

# **Images and Displays**

**Computer Graphics**  
**Instructor: Sungkil Lee**

# Today

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- **Digital Images**
- **Raster Graphics**
- **Vector Graphics**
- **Displays**

# Images

- **Image:**

- **Continuous** 2D distribution of intensity or color, defined as a 2-D function  $f(x, y)$  at spatial coordinate  $(x, y)$
- $f(x, y)$  is the intensity (or gray level) or the amplitude of light.



Lena: the most famous test image in image processing community

# Digital Images

- **Digital image:** a *finite*, *discrete* quantities of image
  - finite range: e.g., 0-255
  - discrete quantities: e.g., 0, 1, 2, ..., 255 (integer only here)
  - usually has 3 channels: RGB (red, green, and blue)
    - motivated by 3 types of cone cells (L, M, S) in the retina
- **Pixel (picture element):**
  - A single element of a digital image
    - For multi-channel images, three channel elements form a pixel.
  - c.f., voxel (volume element), texel (texture element)

# Digital Images: Example

- **3-channel RGB format**

- Intensity of the red channel is stronger than the other two in the example.



red

+



green

+



blue

=

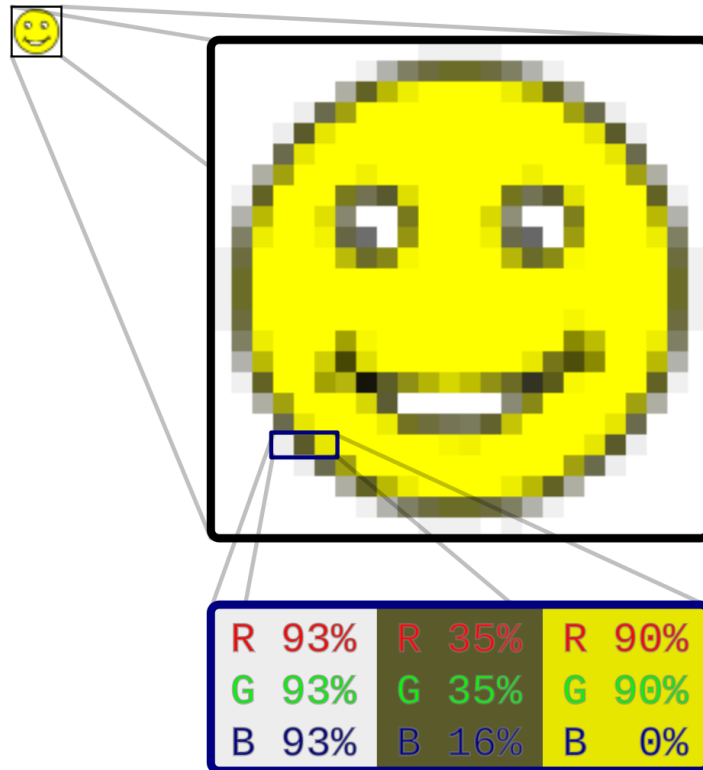


RGB

# **Raster Graphics**

# Raster Graphics

- A raster graphics representation (also called the **bitmap**)
  - *2D array* structure that represents a rectangular grid of pixels.
  - When enlarged, a blocky structure is visible

