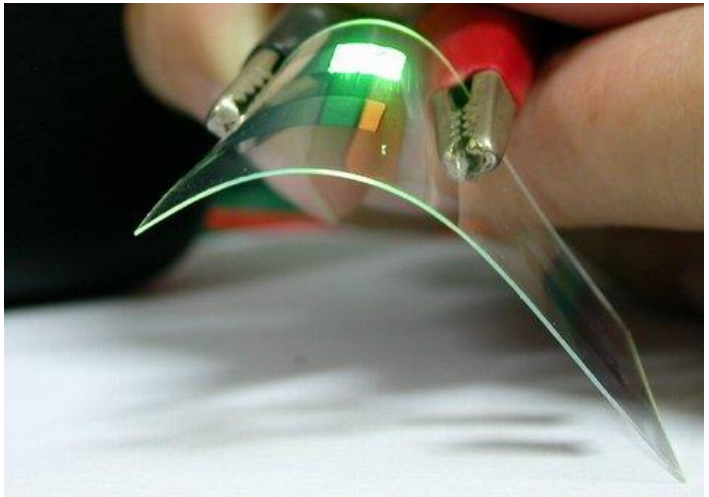




TFT-LCD OLED Micro LED

OLED

- **Organic Light-Emitting Diode(OLED)**
  - Self-luminous
  - Wide viewing angle
  - Low power consumption
  - Thin and light, flexible



Property

- **OLED elements**
  - Metal Cathode
  - Electron transport layer
  - Organic emitters
  - Hole injection layer
  - Anode
  - Glass substrate

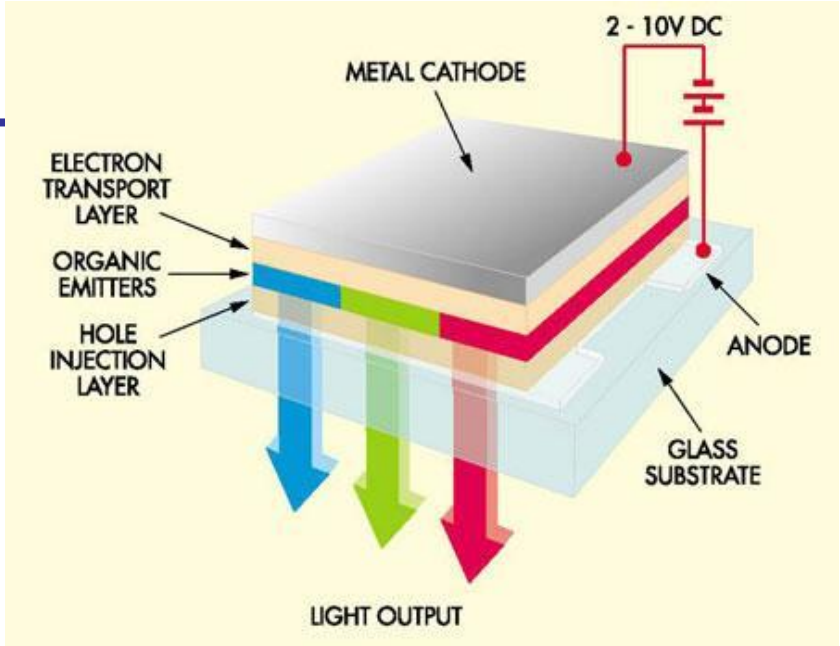
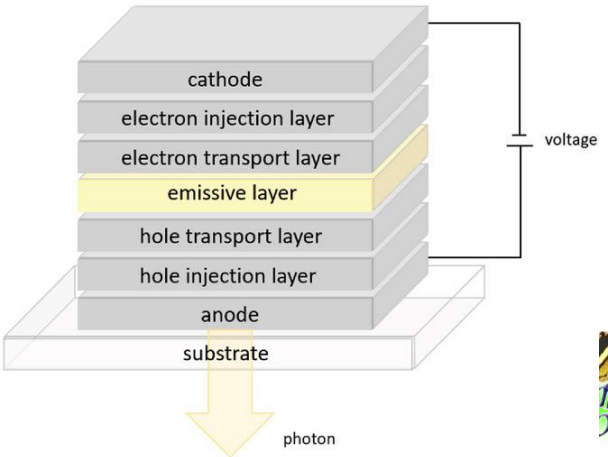


