# Architecture of Computers and Parallel Systems
# Part 8: Computer Display Units

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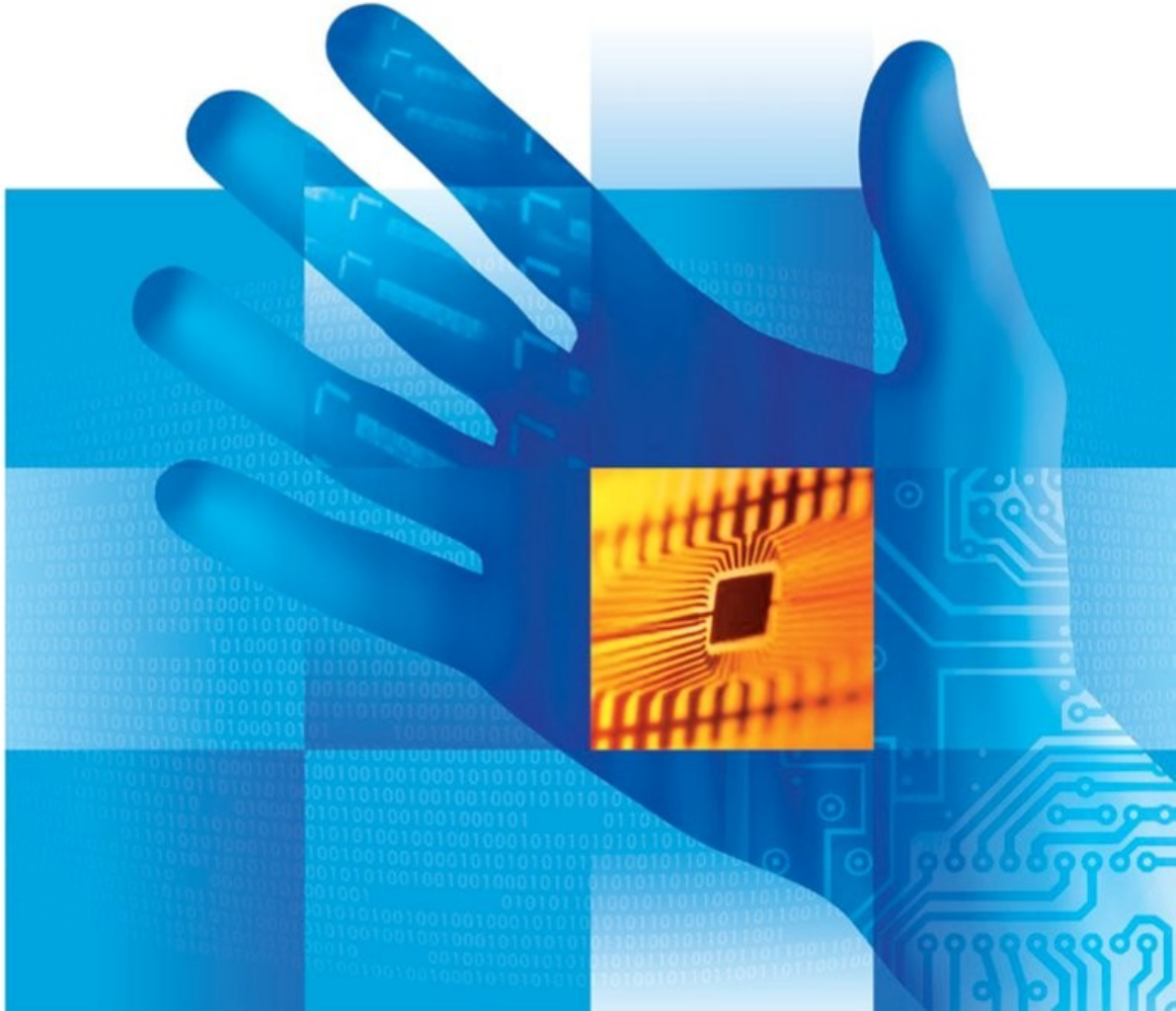


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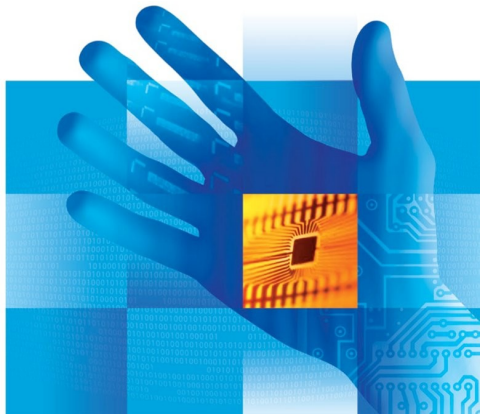


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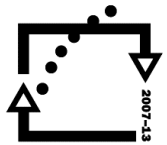
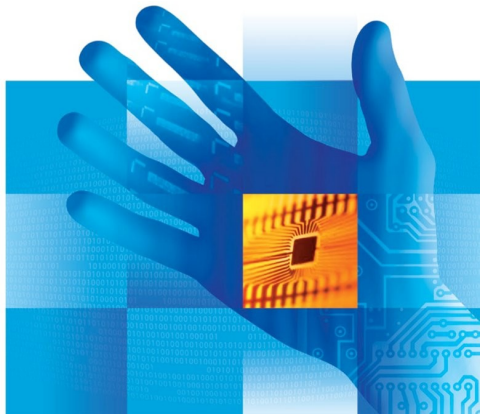



OP Vzdělávání pro konkurenceschopnost

INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ



# Monitors and Displays

Monitors and displays are the most important interface between the user and the computer. They allow to display text and graphical information. Their properties are a major factor that determines the ergonomics of computer work (concurrently with sitting at the right and good quality chair).

The development of display units for computers, TV, PDA and cell phones has made a big progress in the last few decades. The following well known technologies have gained their important place on the market:

- CRT – Cathode Ray Tube
- LCD – Liquid Crystal Display
- Plasma display
- OLED – Organic Light Emitting Diode
- E-Ink – Electronic (Electrophoretic) Ink.

