LCD Displays

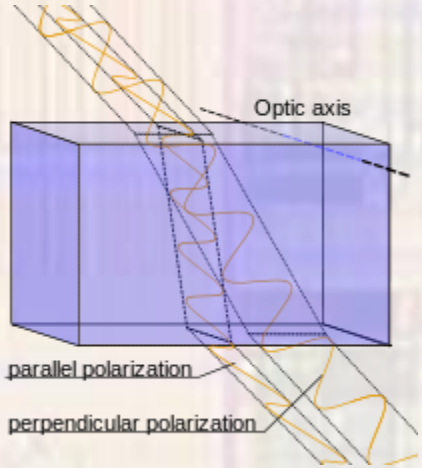
Last updated 3/1/21

LCD Displays

- LCD vs LED Displays (TVs)
  - The vast majority of what are labeled LED displays are actually LCD displays
  - Recently, true LED displays have started to appear (OLEDs)

LCD Displays

- Birefringence
  - Optical Property of a material
  - Index of refraction is dependent on the direction and polarization of incident light



src: Wikipedia

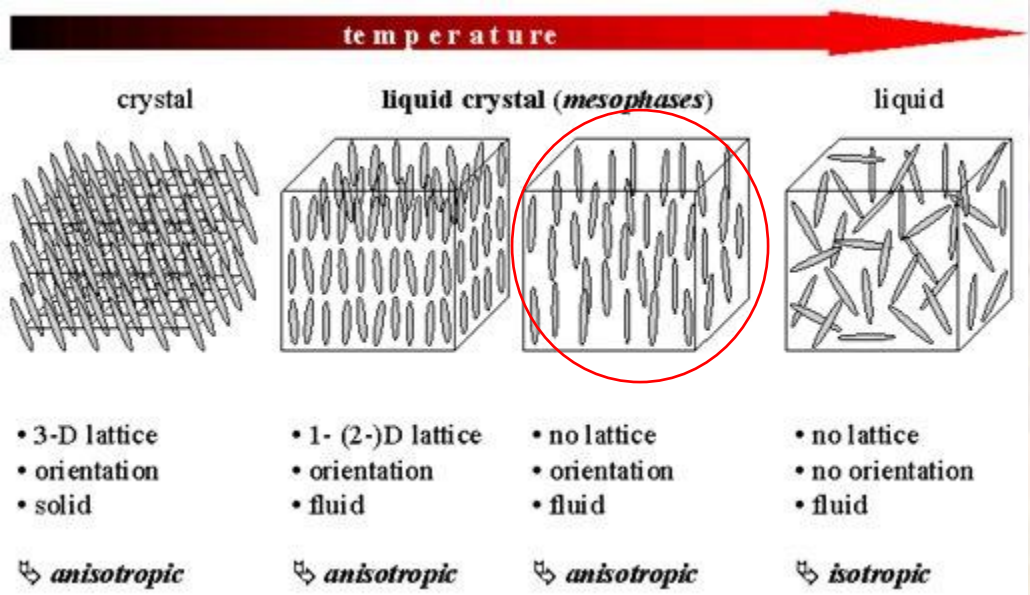
LCD Displays

- Liquid Crystal
  - Birefringent
  - Two major molecular shapes
    - Rods – Calamitic
      - Major Axis – Director

    - Discs – Discotic

LCD Displays

- Liquid Crystal
  - Structure changes with temperature
  - Nematic – have orientation but no lattice structure