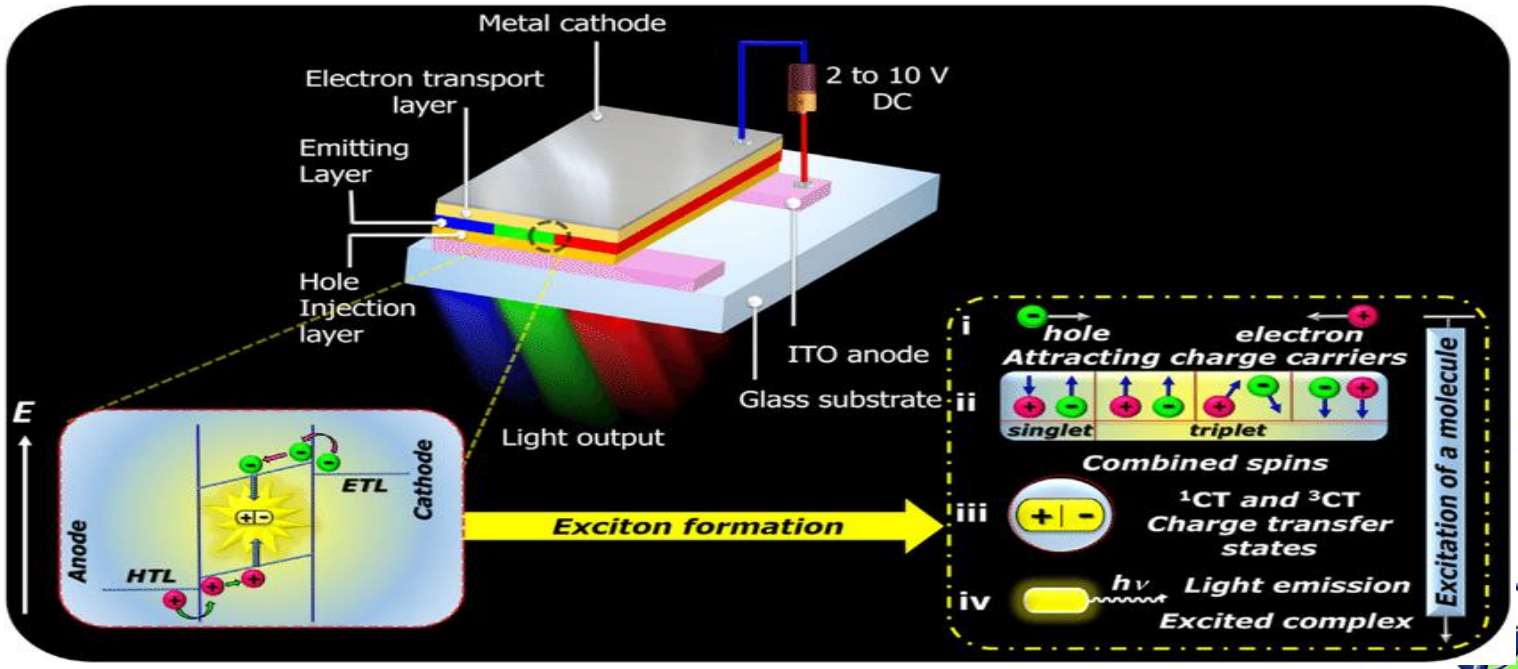
Fig. OLED structure

- **OLED can emit the three primary colors of RGB, which can replace the LCD screen:**
  - Backlight
  - Liquid Crystal
  - Color gel