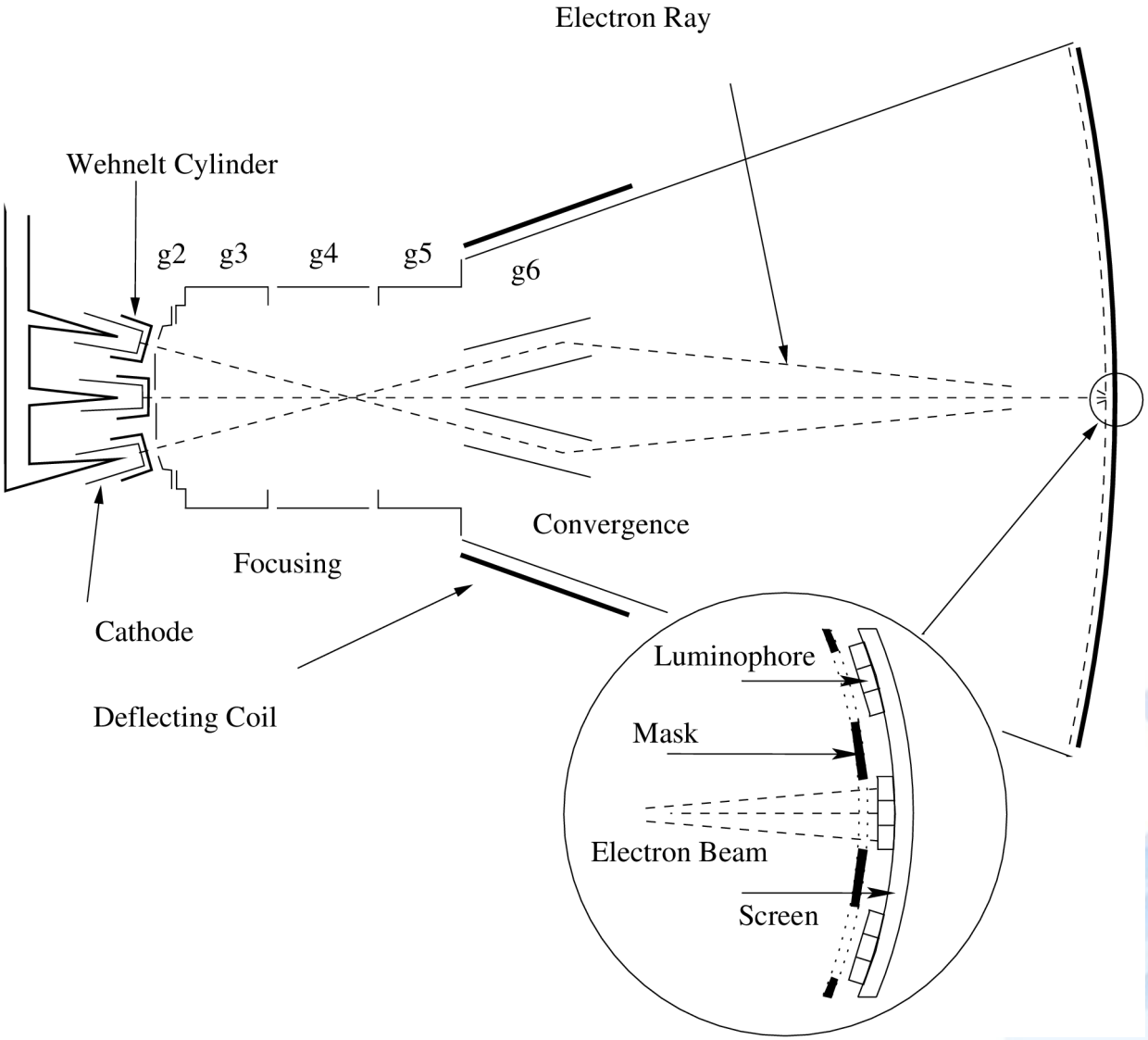
# CRT

The CRT screen is the successor of the tubes. It is a glass vacuum tube. The front part of the screen is covered by luminophores. There is electron gun on the oposit side. To better understand the principle, look at the picture on the next slide.

Electron gun emits electrons and Wehnelt Cylinder guides them to stream. In focusing cylinder (g2-g5) the stream is narrowed to a thin ray. Because the Electron gun is the Cathode and the Screen is the Anode, the electron ray continues to screen. Then the ray has to pass through Focusing Coils, which direct ray to specified point on the screen and it is able to control the ray intensity.

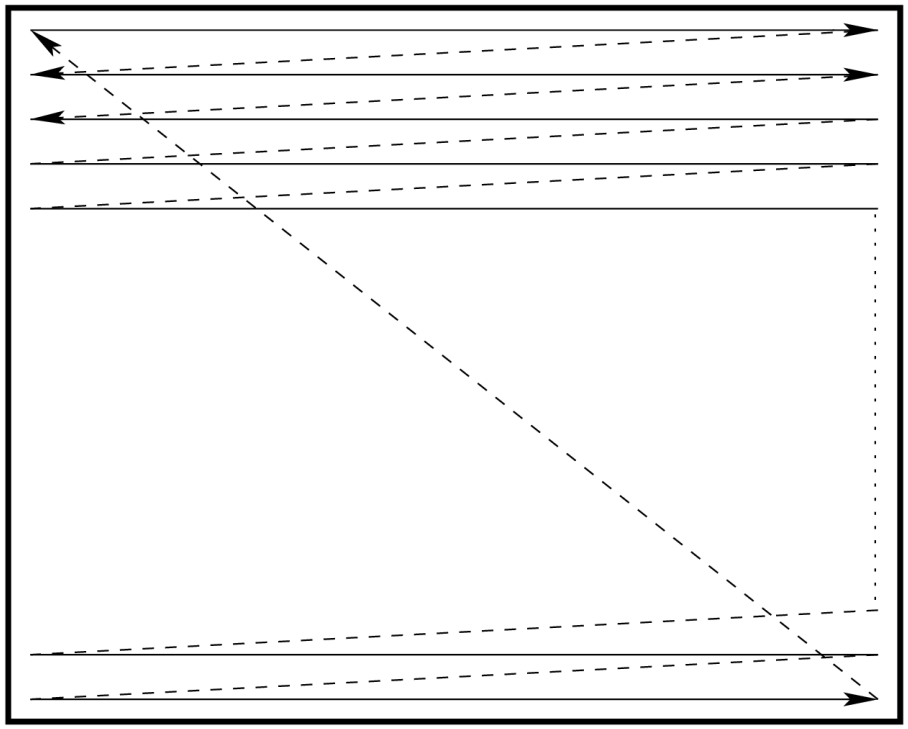
When electron ray reaches the luminophore on the screen, this material transforms the kinetic energy of electrons to photons. Thus the screen emits the light. On the screen there are three types of luminophores – red, green, blue – to achieve the colored light, and three electron guns work in the screen together, for each color individually.