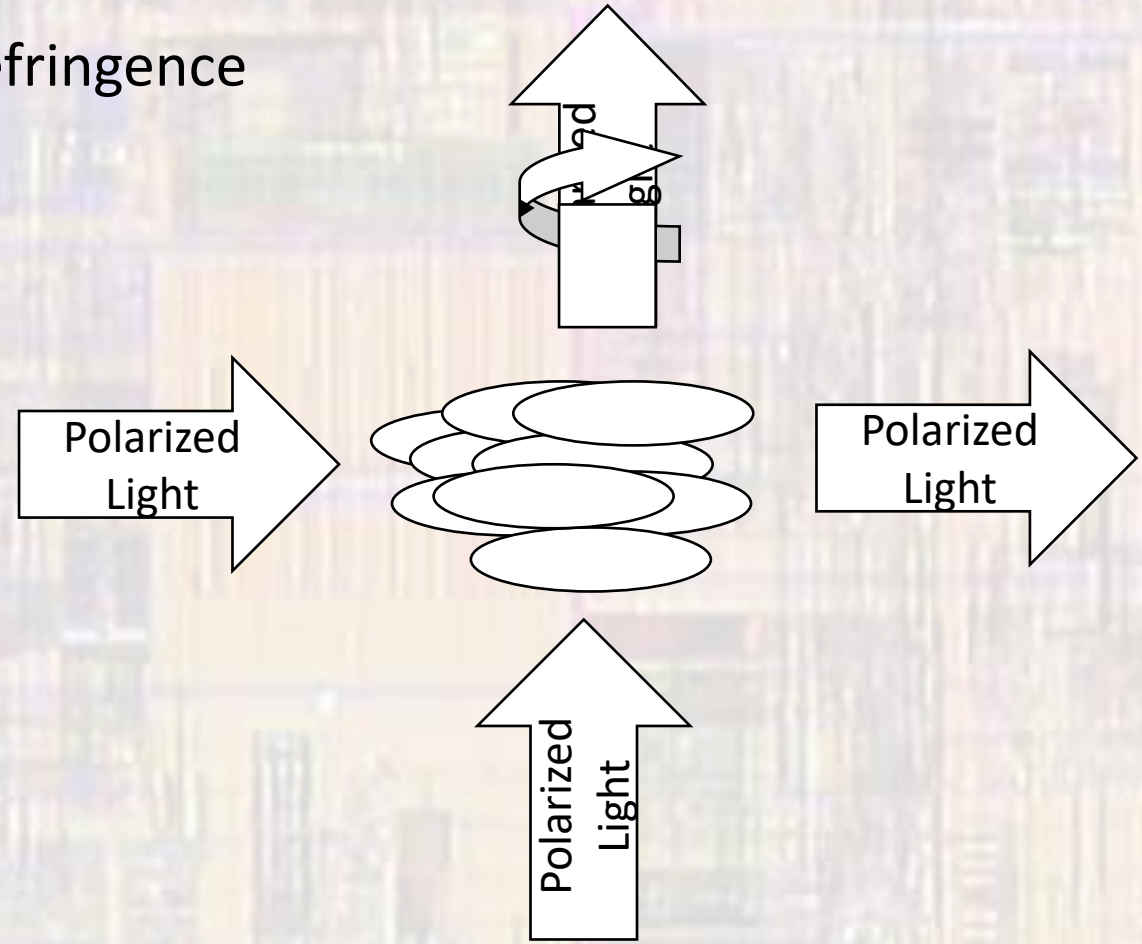


LCD Displays

- Liquid Crystal
  - Cholesteric – Helix structure

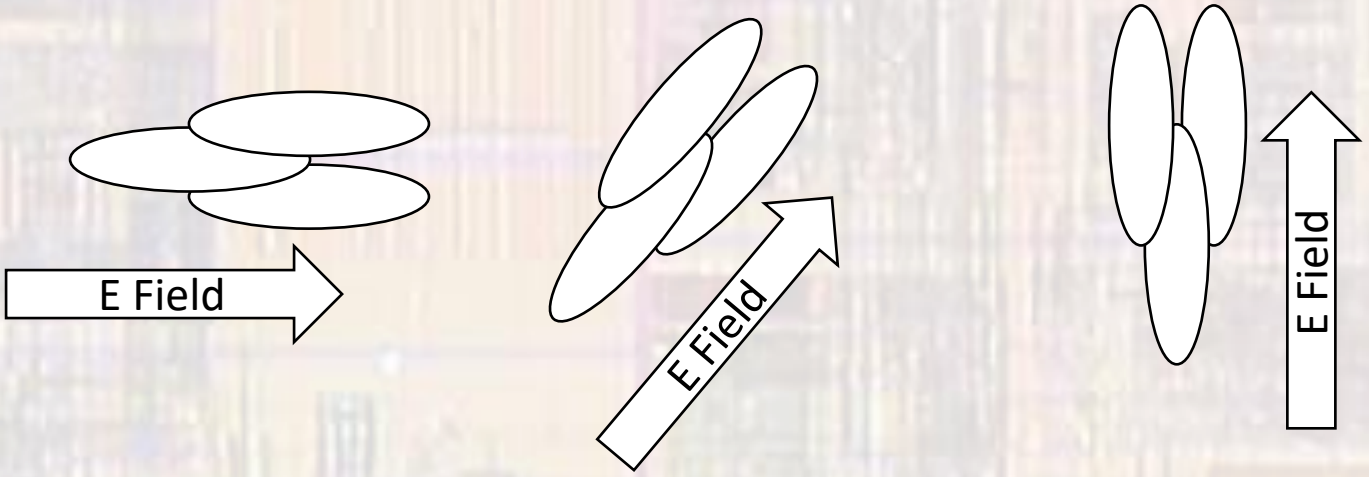
LCD Displays

- Liquid Crystal
  - Birefringence



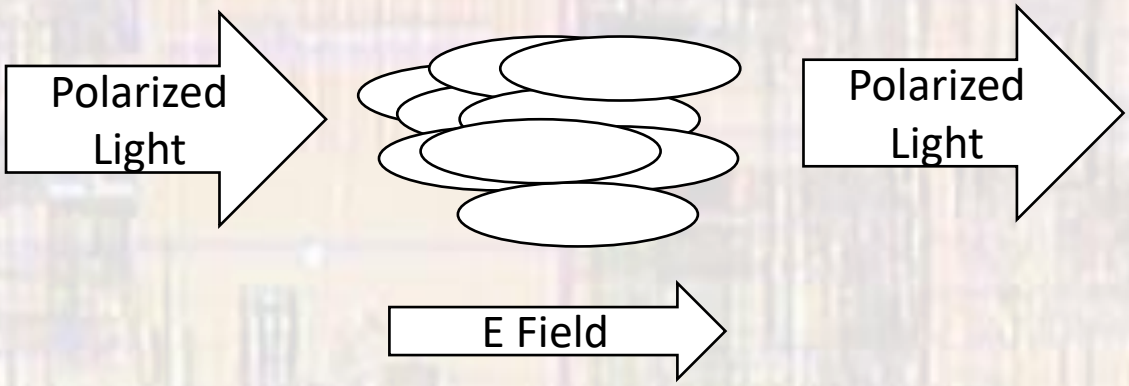
LCD Displays

- Liquid Crystal
  - In an electric field
    - Calamitic crystals align the director to the external E field



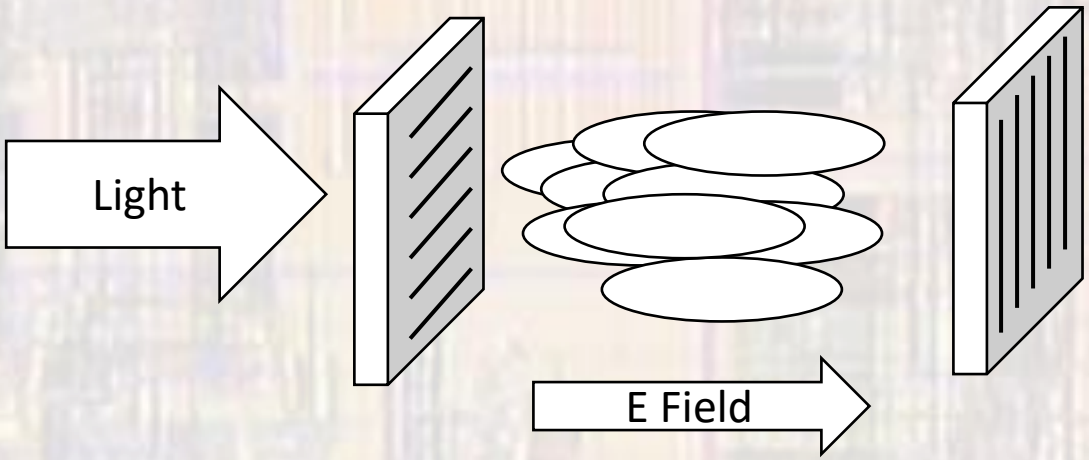
LCD Displays

- Liquid Crystal
  - Put it all together
    - Use an electric field to align the crystals
    - Shine polarized light through it



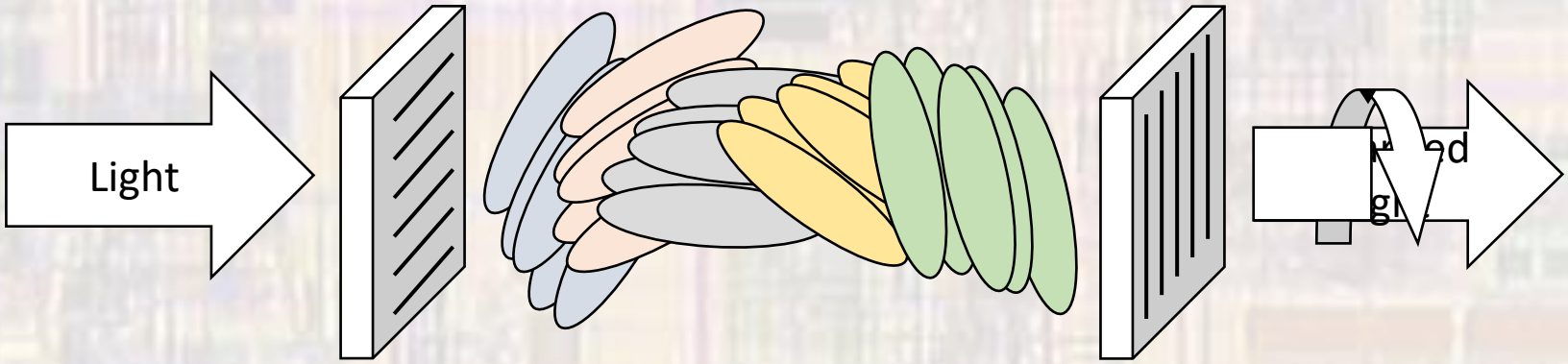
LCD Displays

- Liquid Crystal
  - Add some polarizers
    - Use an electric field to align the crystals
    - Shine polarized light through it
    - If polarizers are out of phase – NO LIGHT PASSES



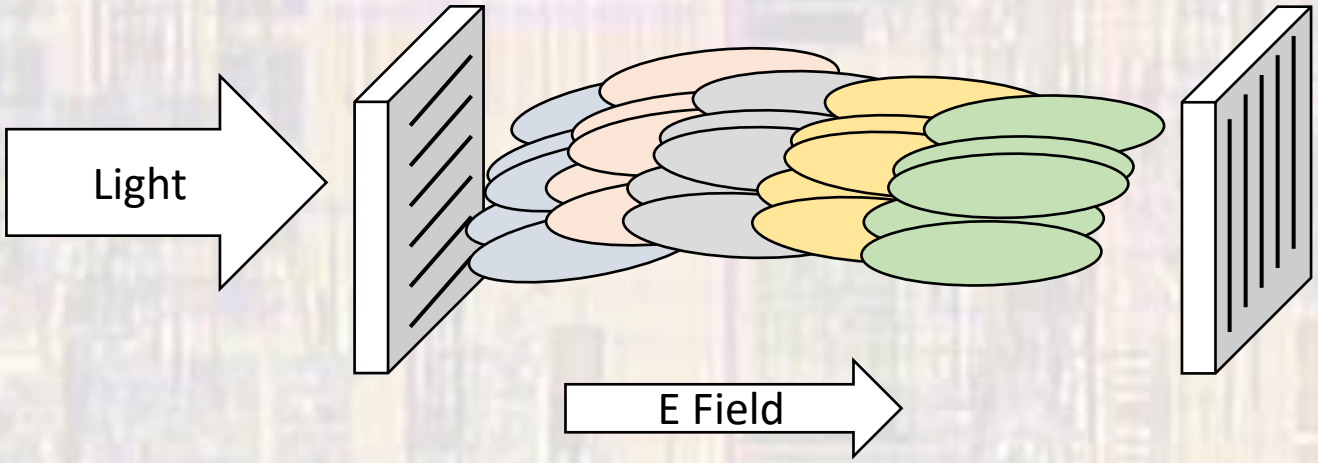
LCD Displays

- Liquid Crystal
  - Use the twisted nematic structure
    - Birefringence of the LC causes the light to rotate
    - If polarizers are out of phase
    - And the rotation matches – LIGHT PASSES