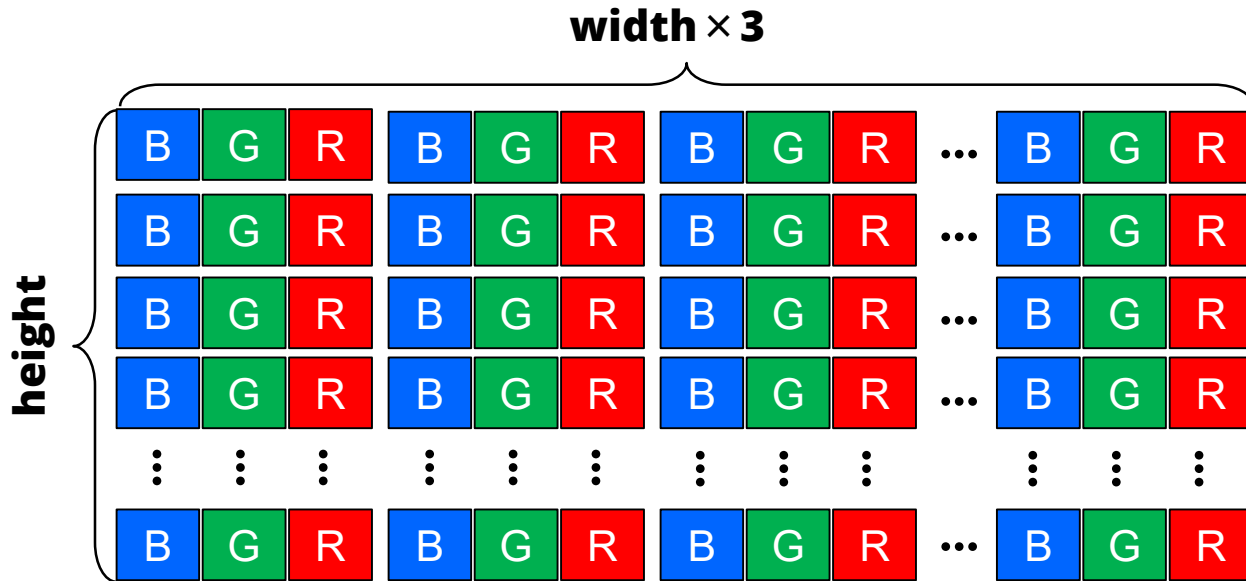


# Raster Graphics

- Memory structure

```
unsigned char image[height*width*3];    // as a 1D array
```

- e.g., BGR format in Windows BMP



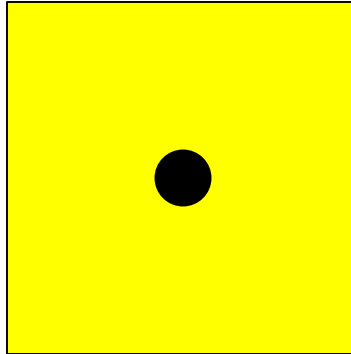
- Note: OpenGL uses 4-byte alignment for texture/images and framebuffer, which may pad additional bytes for each row.



# Raster Graphics

- **Implication of a raster image**

- **approximation** (sampled representation) of a real intensity distribution
  - c.f., a floating-point number in computers is always an approximation.
- A single pixel represents the **color of the pixel center location**, not on its whole pixel area.
- Example:
  - the yellow color of the center approximates the whole pixel area.



# Raster Graphics: Advantages

- **Representation of arbitrary images**

- Brute-force sampling can represent arbitrary images without the function of a continuous image.
- This works, because memory is cheap.

- **Quality control**

- Quality can be higher with denser sampling (higher resolution).

- **Mapping to displays**

- Shapes of most display devices are rectangular.
- The 2D array can easily be mapped to display devices.

# Raster Graphics: Data Types

- **Bitmaps:**
  - boolean per pixel (black or white); e.g., fax, (old) newspaper
- **Grayscale:**
  - integer per pixel (gray levels)
  - Precision: usually 8-bits per pixel (bpp), but often 10, 12, 16 bpp
- **Color:**
  - 3 or 4 integers per pixel (RGBA for 4 integers; "A" means alpha/opacity)
  - Precision: usually 24 bpp (RGB) or 32 bpp (RGBA)
- **Floating-point**
  - Floating-point format is often used for high-dynamic range (48 or 96 bpp)
  - Exposure effects can be captured with HDR formats

# Raster Graphics: Storage Requirements

- **1024 × 1024 image (1 Megapixel) example**
  - bitmap: 128 KB
  - grayscale 8bpp: 1MB
  - grayscale 16bpp: 2MB
  - color 24bpp: 3MB
  - floating-point HDR color: 12MB
- **Think about:**
  - how much memory is required for an arbitrary resolution and bpp.

# Raster Graphics: File Containers

- **Compression of image files**

- When images are stored into disks with particular formats, they are usually compressed. So, you see much smaller file sizes for them.

- **Typical containers**

- BMP: Lossless raw format
- JPEG: Lossy compression (pronounced as "Jay-Peg")
  - Using DCT (discrete cosine transform for compression)
- PNG: Lossless compression (pronounced as "Ping")
  - Using ZLIB for compression
- TIFF, GIF, ... (obsolete)
- WebP (recent container/compression by Google)