# CRT Scheme


Electron Ray
Wehnelt Cylinder
g2
g3
g4
g5
g6
Convergence
Focusing
Cathode
Deflecting Coil
Luminophore
Mask
Electron Beam
Screen

# … CRT

Someone might ask: how is it possible that a thin electron ray creates full screen image? The ray has to “run” over the whole screen. The movement is not random, but driven. Ray starts in the upper left screen corner and from left to right, line-by-line, quickly “draws” the image. Than the ray returns back from the bottom right corner to the upper left corner:



# … CRT

The luminophore is able to emit light only for a few milliseconds and image has to be redrawn many times per second. For human eyes the acceptable minimum refresh frequency is 60Hz. The ergonomic minimum is 72Hz and the best refresh rate is in the range from 80Hz to 100Hz.

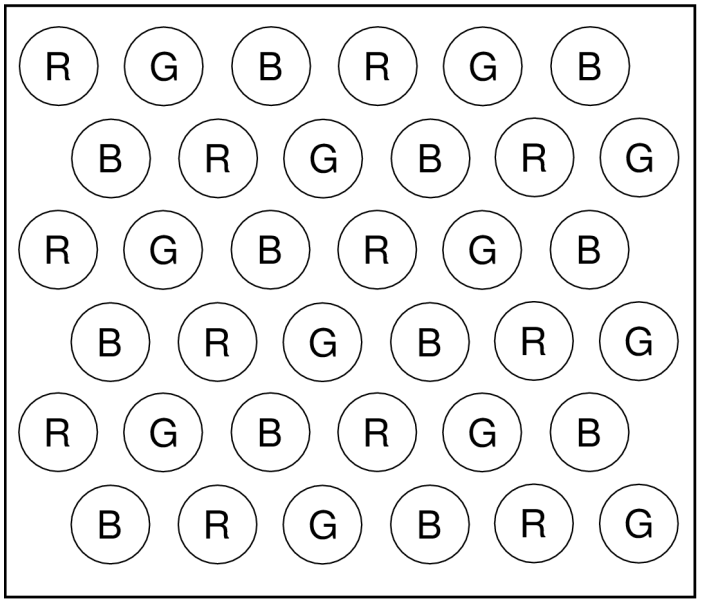
For the image quality the shape of the screen mask it is very important. First RGB monitors used Invar mask. It is metal plate with small round holes arranged as a honeycomb. The main problem of this mask was the lower image quality on the screen edges.

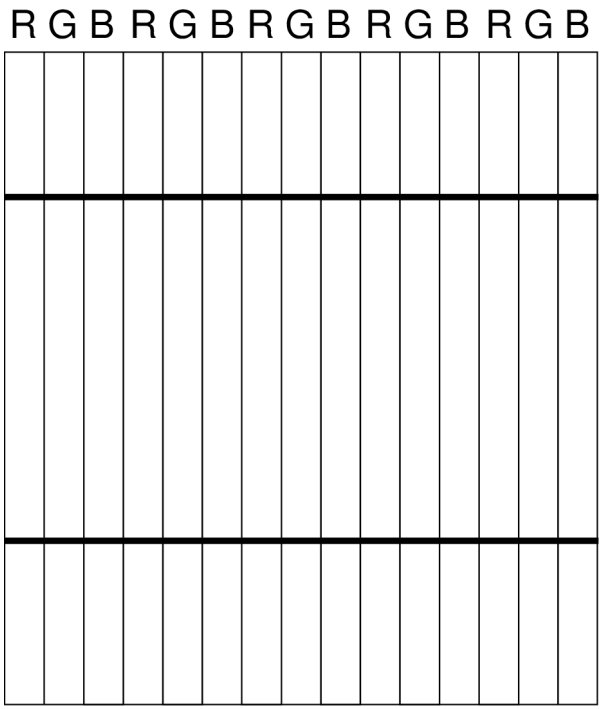
The latest monitors used Trinitron mask (designed and patented by Sony). The luminophor on the screen is organized in columns separated by thin wires. Screen with this technology can be flat and it has very good image on the whole screen surface.

Both mask shapes are showed on the next pictures:

# … CRT

The invar screen with three base color luminophores. No two neighboring cells have the same color.




Trinitron color screen. Horizontal wires keep distances between vertical ones.