OLED Lighting 4 stages

1. **Injection** of negative (electron) and positive (hole) charges at the electrode
2. **Migration** into the bulk material till they meet each other
3. **Formation Excitons** of bound couples of electrons and holes, named excitons.
4. **Radiative recombination** of the excitons will generate light giving electroluminescence



Property

- **Organic**
  - The molecular structure of OLED contains organic matter
    - benzene ring and a compound of metal atoms and other elements (C, N,O,H).
  - organometallic compounds
    - composed by a metal coordinated by organic ligands
  - organometallic molecules stacked into thin film bendable
  - molecular orbitals forms valence and conduction wavefunctions
  - good charge transport and emissive properties

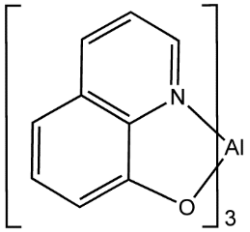
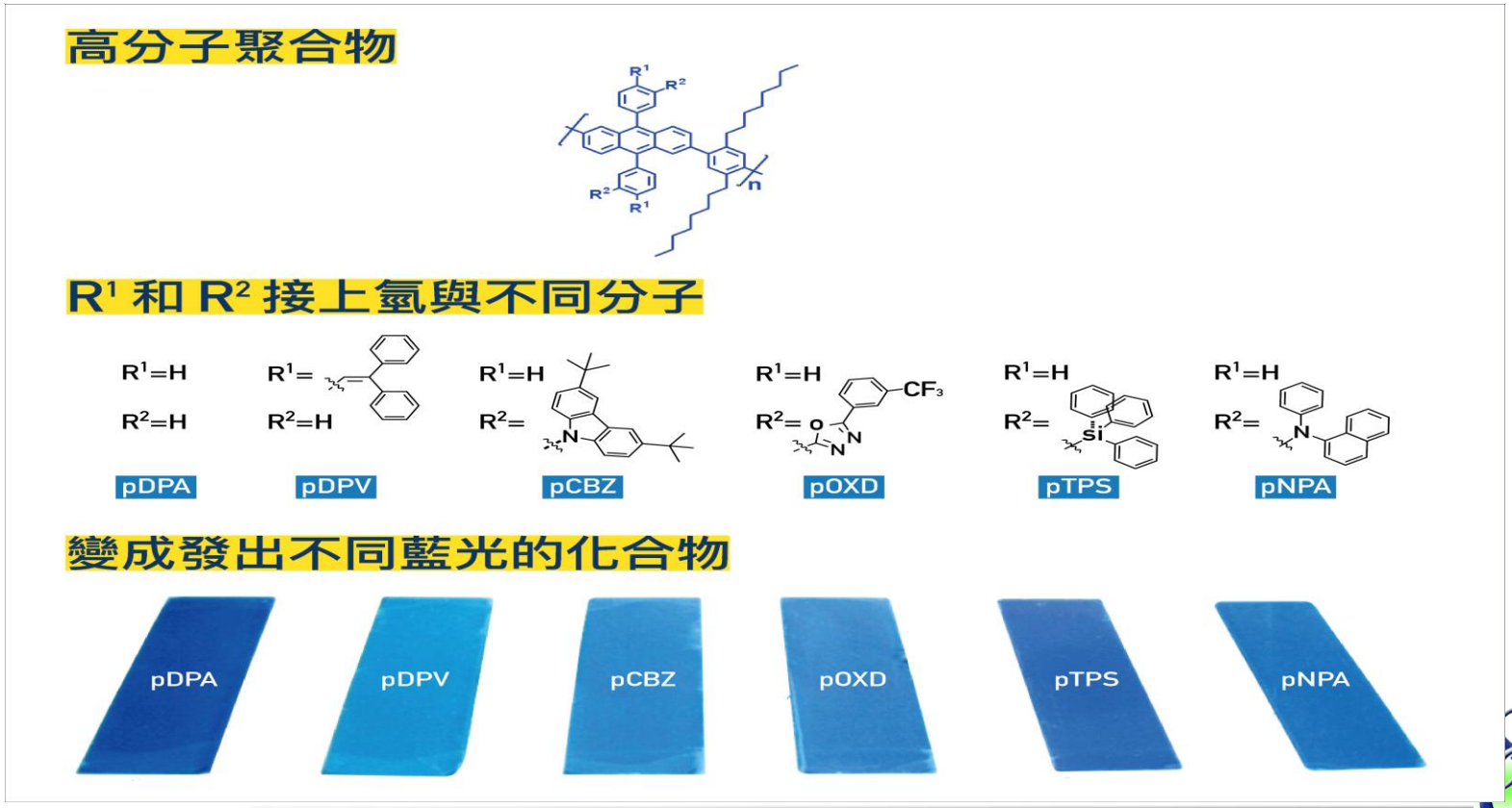