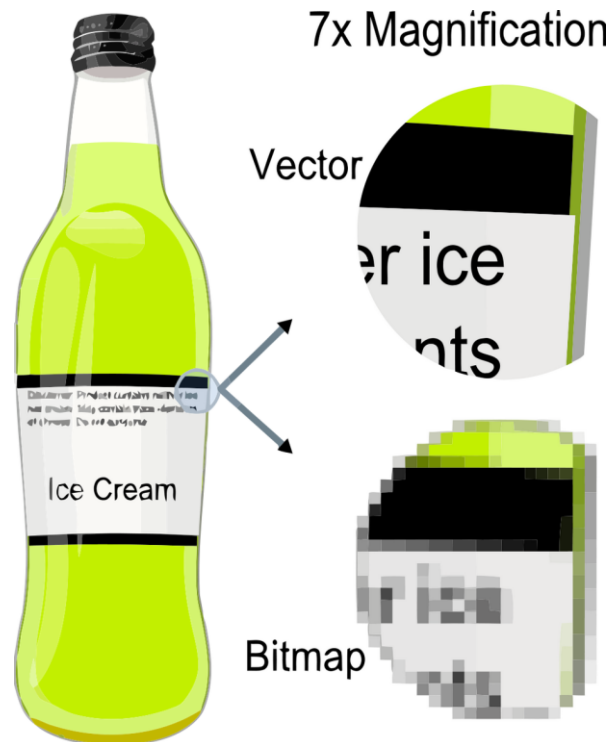
# **Vector Graphics**

# Vector Graphics

- **Unlike the raster graphics, vector graphics uses geometrical primitives such as points, lines, triangles, curves, etc.**
  - The primitives are represented as a mathematical expressions.
  - "Vector", in this context, is more than a straight line.
- **Common tools/formats to manipulate 2D vector graphics**
  - Adobe illustrator
  - Adobe Acrobat
  - SVG (Scale Vector Graphics; recently available on the web)
  - Postscripts (for printers or printer file)

# Vector Graphics

- **Vector graphics representations are usually independent of the output resolution.**
  - Because they are **rasterized on the fly** at the output stage to be displayed.
  - Still, most of display devices use raster display.





# 3D Graphics: 3D Vector to 2D Raster

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- **Input: 3D vector representation**

- Graphics uses vector graphic formats as an input
- Points, lines, triangles, quads, polygons, curves, ...

- **Output: 2D raster representation**

- Raster images whose dimension is identical to the window resolution

# Graphics Terms

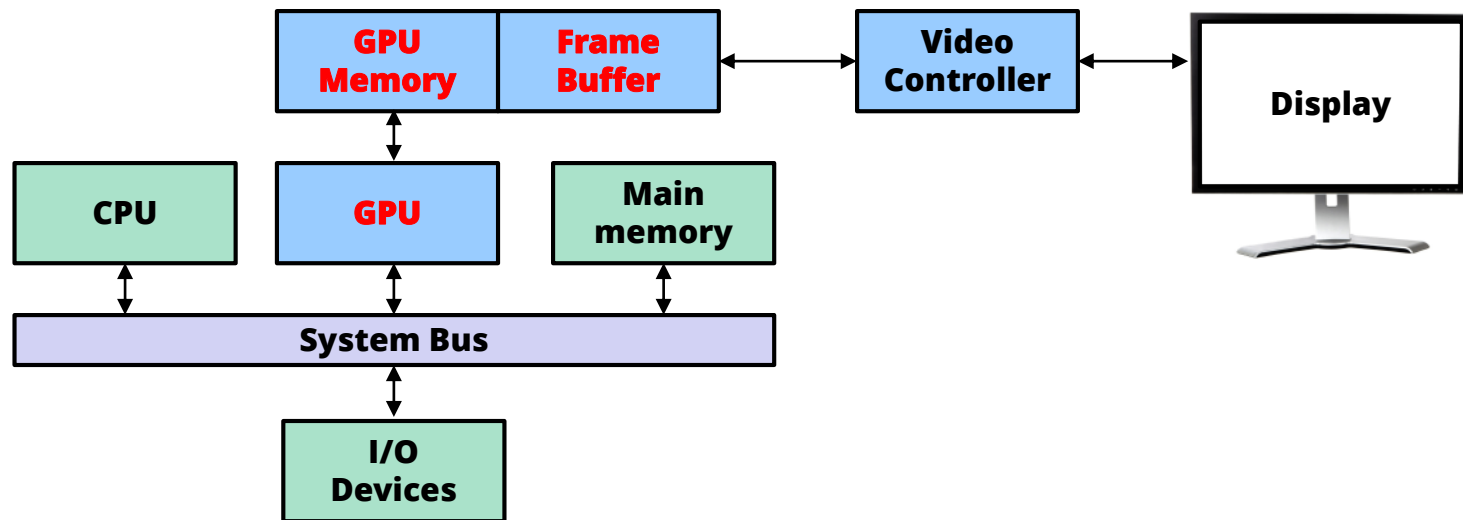
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- ***"capture images" means:***
  - record the light distribution on the sensor (using cameras)
- ***"represent images" means:***
  - encode images numerically (normally binary)
- ***"display images" means:***
  - realize the encoded images as actual intensity distribution on the display devices (e.g., monitors)