# CRT Properties, Pros and Cons

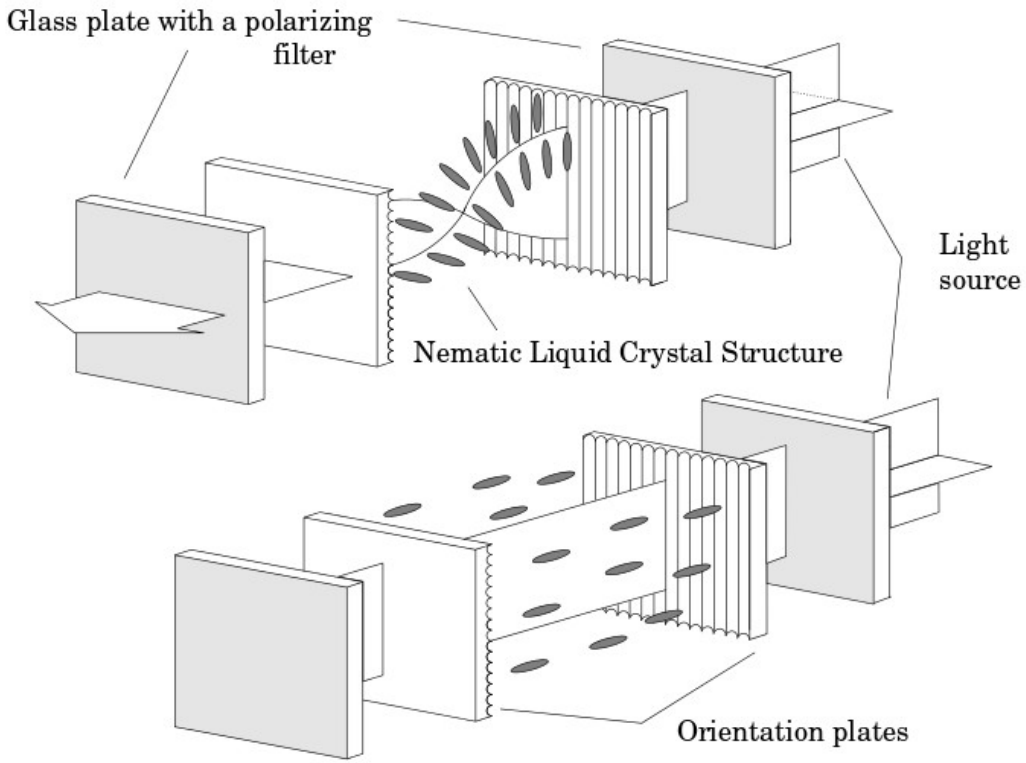
- The main parameters of CRT monitors include: diagonal, resolution, horizontal and vertical refresh frequencies, refresh rate, resolution, bandwidth (how many points it draws per second), weight, power consumption.

- Benefits: sharpness, color fidelity, good response, viewing angle, visible at daylight, work at all temperatures.

- Disadvantages: heavy, high power consumption, slow start, harmful radiation, aging of luminophores.

# LCD

The LCD technology – Liquid Crystal Display – is currently used in most monitors. As the name suggests, the main active components are liquid crystals. But the LCD is assembled from multiple layers:

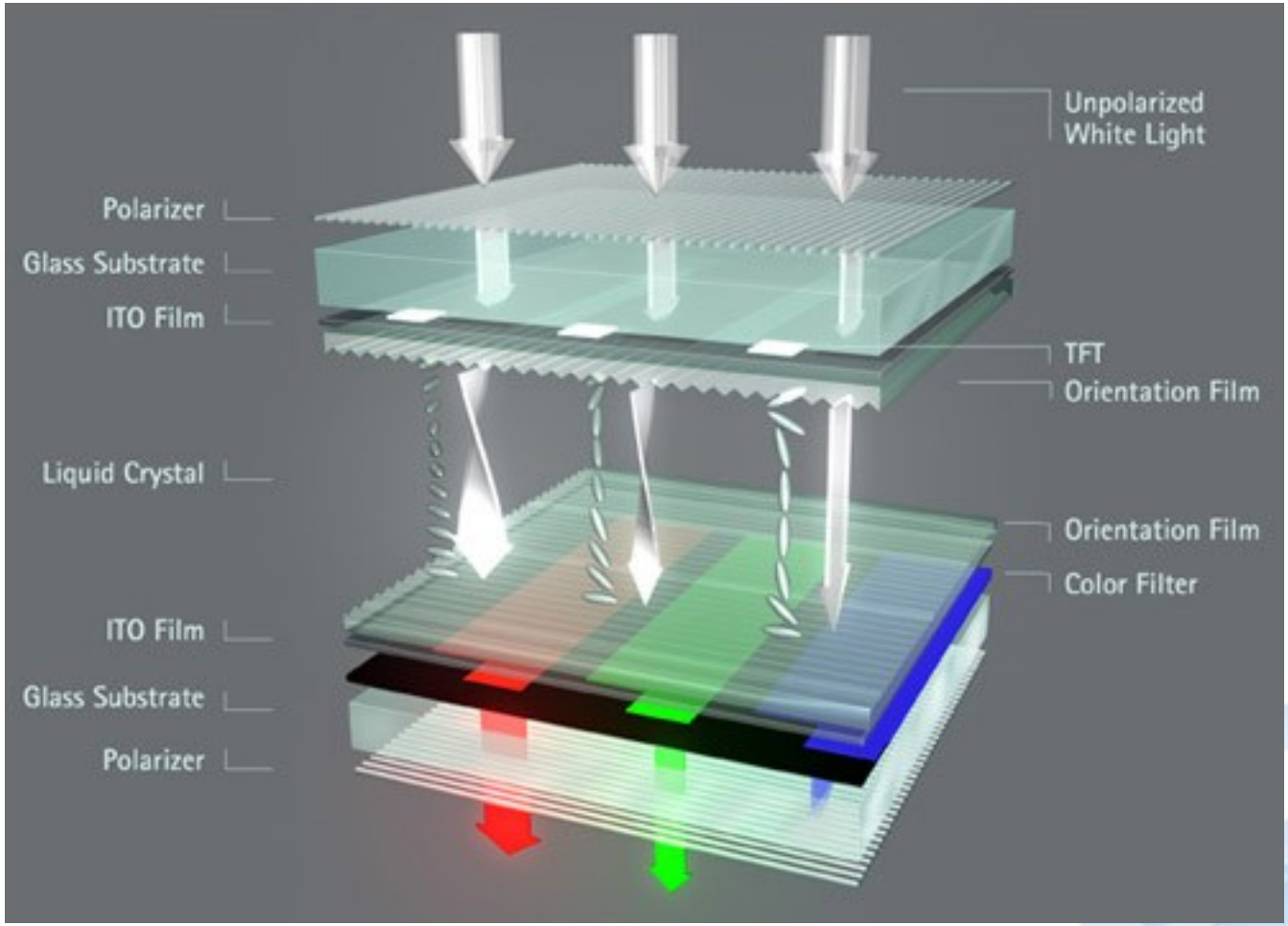


# ... LCD

It can bee seen from the previous scheme that LCD consists (minimally) of five layers. The source of light is on the LCD background. This light is polarized in all directions. The light has to be polarized by the first layer and continues through transparent orientation plate to nematic layer with crystals. Crystals in this layer have one very important property. They are able to change the orientation of the polarized light. Size of change can be affected by the electrical voltage.

