Organic Light Emitting Diodes for Display Technology

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Abstract – Opto-electric devices using organic materials are becoming widely desirable. Organic Opto-electric devices including organic resonant tunneling diodes [20, 21], OLEDs, Organic phototransistors [22], Organic photovoltaic cells [23] and Organic photodetectors [24] have formed a tremendous area of research in chemistry and Physics. Organic Light Emitting Diodes (OLED) are a different type of solid-state lighting source. An OLED device is typically formed in a sheet with emissive organic layer(s) located between a cathode and anode and deposited on a substrate. The substrate can be rigid such as glass or metal or flexible using a polymer plastic. The number of emissive layers depends on the desired light output of the device. OLED technology has great potential for new uses such flexible paper-thin OLED panels, and transparent OLED panels. New technologies, such as sophisticated organic layer structure, were applied to the device. The device also exhibited good durability such as storage stability, which is important performance in practical use. This paper will show possibilities to practical use of OLED in different types of displays, lighting sources for illumination use, back light and others. From a recent environmental problem and energy supply circumstances, light sources of low energy consumption and eco-friendly are demanded. An enormous amount of research effort goes into the field. Organic light-emitting diode (OLED) is regarded as a powerful candidate because it is an area light source, can be driven at low voltage, and does not include a material which is harmful to the human body and environment like mercury. As a light source for illumination or backlight, a white light is usually required. To realize a white OLED device, plural light emissive materials such as blue, green, red are used generally.

Keywords - Organic Light Emitting Diode *(*OLED), flexible paper-thin OLED, transparent OLED.

I. Introduction

The OLED technology is active meaning that it is able to emit light unlike the LCD technology that is dependent on backlight unit to create light. Light is emitted from the smaller OLED pixels with the help of a very thin organic film layer. A layer of organic material is sandwiched between two conductors (an anode and a cathode), which in turn are sandwiched between a glass top plate (seal) and a glass bottom plate (substrate).

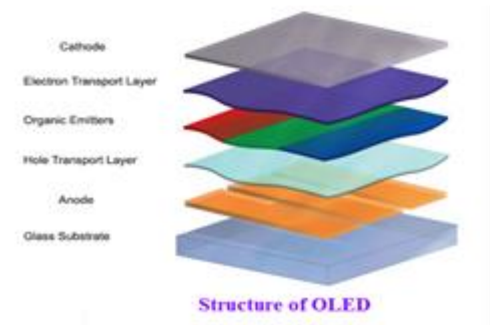

Figure 1. OLED Structure

When electric Current is applied to the two conductors, a bright, electro-luminescent light is produced directly from the organic material as it shown in Fig. 1 [3] . The OLED technology is very dynamic when it comes to light meaning that it can emit all the steps between 0 % to 100 % light. With the help of color films OLED utilize three sub-pixels in red, green and blue to produce any desired color including white [2].

II. History of OLED

In the early 1950s, Bernanose and co-workers at Université de Nancy, France first produced electroluminescence in organic materials. They proposed a mechanism of either direct excitation of the dye molecules or excitation of electrons [5]. In 1977 Heeger, Shirakawa Mac Diarmid discovered a high conductivity in iodine-doped polyacetylene, who later in the year 2000 were awarded the Nobel Prize in Chemistry for "the discovery and development of conductivity in organic polymers." Eastman Kodak Company in 1985 developed bilayer devices based on vapor deposited molecular films consisting of a hole transport layer and a layer electroluminescence generating station. The first diode device was reported in 1987. Finally in 1990 JH Burroughes in the Cavendish Laboratory in Cambridge reported a high efficiency green light emitting polymers using sheets of 100 nanometers thick. In 1998 Kodak, Sanyo Show Full-Color Active Matrix Organic Display and Green Organic LED Shows High Efficiency. In 2003 Sony demonstrated a 24.2 inch OLED panel. In 2007 Sony has started to sell the XEL-1, the world's first OLED TV in Japan. In 2008 Samsung shows a 40 inch HD AMOLED and shows interesting flexible and transparent OLEDs. In 2010 Samsung is showing a new 7 inch Super-AMOLED display [6]. Interestingly, they are showing it in a new phone prototype. In 2011 Panasonic Electric Works announced that they developed a new highly efficient OLED device - featuring 128 lm/W efficiency. In 2012 LG presents TV 55 inch display [1].