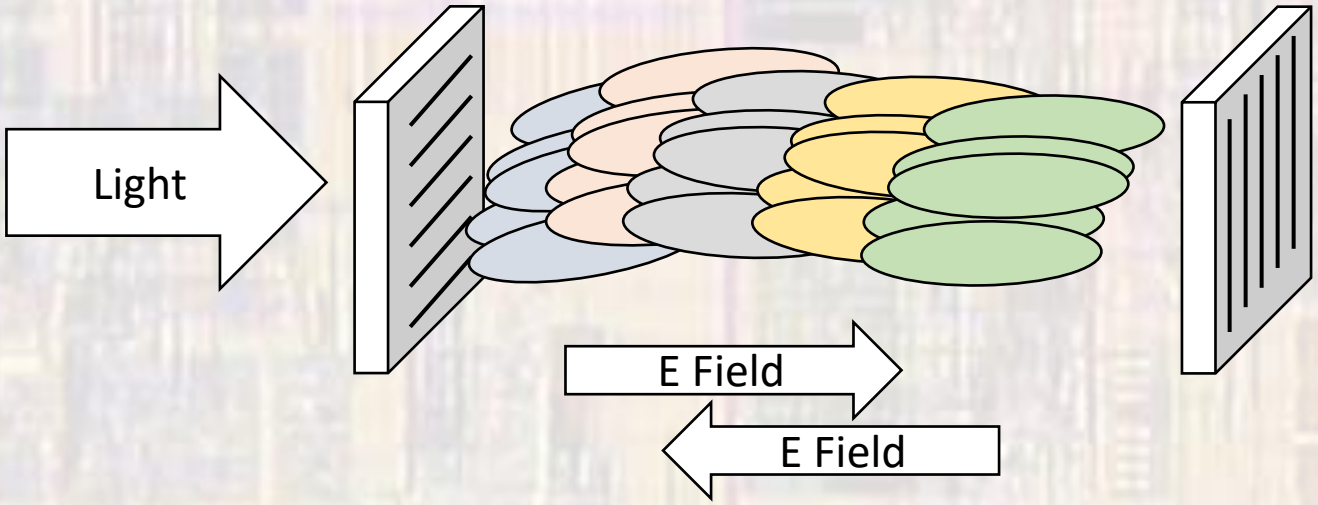
LCD Displays

- Liquid Crystal
  - Use the twisted nematic structure
    - Now add an electric field
    - Directors align with the E field
    - Light is not rotated - NO LIGHT PASSES



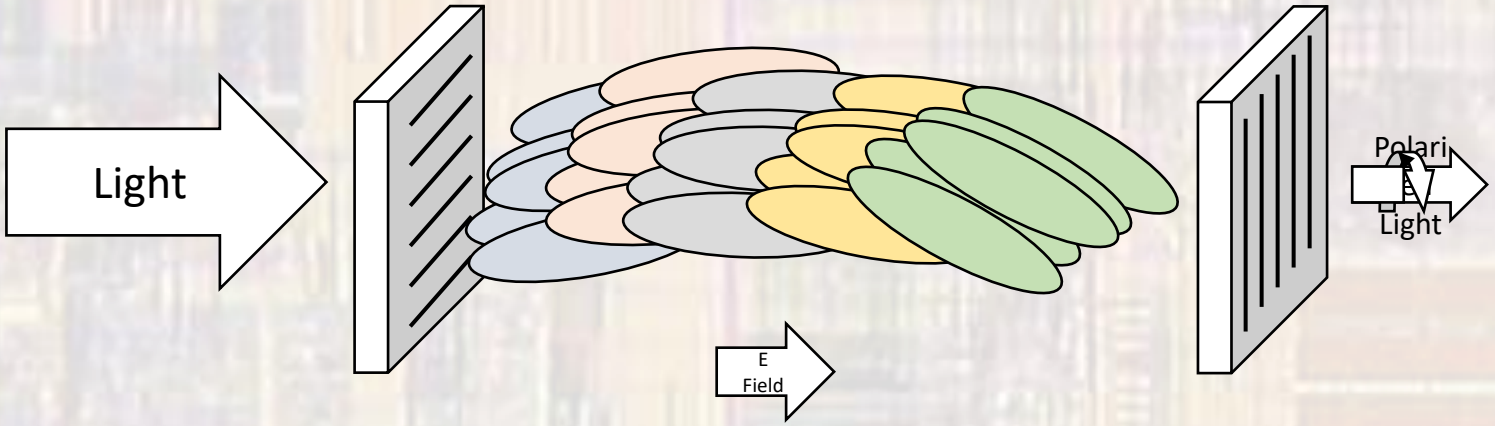
LCD Displays

- Liquid Crystal
  - Use the twisted nematic structure
    - Note – the absolute direction of the E field is not important



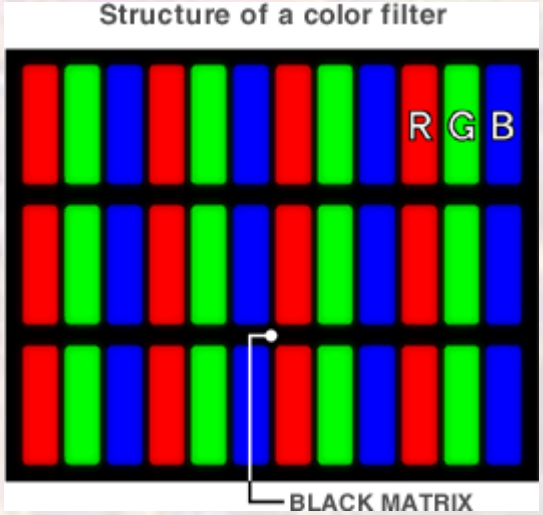
LCD Displays

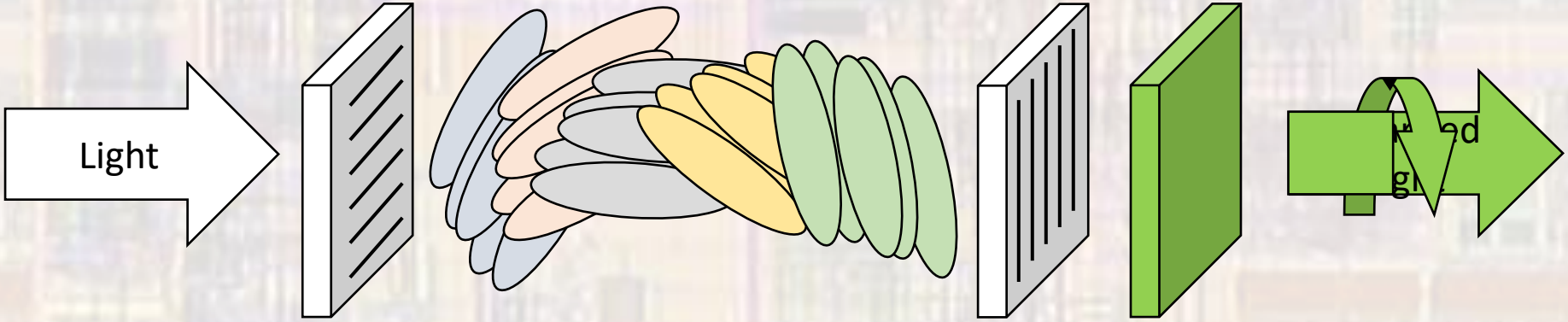
- Liquid Crystal
  - Use the twisted nematic structure
    - Amount of light that passes is dependent on the voltage
      - Gray scales
    - Normally white– Polarizers rotated, no field – light passes
    - Normally black – Polarizers aligned, no field – no light