The light with changed polarization passes through the second orientation layer to the outer polarization filter. This filter has a orthogonal polarization relative to the first filter. Thus, only light with changed polarization in the middle layer can pass through the last layer. Brightness (intensity) of the output light is controlled by the voltage in the middle layer in nematic structures. Orientation filters help to set correct orientation of crystals in this structure. Because crystals are in liquid, their position change is delayed.

# RGB LCD


Unpolarized
White Light
Polarizer
Glass Substrate
ITO Film
TFT
Orientation Film
Liquid Crystal
Orientation Film
Color Filter
ITO Film
Glass Substrate
Polarizer

# … RGB LCD

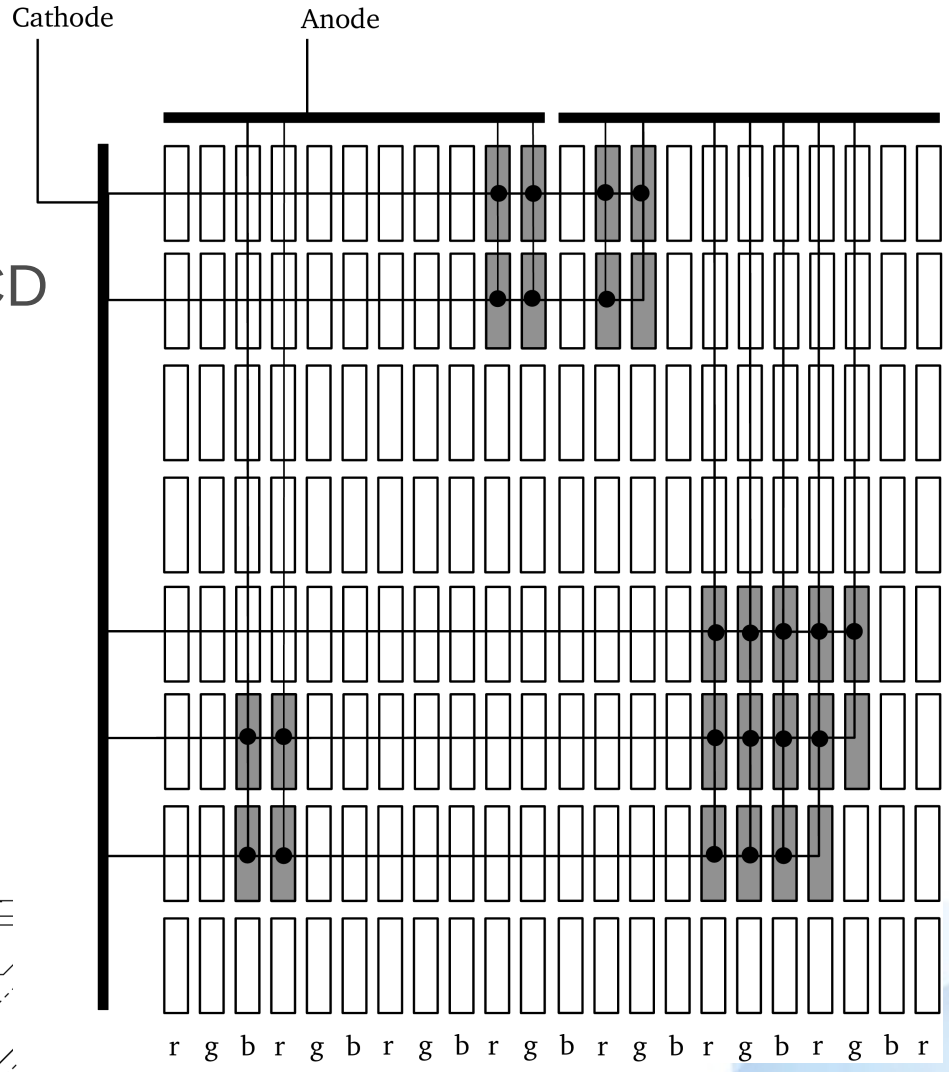
When we need a color LCD, it is necessary to add the colored layer. You can see this on the previous picture. Light from front polarized filter passes through one basic color – RGB – and because the source of light is white, the result is exactly one basic color. Colored filter does not pass any other colors.

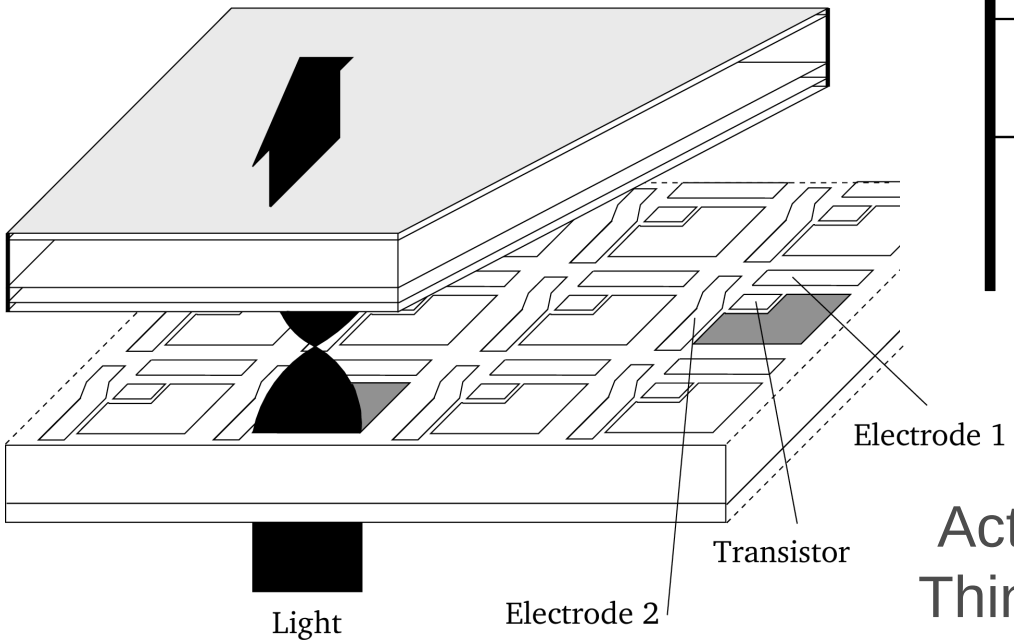
The resulting color is the combination of all three colors. Thus all pixels on the color display consist of three smaller cells with different colors.