Fig. Alq_3 commonly used in small molecule OLEDs

Organic Light-Emitting Diodes (OLEDs): Working Principles and Device Technology,https://link.springer.com/chapter/10.1007/978-3-319-31671-0_3

OLED Color Property

- **OLED color depends on**
  - Types of molecule
  - Structure of the benzene ring

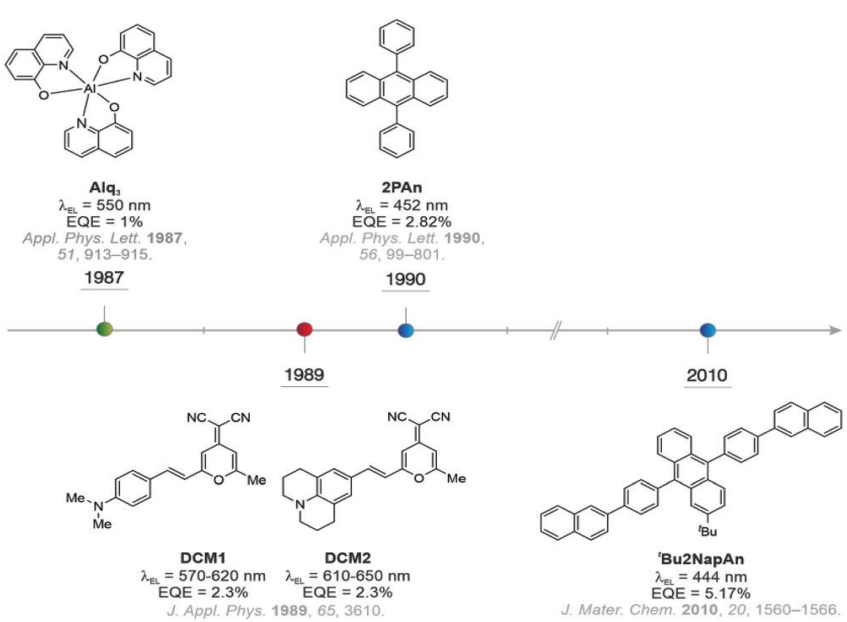


Light Emitting Mode

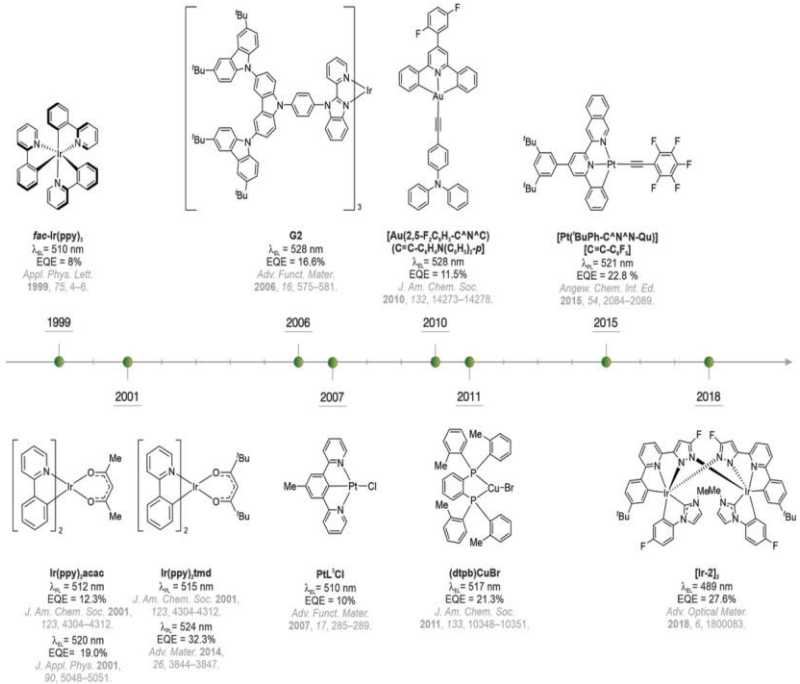
OLED light emitting mode:

Fluorescent (poor luminous efficiency and short life) 1st generation