LCD Displays

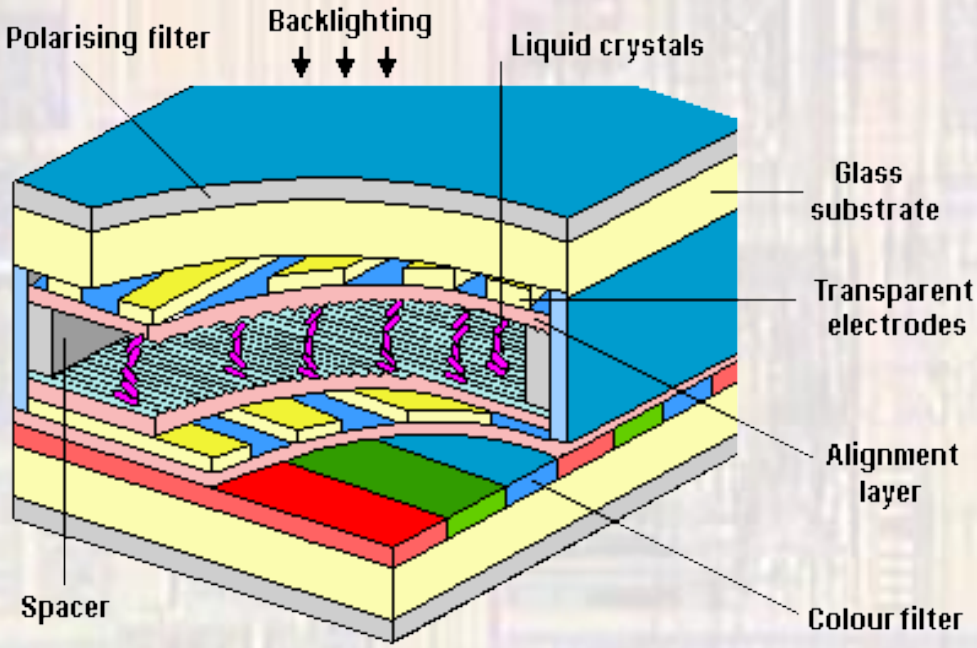
- Liquid Crystal
  - Use the twisted nematic structure
    - Color – add a color filter (R,G,B)





LCD Displays

- Passive Matrix
  - Rows and columns used to address pixels
    - Create an electric field or not
  - Depends on persistence of the color filter
    - Similar to old CRT displays
  - Still used in small LCD displays (e.g., 7seg)