The previous picture also shows, how LCD display controls the intensity of output light. We can get higher or lower light intensity by bigger or smaller rotation of light.

# LCD Control

Passive control of LCD by net of wires.




Active control with TFT – Thin Film Transistor.

# … LCD Control

The control of all screen pixels is needed to draw the image on the LCD screen. As it was mentioned earlier, the brightness of pixel is controlled by the voltage in the middle layer.

There are two known ways to control all pixels. The first one is **passive display**, where wires are integrated in both orientation layers. The bottom layer integrates horizontal net of wires and the top layer the vertical net. The pixel on the screen is selected by proper horizontal and vertical wires and it is activated with required voltage. But interference between the wires causes blur. Whole image is then drawn in the same way as on CRT monitor.

The second more sophisticated method to control LCD is **active display** with TFT. All cells in display have their own control transistor and pixel activation is faster and accurate.

Both schemes, active and passive control, are on the previous slide.

# LCD Properties, Pros and Cons

- The main parameters of LCD monitors include: diagonal, resolution, thickness, brightness, contrast, viewing angle, color depth, response time.

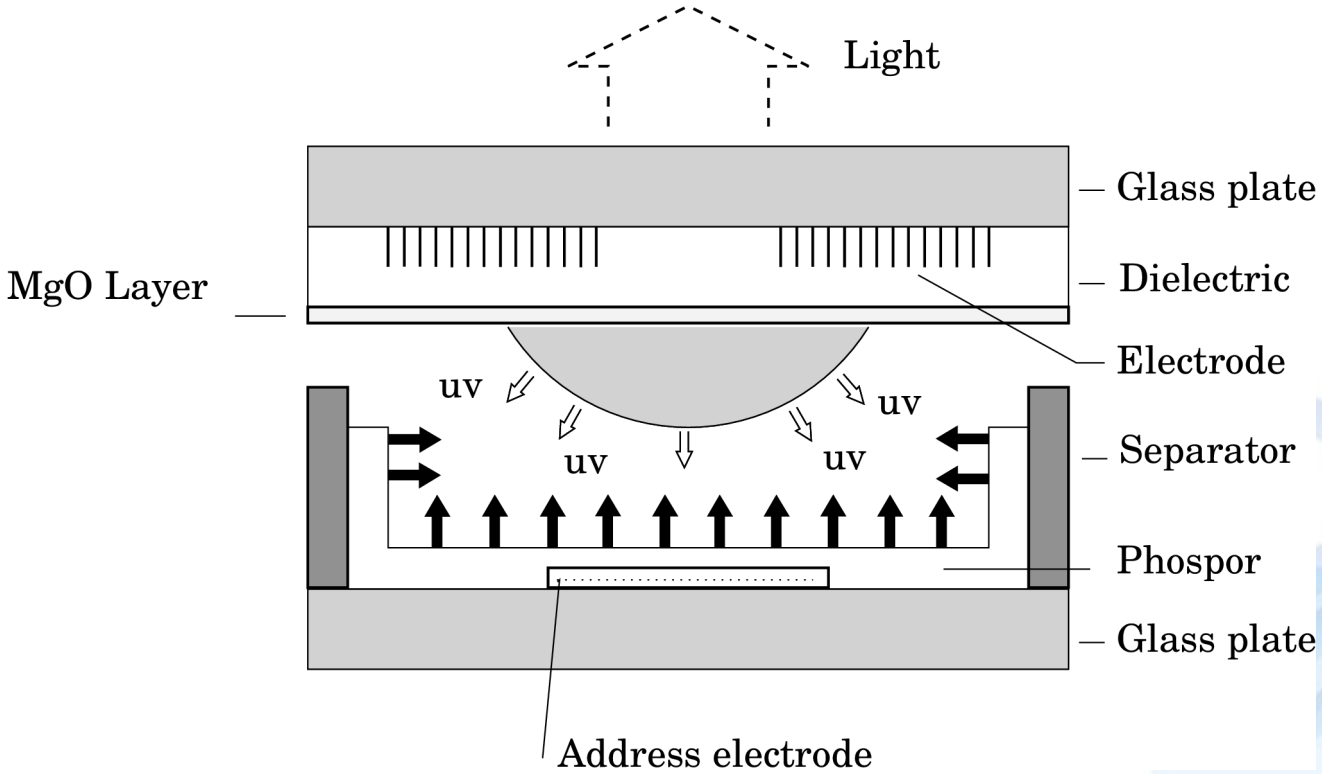
- Benefits: low power consumption, light(weight), small dimensions, stable image.

- Disadvantages: slow response, fixed resolution, color distortion, limited viewing angle, low brightness (on daylight), backlight.

# Plasma Display

Plasma displays are not directly designed for computers due to very high power consumption. They are mostly used for large TV screens.

The scheme of one plasma cell is below:



# … Plasma Display

The working principle of the display is based on the usage of the fourth state of the matter – plasma. The plasma is created in the small closed cell depicted on the previous scheme. The cell contains rare gases. When the voltage is connected to electrodes, gases will create the mixture of free electrons and positive atoms. Electrons are attracted to the anode and atoms to the opposite site. Now the state relaxes.

Where is the plasma? At first we need “to shake” the cell to start collisions of electrons and atoms. How to do that? It is possible by using the alternating current. The mess creates the plasma inside the cell and it produces a UV light. The UV light is in the cell transformed by the phosphor to the visible light.

The intensity of the cell light can be regulated by the intensity of AC power. The color filter has to be added for the color plasma display, like on LCD.