Phosphorescent => PHOLED 2nd generation



A selection of first-generation OLED emitters based on fluorescent molecules.



The second generation of green OLED emitters is based on phosphorescent molecules.

Advanced Materials, Volume: 33, Issue: 9, First published: 18 January 2021, DOI: (10.1002/adma.202005630)
https://onlinelibrary.wiley.com/doi/full/10.1002/adma.202005630

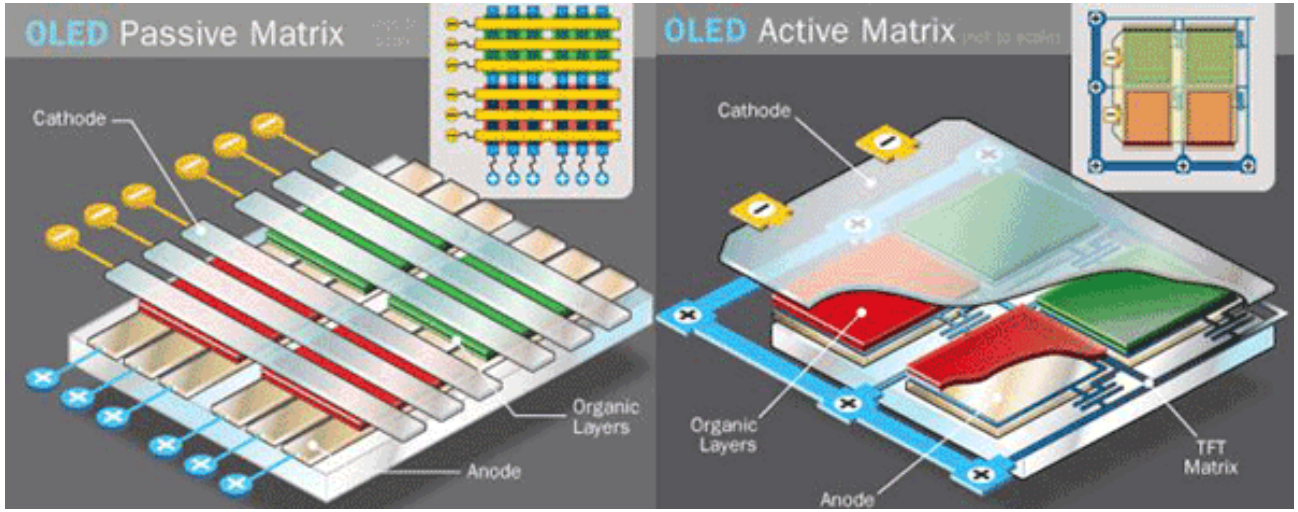
A Brief History of OLEDs—Emitter Development and Industry Milestones

OLED Pros. & Cons.