III. OLED technology

Today, OLED technology is the leading next-generation technology in a series of FPD (flat panel displays). Regularly affect any news about when the next display panel based on organic electroluminescence. Devices OLED – its full-color light-emitting devices, which provide high brightness, low power consumption, wide viewing angle, good contrast. In addition, they are compact and lightweight, can withstand significant mechanical loads, have a wide range of operating temperatures and have sufficient life. Scope of such displays is rather broad: from cell phones and car radio to the helmet mounted indicator displays on the windshield of vehicles lighting. In the subsequent development of phosphorescent materials, devices OLED can be not only effective in mapping, but also thin-film light source, replacing numerous discrete incandescent large and expensive non-organic LEDs. It is not excluded that a few years TFT LCD display monitors will be replaced based on OLED [7].

A. Description how the OLEDs produce the light

OLEDs produce light by the recombination of electrons and holes. In the case of the OLED, when a voltage is applied across the device, electrons are injected from cathode and holes are injected from anode. Transport and radiative recombination of electron-hole pairs is at the emissive polymer layer(s) [7], as we can see in Fig. 2 [8]. As the electrons drop into the holes, they release energy in the form of light.

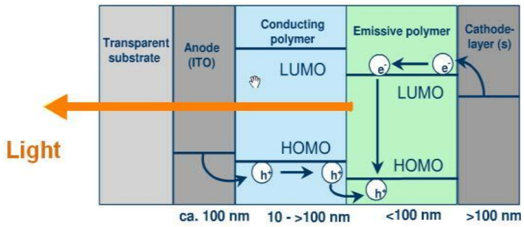

Figure 2. OLED energy diagram

The color of the light emitted depends on the composition of the organic emissive layer. Multiple layers (for example red, green and blue) can be combined in one device to produce any desired color including white, as it shown in Fig. 5 (b) [10].

IV. OLED TYPES

OLED is a monolithic thin-film semiconductor device that emits light when voltage is applied to it. OLED consists of a series of thin organic films. Operating voltage OLED is only 2-10 V, as it shown in Fig. 1. Here will be described five basic OLED types.

A. Passive Matrix OLED (PMOLED)

PMOLEDs have strips of cathode, organic layers and strips of anode. The anode strips are arranged perpendicular to the cathode strips. As it shown in Fig. 3 [11], the intersections of the cathode and anode make up the pixels where light is emitted. External circuitry applies current to selected strips of anode and cathode, determining which pixels get turned on and which pixels remain off. Again, the brightness of each pixel is proportional to the amount of applied current. This type of OLED is easy to make but consumes more energy than the alternative system, for this reason are ideal for small displays (1 to 3 inch) such as those you find in cell phones, PDAs and MP3 players. Even with the external circuitry, passive-matrix OLEDs consume less battery power than the LCDs that currently power these devices [12].

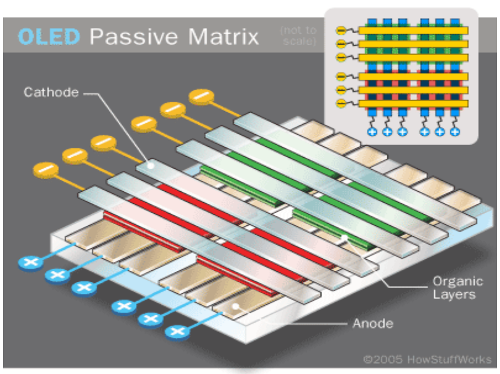

Figure 3. Passive Matrix OLED (PMOLED)

B. Active-matrix OLED (AMOLED)

AMOLEDs consume less power than PMOLEDs because the TFT array requires less power than external circuitry, so they are efficient for large displays.