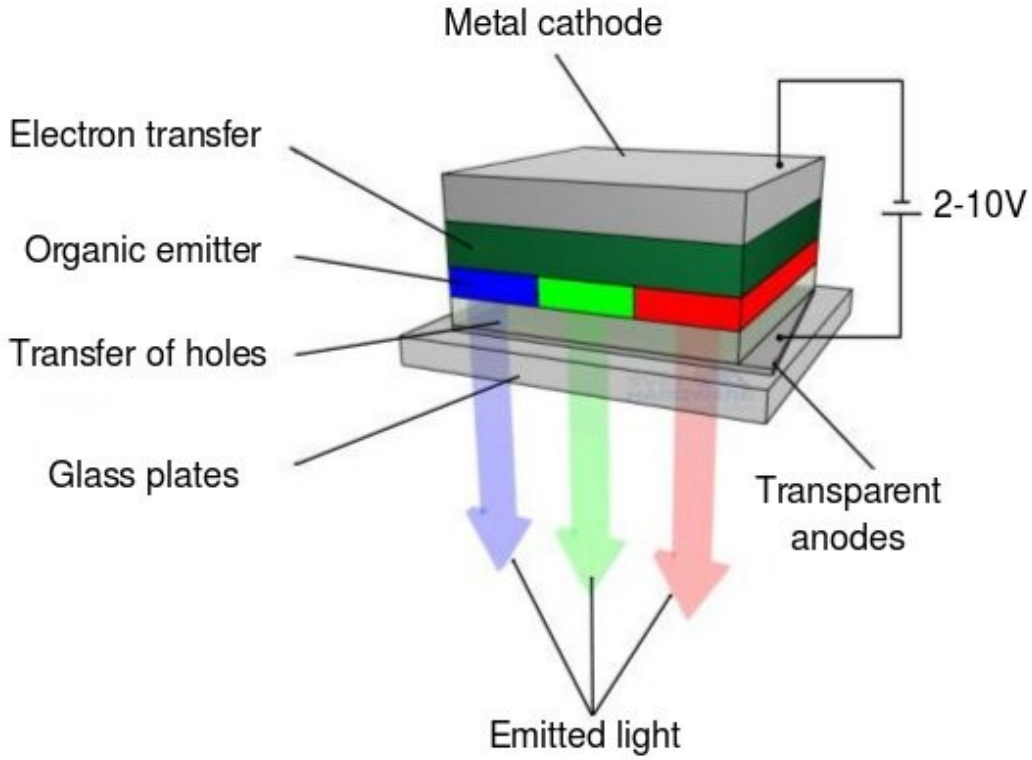
# Plasma Display - Pros and Cons

- Benefits: good contrast and brightness, all cells are source of light and backlight is not needed, good viewing angle.

- Disadvantages: high power consumption, memory effect, cells aging, high price.

# OLED Display

OLED – Organic LED display uses the newest semiconductor technology with organic materials. The scheme of one RGB pixel of a display is below. The organic emitter is inserted between two semiconductor layers.

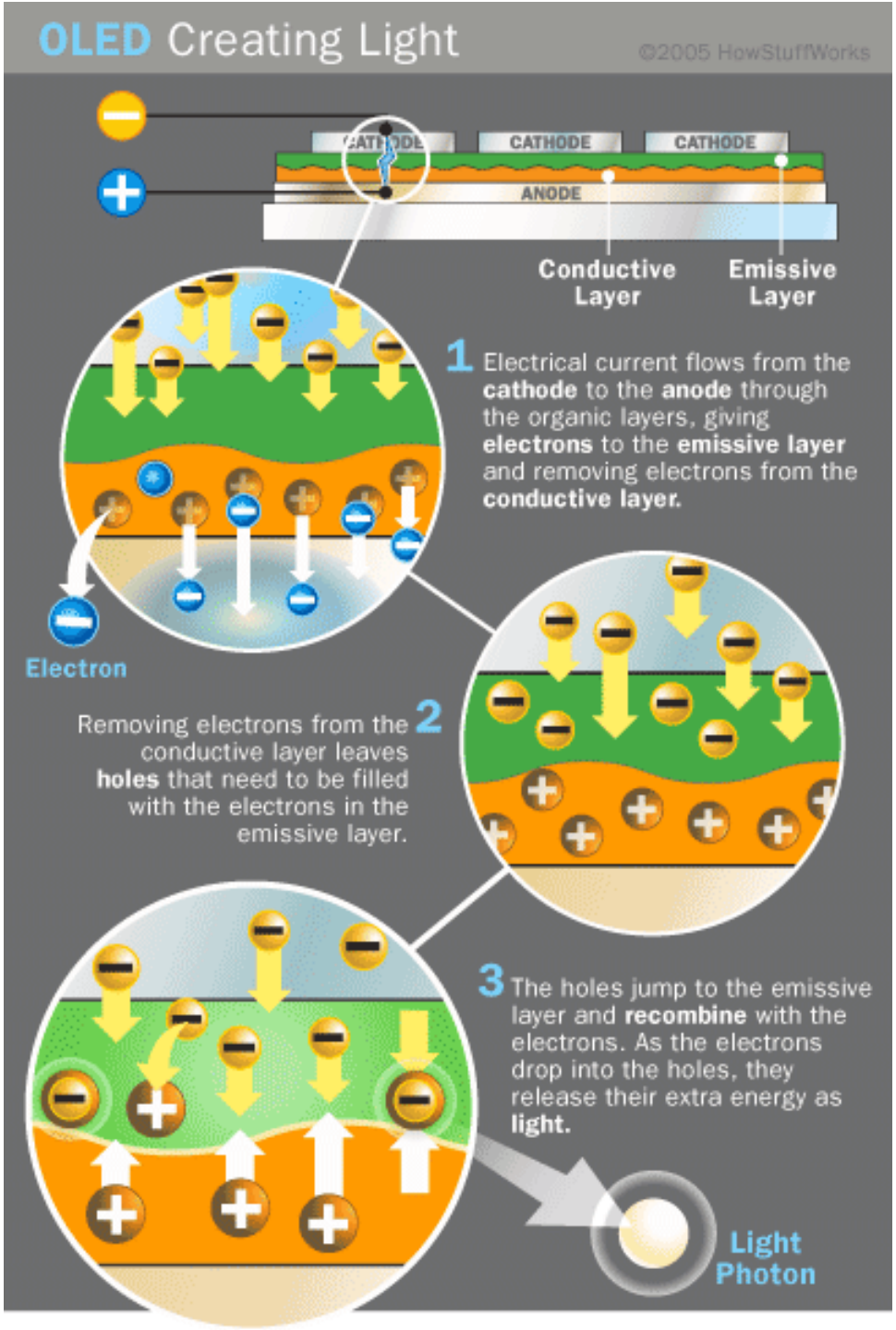


# … OLED Display

The previous figure shows the OLED structure. The metal cathode is at the back of all layers. The second layer is semiconductor for electron transport. The next layer is an organic material capable of emitting light. The fourth layer is a transparent material for holes transport. Under the glass plate there are transparent anodes.