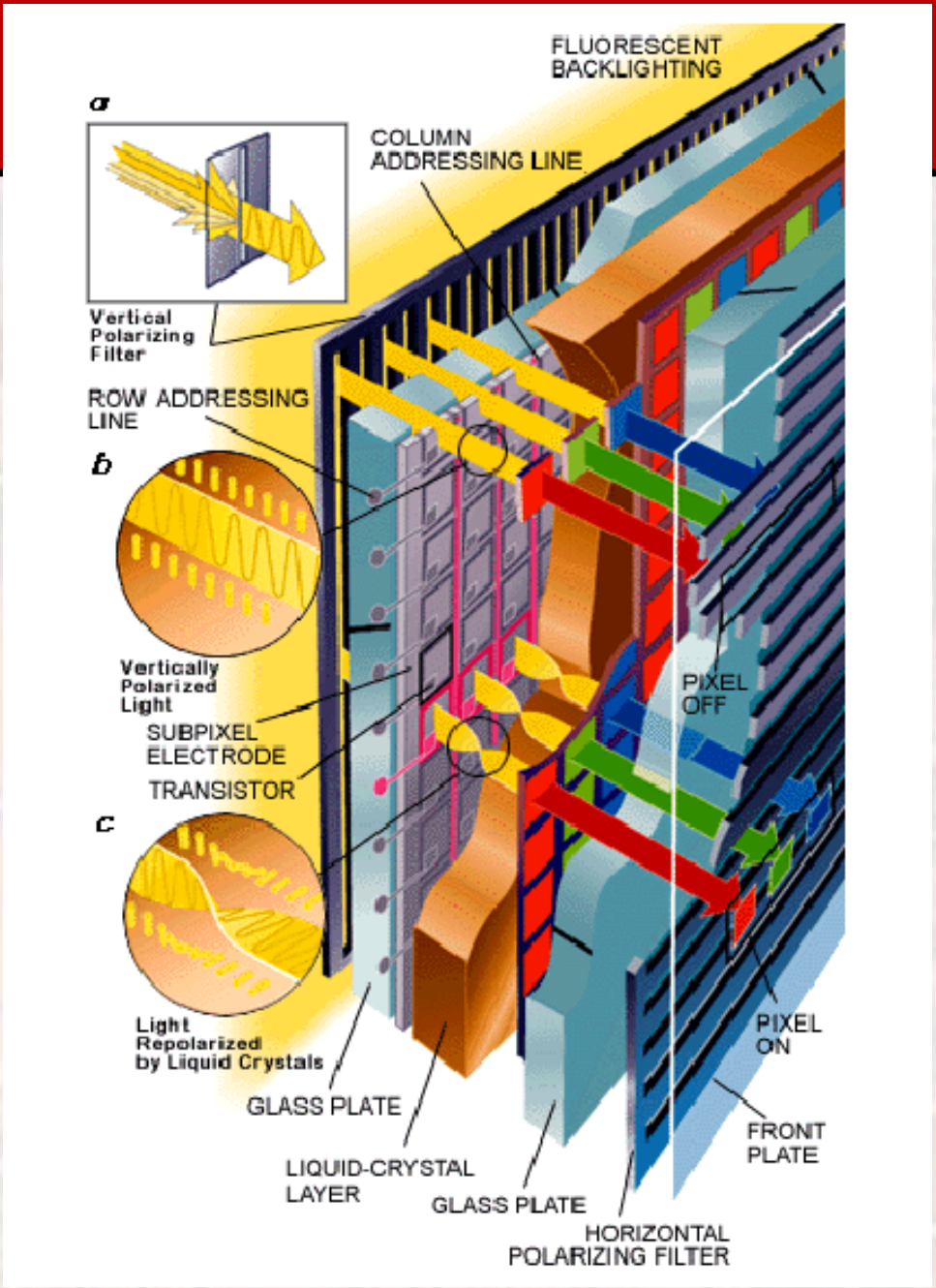


ITO
Indium Tin Oxide

Aligns directors

LCD Displays

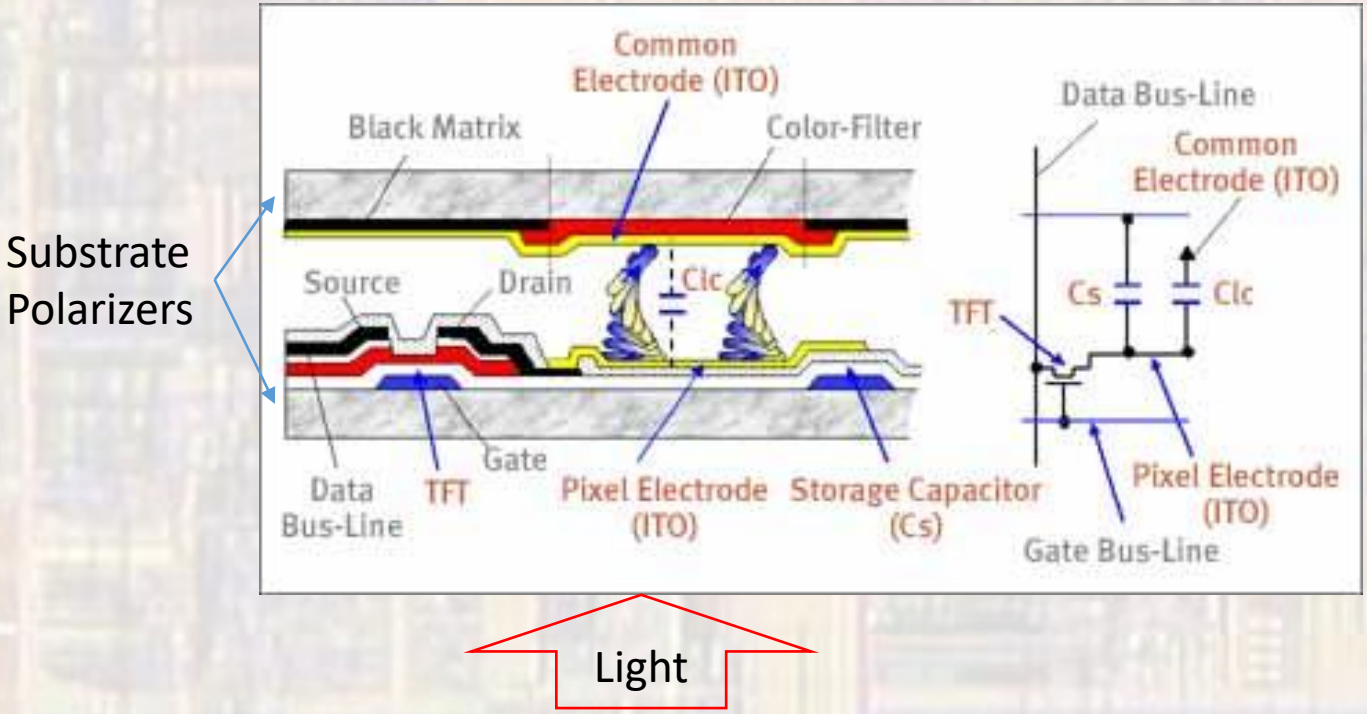
- Active Matrix



LCD Displays

- Active Matrix
  - Rows and columns used to address pixels
  - Thin film transistors used for selection
  - Capacitors used for persistence

Single Pixel – 1 color



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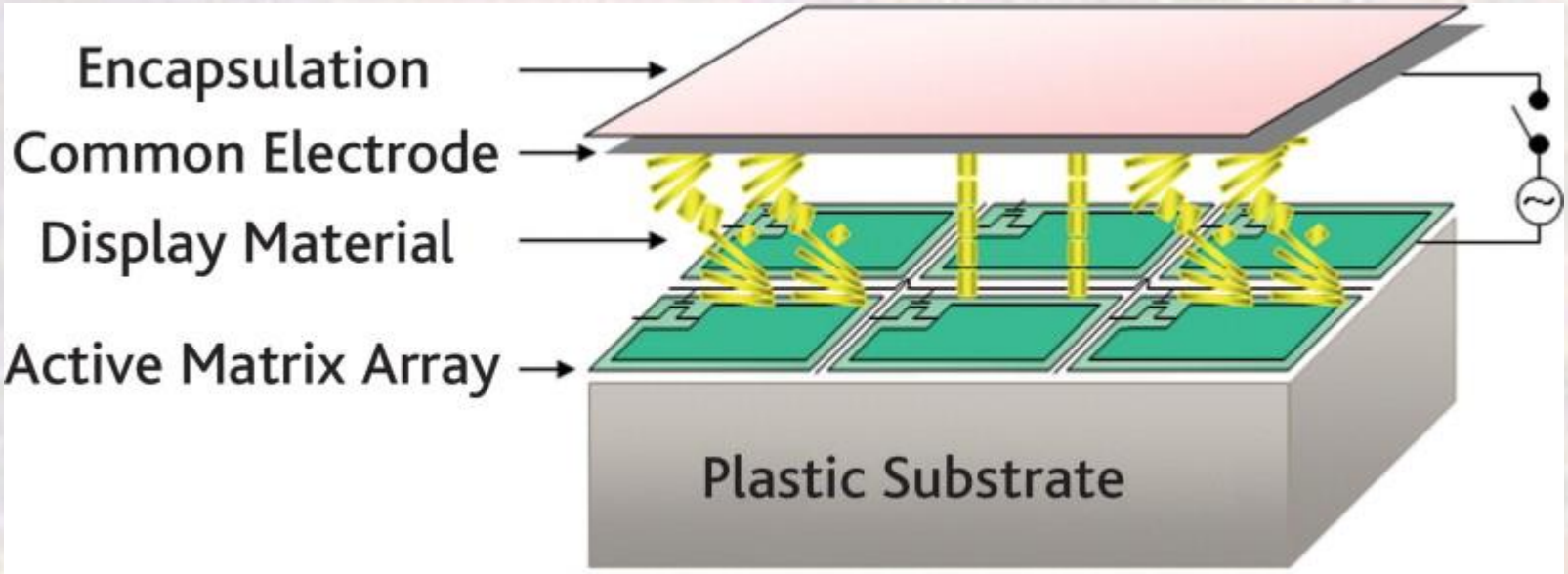
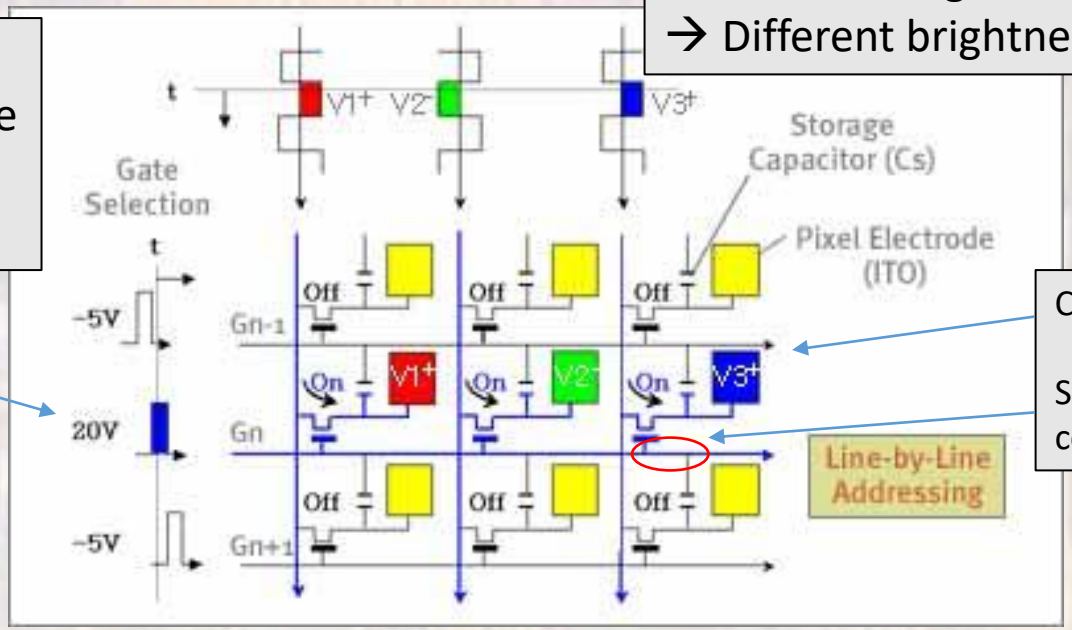


LCD Displays

- Active Matrix
  - Scan 1 row at a time
  - 1 column for each sub-pixel
  - 3 columns within a sub-pixel – RGB
  - Voltage differential determines brightness (V_{stored} – (-5v)