# Displays

# Raster Display System

- **Screen image is defined by a 2D array in RAM**
  - The memory area is called the *frame buffer*.
  - Most modern systems have it in **Graphics Processor Unit (GPU)** memory.
  - GPU memory is often shared with main memory.
- **Common architecture of a raster display system**



# Display Devices

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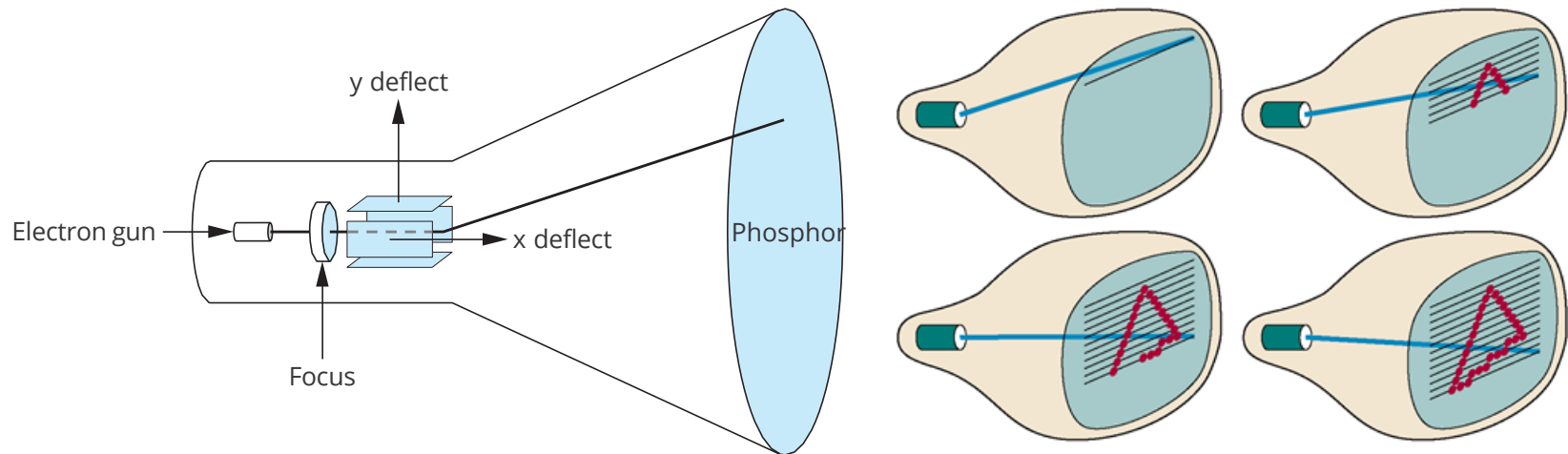
- **Typical computer displays**

- CRT (Cathode Ray Tube)
- LCD (Liquid Crystal Display)/LED (Light Emitting Diode)
- OLED (Organic LED)
- AMOLED (Active Matrix OLED)

# Cathode Ray Tube (CRT)

- **Raster scan display**

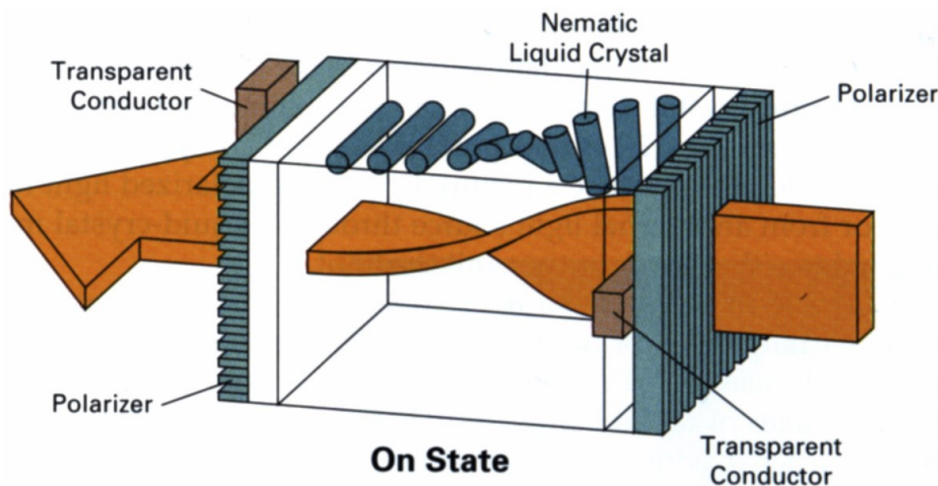
- Can be used either as vector (calligraphic or random-scan) display device or raster display system (from frame buffer)
- TV-standards: PAL, NTSC
- Direct view storage tube (DVST):
  - an early alternative for persistent display without constant refresh