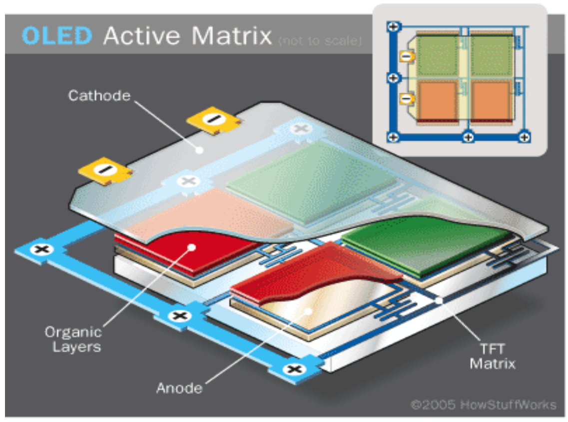

Figure 4. Active Matrix OLED (AMOLED)

AMOLEDs also have faster refresh rates suitable for video. The best uses for AMOLEDs are computer monitors, large-screen TVs and electronic signs or billboards [12]. Active matrix displays, instead of having current distributed row by row, use thin film transistors (TFTs) that act like switches to control the amount of current, hence brightness, of each pixel, as it shown on Fig. 4 [11]. Typically, two TFTs control the current flow to each pixel. One transistor is switched to charge a storage capacitor for each pixel and the other creates a constant current source from the capacitor to illuminate the pixel. Fig. 5 [13] shows a conventional pixel structure for an active matrix OLED (AMOLED). The anode layer overlays a thin film transistor (TFT) array that forms a matrix. The TFT array AMOLED panel is designed to deliver light emission with the TFT layer on the rear side of the panel itself is the circuitry that determines which pixels get turned on to form an image**.** Therefore, the top emission structure offers more efficient light emission than is typical with bottom emission structures where TFT layers are placed on the front side of the panel, limiting the light-emission aperture. This technology has a micro-cavity structure which incorporates color filters. This cavity structure uses an optical resonance effect to enhance color purity and improve light-emission efficiency. In addition, the color filter of each RGB also enhances the color purity of emitted light, and reduces ambient light reflection [14].

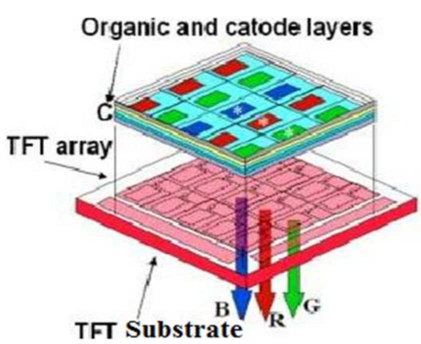

Figure 5. AMOLED Panel Structure

C. Transparent OLED

Transparent OLEDs have only transparent components (substrate, cathode and anode) and, when turned off, are up to 85 percent as transparent as their substrate. When a transparent OLED display is turned on, it allows light to pass in both directions as it shown in Fig. 6 [11]. A transparent OLED display can be either active or passive matrix.

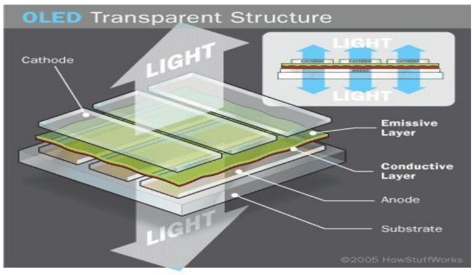

Figure 6. Transparent OLED

This technology can be used for tablets, heads-up displays, in the car, for window wall big screen and in many other devices.

D. Top-emitting OLED

Top-emitting OLEDs have a substrate that is either opaque or reflective. They are best suited to active-matrix design. Manufacturers may use top-emitting OLED displays in smart cards as it shown in Fig. 7 [11].

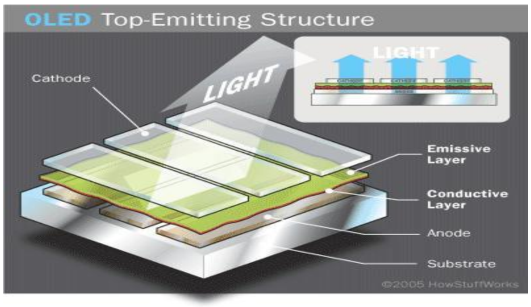

Figure 7. Top Emitting OLED

E. Flexible or Foldable OLED (PLED)

Flexible OLEDs have substrates made of very flexible metallic foils or plastics. Flexible OLEDs are very lightweight and durable. Their use in devices such as cell phones and PDAs can reduce breakage, a major cause for return or repair. Potentially, flexible OLED displays can be attached to fabrics to create "smart" clothing, such as outdoor survival clothing with an integrated computer chip, cell phone, GPS receiver and OLED display sewn into it. Fig. 8 [11] shows flexible display.