Different voltages → different values stored → Different brightness

Nominal Row and common electrode voltage = -5V
FET OFF



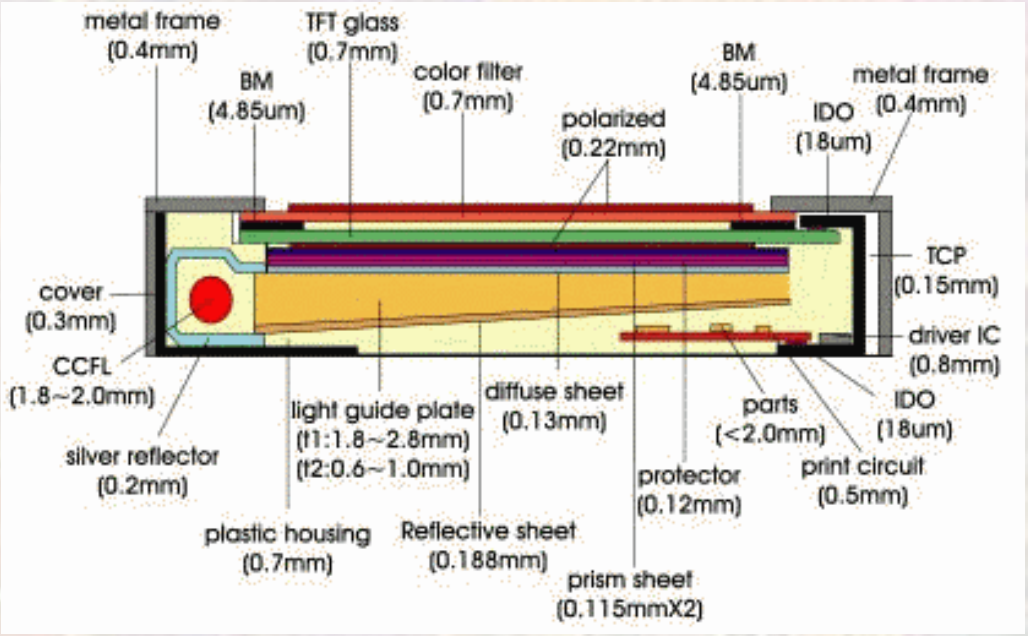
FET on HARD

Common Electrode per row

Shared row access and common electrode

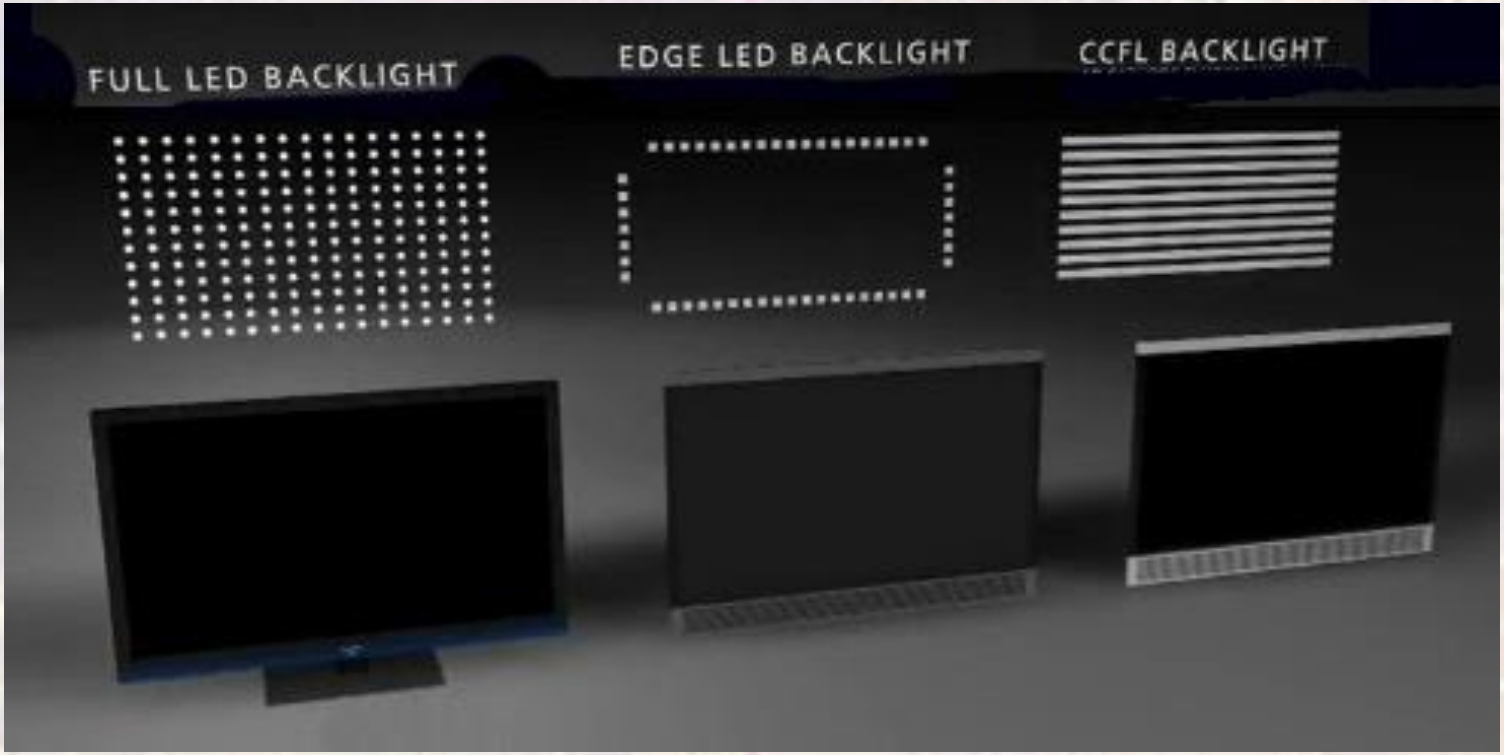
LCD Displays

- Where does the light come from?
  - Edge lit with Diffuser
  - Cold Cathode Florescent or LEDs



LCD Displays

- Where does the light come from?
  - Back lit with Diffuser
  - Cold Cathode Florescent or LEDs
  - Full LED backlight allows for local dimming