Pros.	Cons.
Self-luminous	Poor sunlight readability
High viewing angle (about >160°)	Insufficient life of light-emitting elements (color decay)
Fast response time (theoretical about 1μs)	Lack of mass production and large-size panel technology, expensive
Good flexibility and bendable	
Thin and light panel (2 mm)	

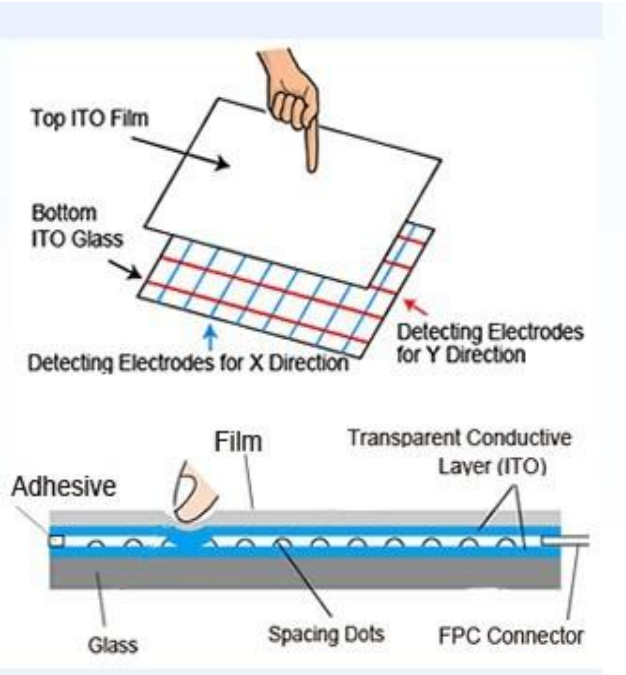
PMOLED and AMOLED

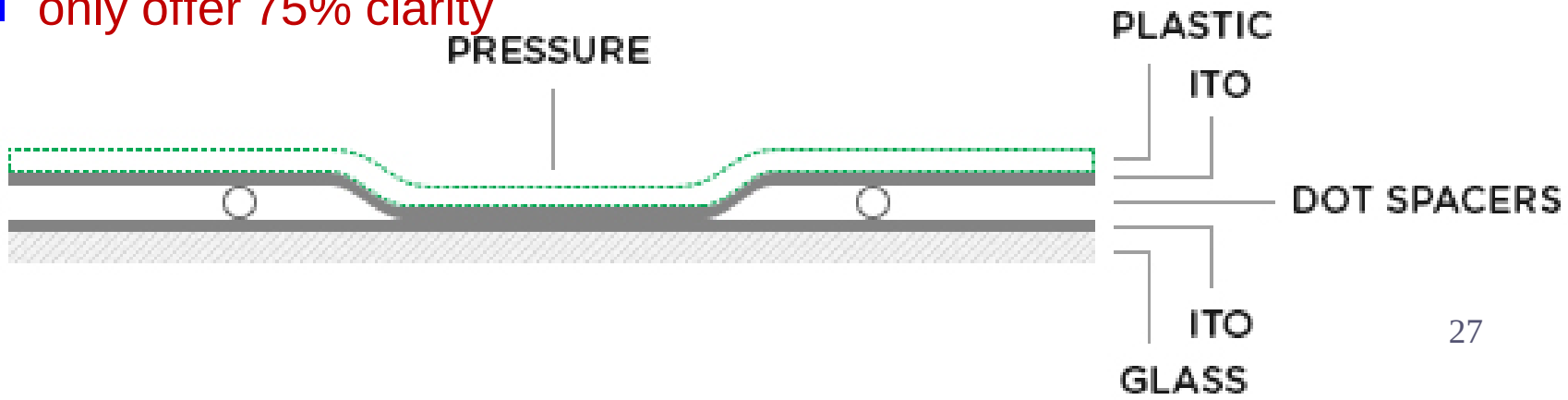
- **OLED drive modes can be divided into:**
  - Passive-matrix OLED, PMOLED
    - Supply power to specific positive and negative poles from an external power source, and the corresponding pixels will be lit.
  - Active-matrix OLED, AMOLED
    - The OLED is controlled by the Thin-Film Transistor in the structure.