Figure 8. Flexible OLED

V. MEASURING THE CHARACTERISTICS OF DISPLAYS

Here will be described measuring different types of video broadcast monitors, and their application areas in television production. It also defines the technical characteristics required of those monitors. Broadcast monitors are used in a professional TV production environment for evaluation and control of the images being produced, and must provide reliable and repeatable results. The purpose of a monitor is to display the signal as it is, and it must not attempt to 'enhance' or otherwise alter the image.

A. Contrast ratio

Definition of Contrast Ratio is calculated as follows: Contrast Ratio (CR) = Brightness on 100% white state/ Brightness on 0% black state without degradation, particularly in bright environments as it shown in Fig. 9 [16]. Optical characteristics are determined after the unit has been ON and stable for a minimum of 45 min. in a dark environment at 25 degrees Celsius. The values specified, are at a distance of 80 cm from the displays surface and at a viewing angle – horizontal and vertical – of 0 degrees.

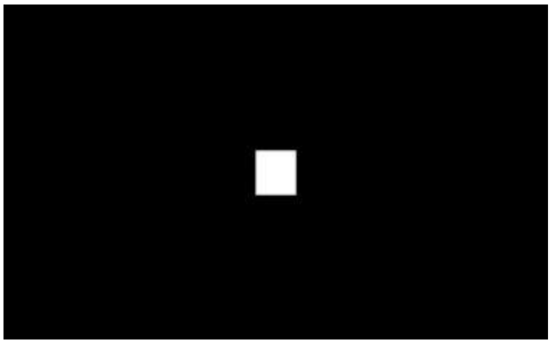

Figure 9. Test for Measuring

B. Color Gamut Measurement

Color Gamut is the range of colors that a display can produce. Essentially all current consumer image content is created using the sRGB and ITU-R BT.709 (Rec.709) standards. If we want to see accurate image colors then the display must match the standard that was used to create the content. Note that standard consumer content does not include colors outside of the standard sRGB/Rec.709 Gamut, so a display with a wider Color Gamut cannot show colors that are not in the original and only produce inaccurate exaggerated on-screen colors. The color accuracy of the images produced by a TV will depend on how closely it reproduces the colors of the sRGB/Rec.709 color space. The Color Gamut for the ISF Expert modes is 99% of sRGB/Rec.709, which is visually indistinguishable from perfect. For the other Picture Modes the default Gamut is 116% of sRGB/Rec.709, which is designed to produce somewhat over-saturated colors, which may be a personal preference for some viewers, but can also help in high ambient light because it helps compensate for washed out image colors. A menu option allows the default Color Gamut to be changed. OLED technology shows the largest color range of any other type monitor ever offered, as it shown in Fig. 10 [11]. Color standards of iPhone, LCD Monitor and OLED monitor are displayed more accurately and, if desired, the OLED panel's native color gamut can be displayed.

Figure 10. OLED Color Gamut Diagram

Fig. 11 [15] shows the OLED color gamut measuring with the instrument Minolta CS200/2000. True color reproduction is essential for broadcast applications.

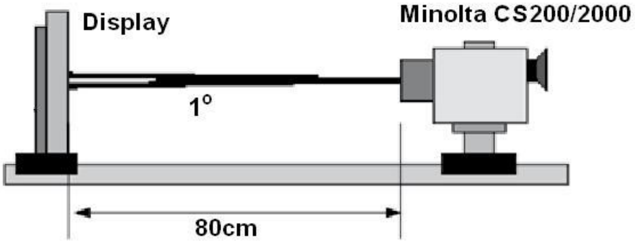

Figure 11. OLED Color Gamut Measuring

C. Response Time

Response time is defined as the time required for the display to transition from 90% white to 10% black = TR (rise time), and from 10% black to 90% white = TD (decay time). The signal for measuring response time is shown in Fig. 12 [15]. Fig. 13 [16] shows the block diagram for measuring the displays response time.