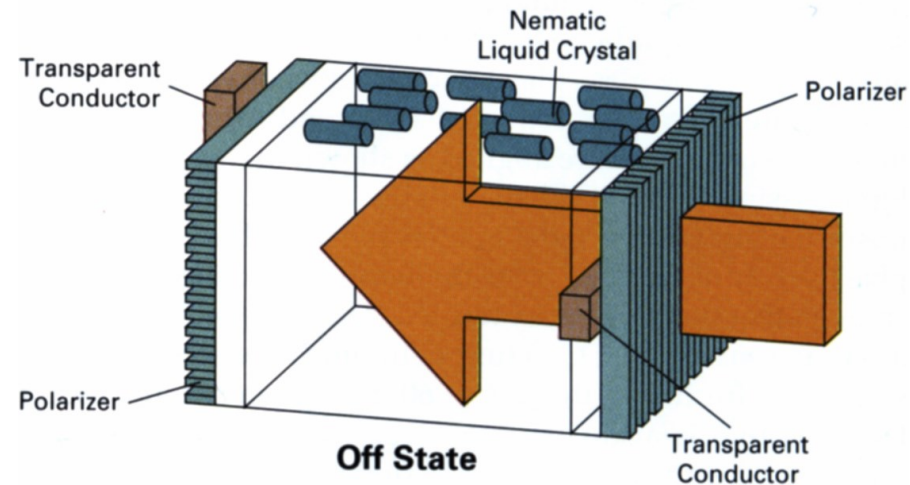
# LCD Flat Panels: Twisted Nematic (TN)

- **Principle:**

- Block or transmit backlight (e.g., LED) by twisting its polarization
- Fundamentally raster technology
- Light may leak at the maximum voltage (i.e., blocked)
- Faster response than IPS or VA panels



**Voltage off: white (on state)**



**Voltage on: black (off state)**

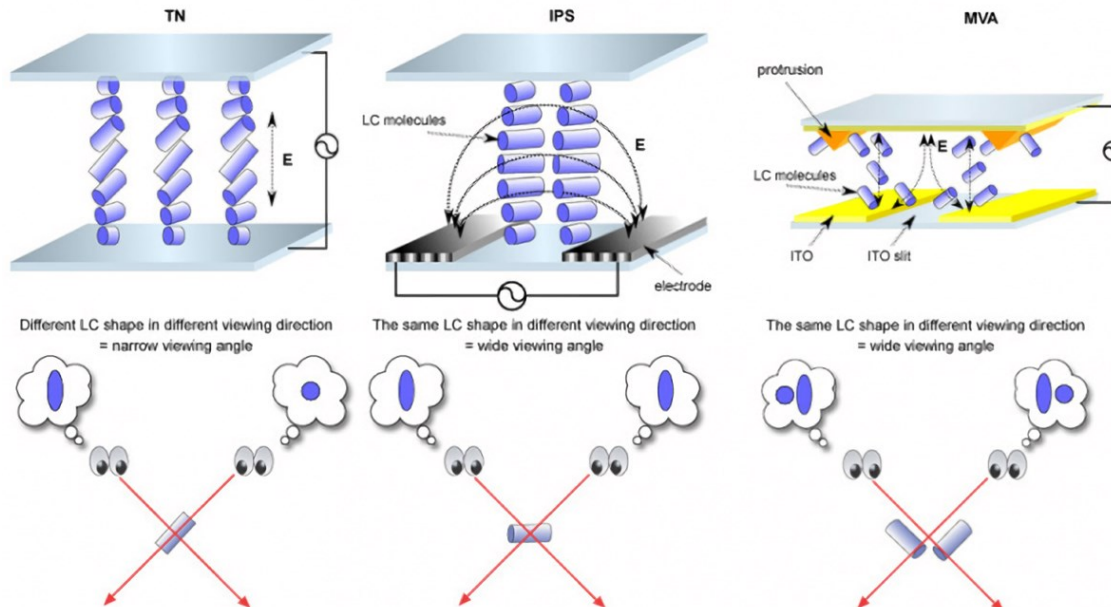
# LCD Flat Panels: IPS and VA

- **IPS (In-plane Switching) panels**

- Horizontally rotates LCs in its plane
- Good for wide-angle viewing and touch-sensitive screen