When the power is connected to electrodes, electrons start to cumulate in the organic layer closer to the anode. Holes cumulate on the opposite site of an organic material. Holes and electrons start “to collide” in organic layer, electrons and holes eliminate each other and emit photons. This principle is called **recombination**.

The whole principle is illustrated on the next animation (from howstufworks.com).


OLED Creating Light
©2005 HowStuffWorks
CATHODE
CATHODE
CATHODE
ANODE
Conductive Layer
Emissive Layer
1 Electrical current flows from the cathode to the anode through the organic layers, giving electrons to the emissive layer and removing electrons from the conductive layer.
Electron
2 Removing electrons from the conductive layer leaves holes that need to be filled with the electrons in the emissive layer.
3 The holes jump to the emissive layer and recombine with the electrons. As the electrons drop into the holes, they release their extra energy as light.
Light Photon

# AMOLED/PMOLED Display

The acronym AMOLED and PMOLED means Active / Passive Matrix OLED. This is the same principle as the active and passive LCD displays.

Display pixels are organized into a rectangular matrix. Each OLED is activated in passive displays with two orthogonal electrodes. Electrodes pass through the entire width and height of the display.

In AMOLED displays all OLEDs are activated by their own transistor.

# OLED Display Properties, Pros and Cons

- OLED Display is a light source and does not need a backlight. Its output power is about 30 lm/W (Lumen per Watt), maximally 50 lm/W (classical bulb has 10-15 lm/W). OLED has higher efficiency.

- Benefits: high contrast, full range of color, low power consumption (directly proportional to required brightness), good viewing angle, without delay.

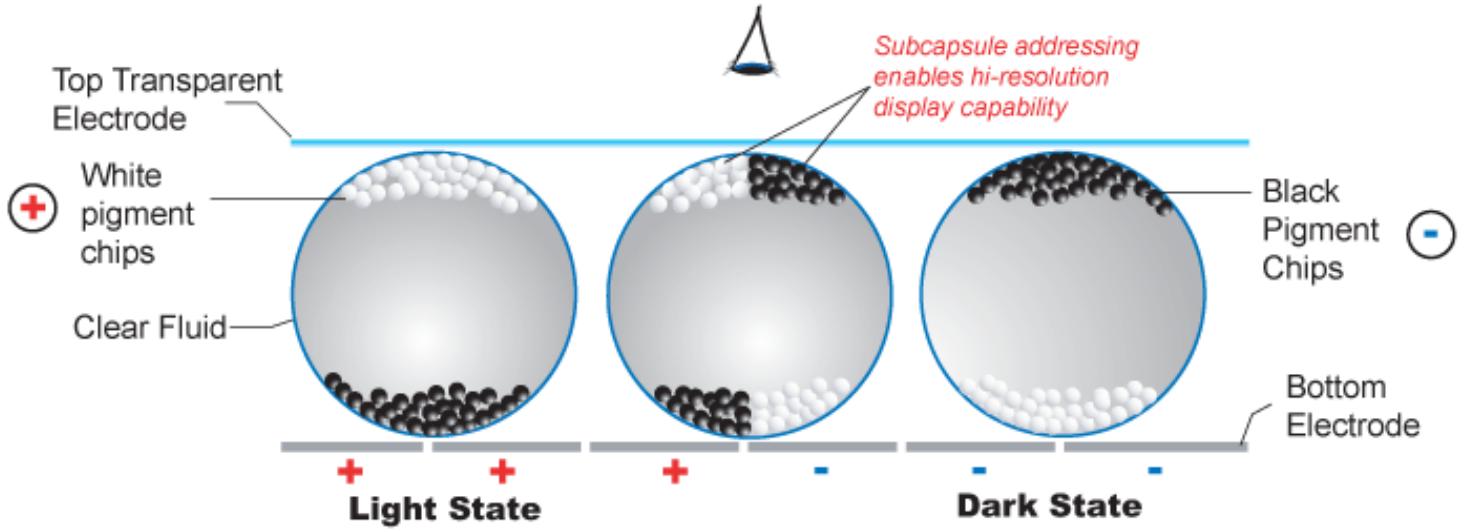
- Disadvantages: evaluation is here really very brief: the OLED technology does not have any known ones!

OLED is the technology of the future!

# E-Ink Display, Electronic Paper

E-book readers became nowadays very popular. They are based on an electronic paper, which uses the electronic ink – E-Ink.

The scheme of one E-Ink cell is visible on the next picture:



# E-Ink

One cell is in E-Ink technology called capsule. All capsules have diameter in tens or hundreds of micrometers. Capsules contains electrophoretic (electrically separable) liquid. The liquid consists of the hydrocarbon oil, which is transparent and chemically stable for very long time. White particles with the positive charge swim in the oil. Black particles have the opposite charge. The oil is thick enough to keep particles in a stable position.

White inorganic particles have the core made from the titanium oxide. The cover is silicon oxide and polymer. Black particles are made from the carbon.

When the voltage is connected to electrodes, particles are attracted to the opposite charge. The top of black or white particles is then visible through the top transparent electrode. Particles stay in last position without current after voltage disconnection.

The latest E-Ink technology uses divided electrodes and it is able to display 16 levels of the gray color.

# E-Ink Pros and Cons

- Benefits: high contrast, readable on direct sunlight, high resolution, wide view angle, does not need backlight, zero power consumption after image redraw.

- Disadvantages: few levels of gray, no colors, slow redraw with long response.