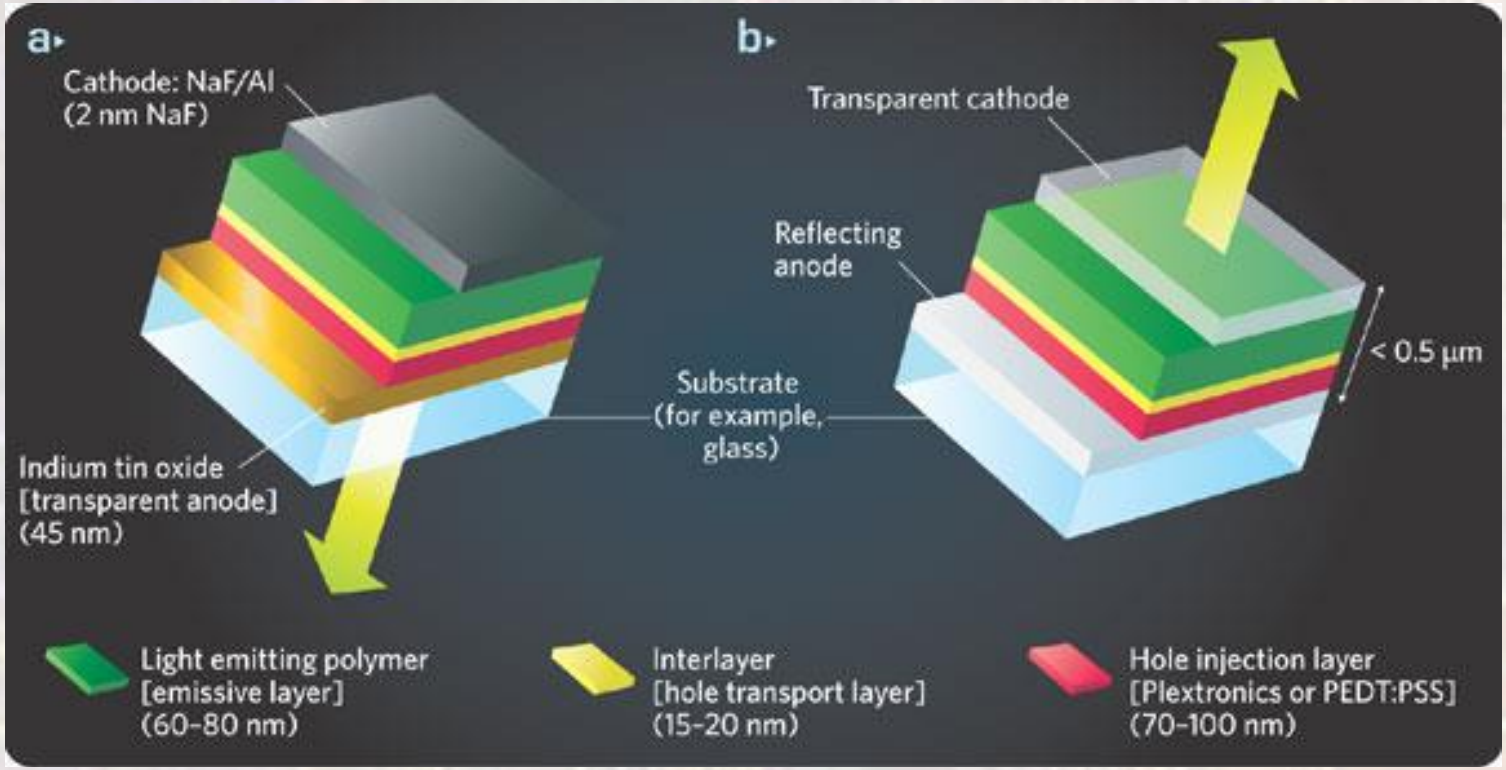


LCD Displays

- Video Terms
  - Progressive – lines are addresses sequentially
  - Interlaced – odd lines are addressed sequentially followed by even lines
  - 720p – 1280 columns x 720 rows - progressive
  - 1080i – 1920 columns x 1080 rows – interlaced
  - 1080p – 1920 columns by 1080 rows – progressive
  - 4K UHD – 3840 columns by 2160 rows
  - 4K DCI – 4096 columns by 2160 rows (cinema movies)
  - 8K UHD - 7680 columns by 4320 rows
  - 24Hz – frame rate for TV and movies
  - 60Hz – frame rate of Blu-ray – interlaced (30 progressive)
  - 120Hz – frame rate used to offset some LCD characteristics wrt. motion
    - May or may not actually be frame rate – backlight tricks
  - 240Hz – marketing gimmick ?

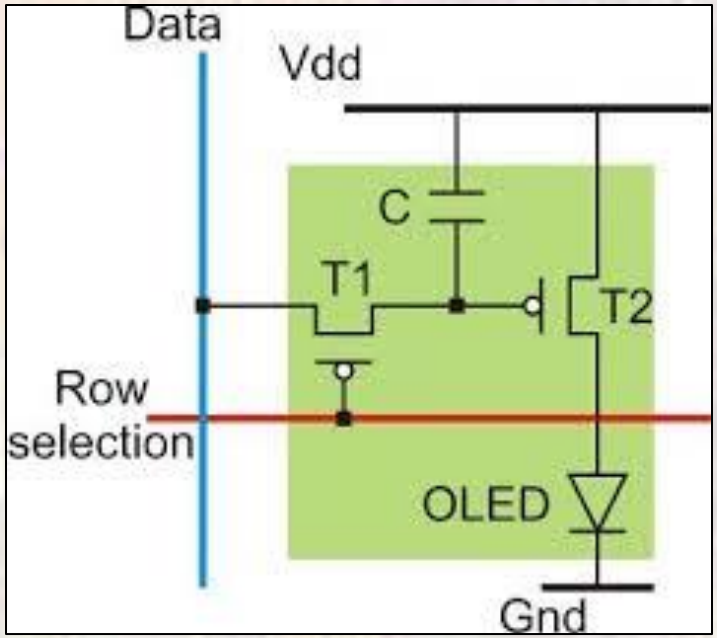
LCD Displays

- OLED
  - LED constructed of organic material
  - Engineered to create R,G, or B
    - Can add color filters for fine tuning



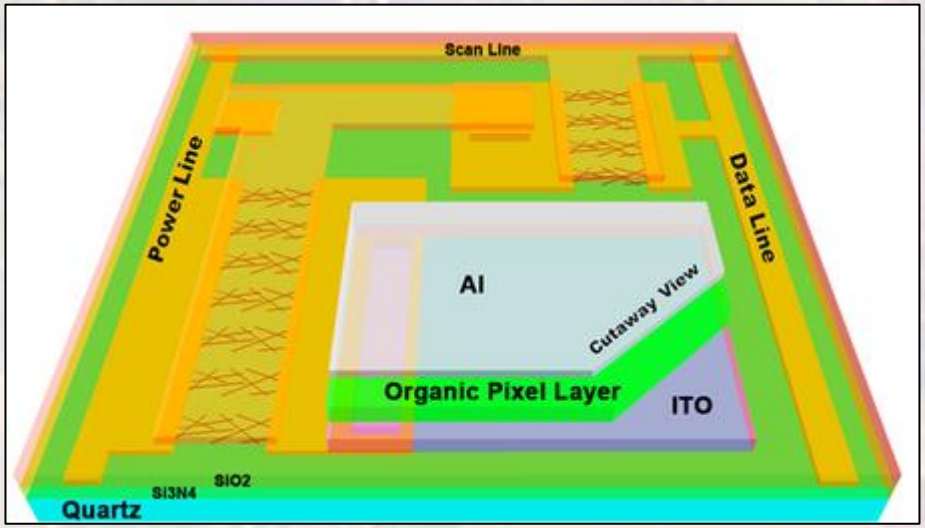
LCD Displays

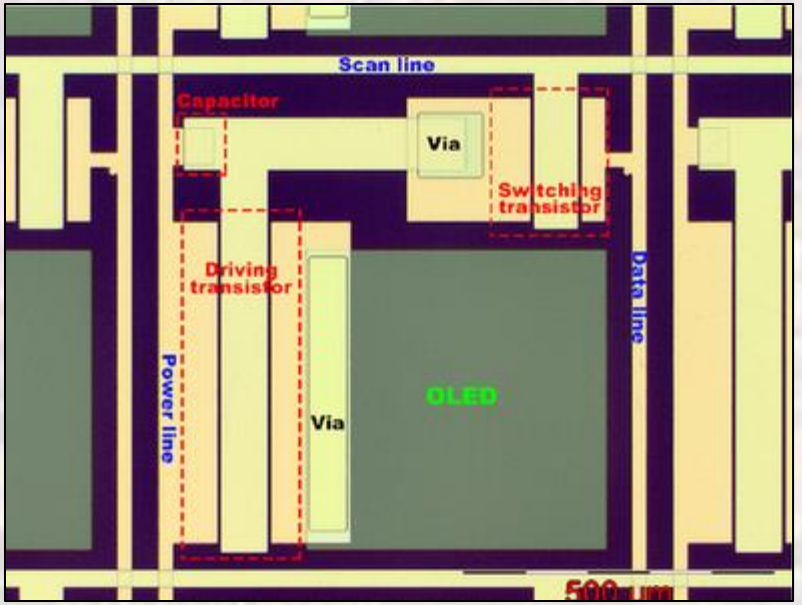
- OLED
  - Control the current flow in the LED
    - Voltage stored on a capacitor
    - Modulates current in the transistor (T2)
    - Intensity ≈ current