- **VA (Vertical alignment) panels**

- Vertically aligned LCs (at voltage off) tilt at the voltage on
- Wide-angle viewing and higher contrast

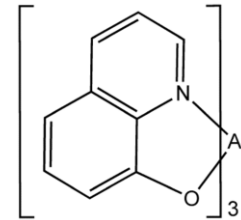
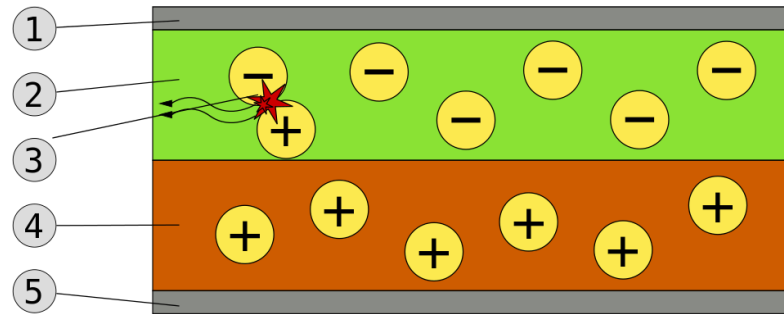




# OLED (Organic Light Emitting Diode)

- **Principle:**

- Self-emit or not light by organic materials
- Works without backlit: better in contrast ratio than LCD
- Fundamentally raster technology

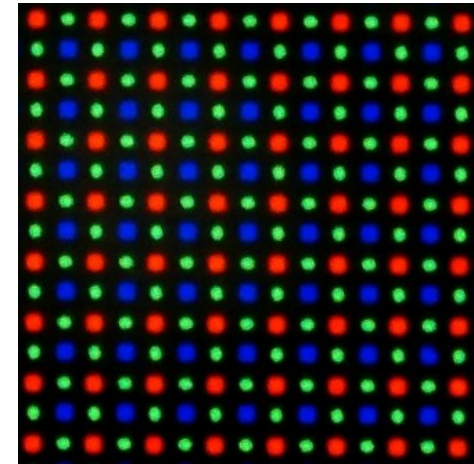
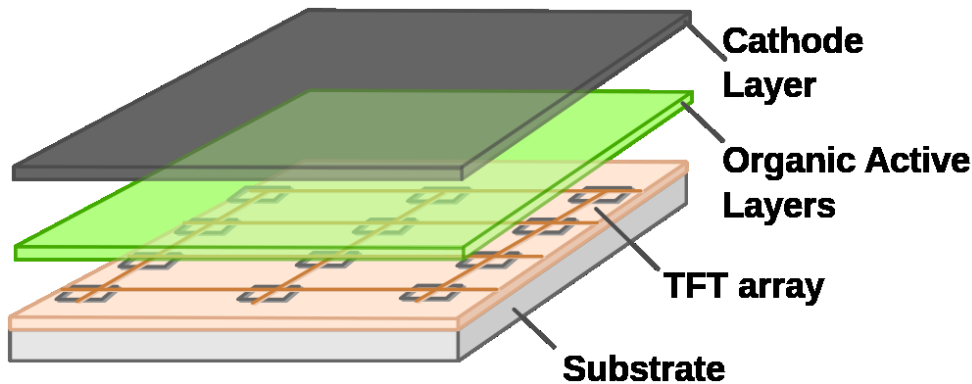


**1. Cathode (-), 2. Emissive Layer, 3. Emission of radiation, 4. Conductive Layer, 5. Anode (+)**

# AMOLED (Active-Matrix OLED)

- **Principle:**

- Active matrix addressing:
  - Each element's state is maintained by individual circuits.
  - Faster than passive matrix addressing in refresh rates



**Pentile matrix pattern on Galaxy S6/S7**

※ Super AMOLED (Samsung Elec. Co. Ltd.) = AMOLED + touch digitizer