Touch Panel Resistive Type

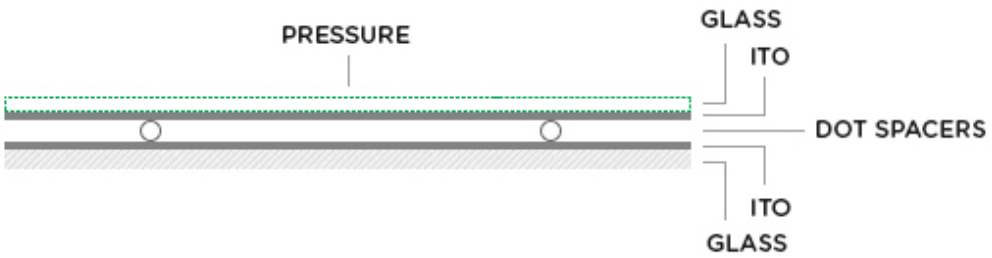
- Voltage detection (Indium tin oxide (ITO))
- Resistance changes when the finger touches top plastic /Digital and analog
- 4, 5, 6, 7 or 8-wired models
- Film/Glass、Film/Film and Film/Plastic
- Market share: more than 60%
- only offer 75% clarity

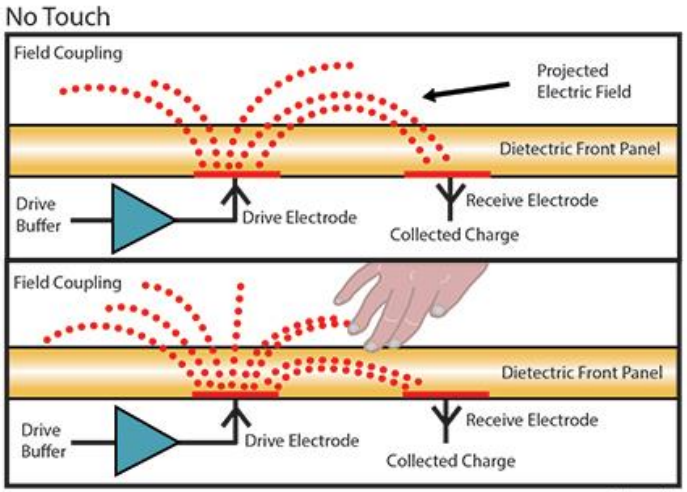




Touch Panel Capacitive Type

- Using the capacitance change produced by the electrostatic combination between the electrode and the human body
- the induced current can be used to detect its coordinates and improve the resistance-type non-scratch characteristics.
- Market share: about 24%
- Good clarity and durability, can only respond to the touch of a finger or special tools.





Resistive v.s Capacitive

	電阻式	電容式
透光度	80%	91.5%
硬度	3H	7Mohs
準確率	98.5%	99%
反應時間	20ms	3 ms
操作高溫	50 C	70 C
抗 UV	無	有
起始力量	50mg	0 mg

LCD/OLED/Micro LED Comparison

Technology	TFT LCD	OLED	Micro LED
Light Source	LCD backlight	Self emmit	Self emmit
Cost	Low	Medium	High
Power Consumption	High	60%–80% of LCD	30%-40% of LCD
Brightness	Low	High	High
Efficiency	Low	Medium	High
Lifespan	Long	Medium	Long
Contrast	Low	High	High
Response Time	ms	μs	ns

Conclusion

- Lightweight, flexible, self-luminous and other characteristics, making OLED has various development possibilities.
- The high price keeps OLED from entering the market for a long time.
- Taiwan does not invest in the OLED industry.
- OLED is still one of the future trends, but we must first overcome the problems of burn-in, color decay and yield.

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