LCD Displays

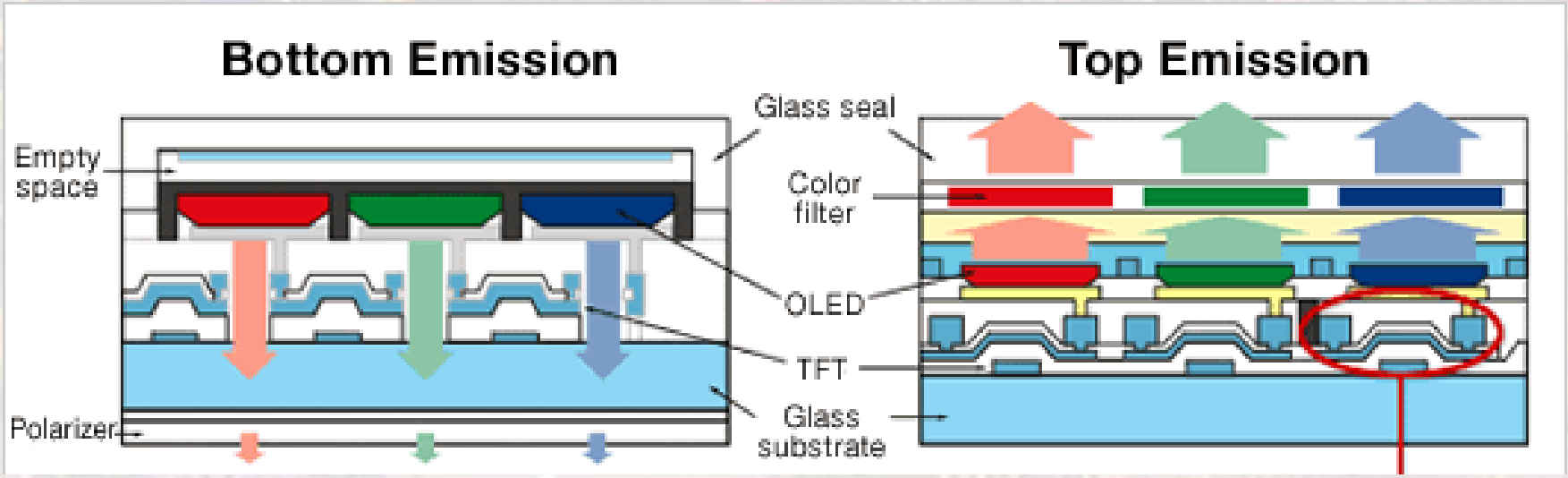
- OLED
  - Physical structure





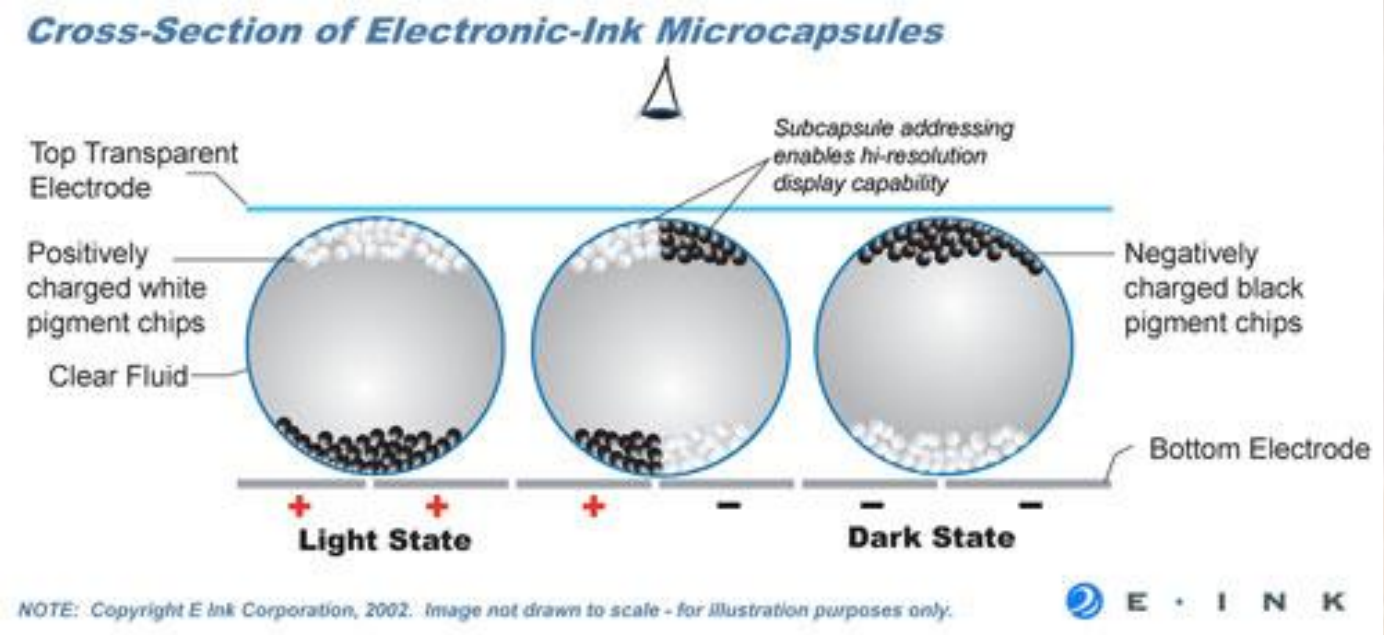
LCD Displays

- OLED
  - Top or bottom emission configurations



LCD Displays

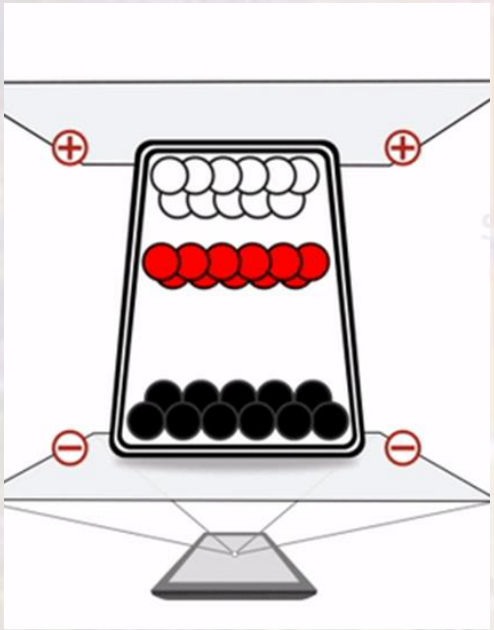
- E-Ink
  - Charged micro-particles in clear spheres
    - Approximately the size of a human hair
  - Kindle, …
  - No passive current required

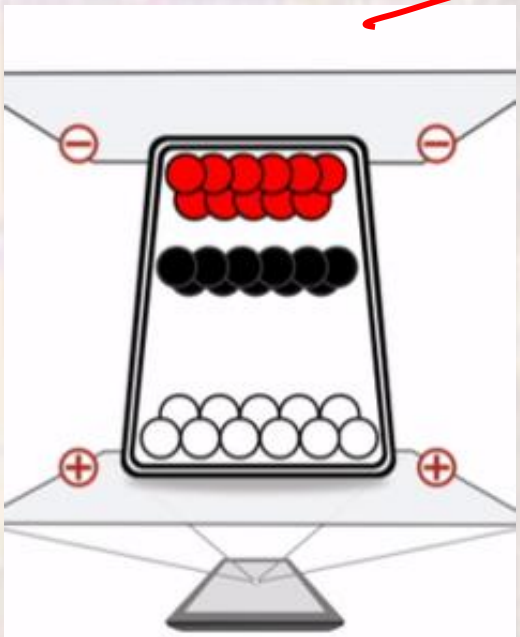


LCD Displays

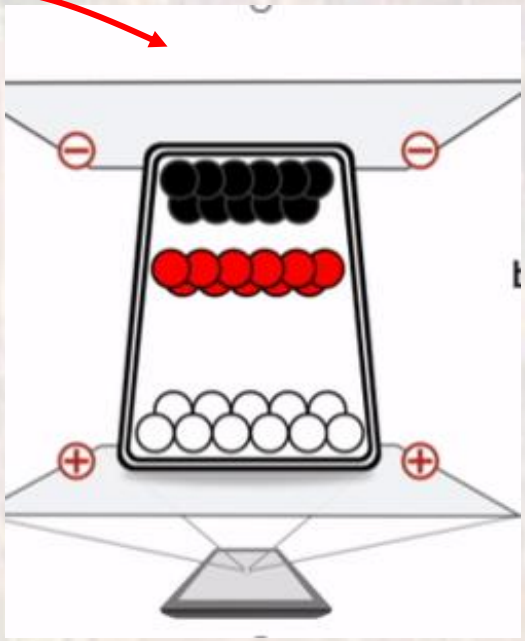
- E-Ink – 3 color
  - White – negative charge
  - Red – positive charge – Q
  - Black – positive charge - q

Momentarily charge the top plate to +, pushing away the red balls
Then return the potential





V+



V++

LCD Displays

- E-Ink – 3 color
  - White – negative charge
  - Red – positive charge – Q
  - Black – positive charge - q

Mobility differences in the Red and Black balls cause a smaller field to move The Red balls to the top. A larger voltage Forces the black balls past the Red balls