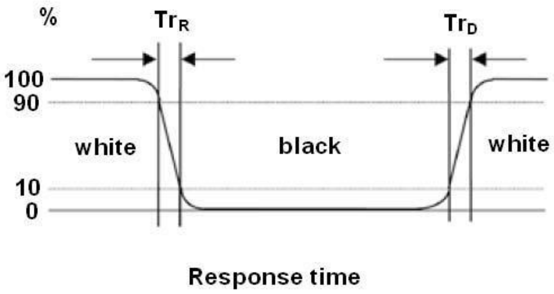

Figure 12. Video signal for Measuring Response Time

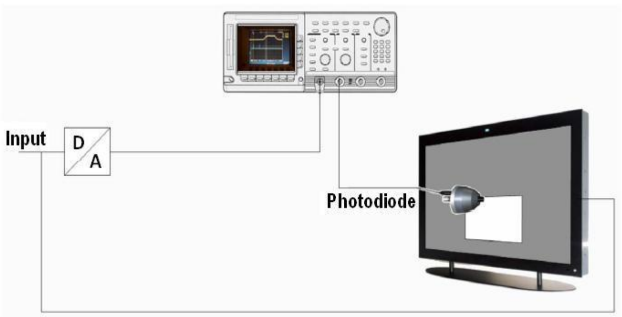

Figure 13. Response Time Measuring

D. Viewing Angle

Viewing Angle is the angle at which the contrast ratio is still greater than 10:1. The angles are determined for the horizontal or X axis and the vertical or Y axis as it shown in Fig. 14

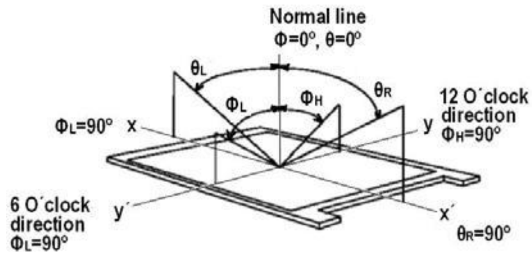

Figure 14. Measuring the Displays Viewing Angle

VI. DIFFERENCE BETWEEN LCD, PLASMA AND OLED DISPLAYS

Table I. shows a results and differences between LCD, plasma and OLED displays. As it can see, OLED displays have many advantages over LCDs as well more colors, increased brightness and contrast ratio, faster response time for full motion video, less power consumption. OLEDs devices are extremely efficient between 95% and 99% of the input energy converted to light. Since the layers that make up the OLED are very thin, photons are not trapped within the active region, as can be the case with LCD devices. The contrast ratio is an area where OLED display trumps plasma display though, since it offers blacker blacks and brighter whites. The contrast ratios for plasma displays are around the 5,000:1 mark whereas for OLED displays this figure runs up to 1,000,000:1. Viewing angles of both these displays perform equally well, and offer optimal viewing even at 178 degrees. The reason for this is that both displays employ pixels that are emissive in nature and create light rather than block the light from an external source. Color accuracy is another area where OLED display is better than plasma display since it is easier to break up organic compounds than rare gases. Both materials are capable of producing all the colors in the spectrum, but the better technology of OLED display produces more vibrant colors. One of the major plasma display problems is the screen burn effect, in issue which is absent in OLED display. In plasma displays if you keep a certain image static for a few hours, you will see ghostly traces of this image once you change the picture. Plasma displays have an advantage in response time, but these values are so small and this differences not so important for human eye. Also plasma has longer lifetime, approximately about 50.000-60.000 hours. When you compare the power consumption OLED display sets are the clear winners.

Source of light	Fluorescent	LED	OLED
Over all Efficiency	15%	22%	84%
Black level/ contrast	0 -- ∞	1/1000	0 -- ∞
Resolution in dpi	40	300-800	1000
Refresh rate	60fms	120fms	LED < OLED
Viewing angle	Lambertian	Non- Lambertian	Lambertian

Table 1. Table of difference between LCD, Plasma, and OLED

VII. FABRICATION OF OLEDs

Polymer-based OLEDs are attractive due to their excellent film forming properties and their ease of application over large surfaces through simple, economically viable coating techniques such as spin coating or ink-jet printing. Small molecule emissive materials are typically coated as thin films via vacuum-deposition which is difficult over large areas and is not as cost effective. The main part of manufacturing OLEDs is applying the organic layers to the substrate. This can be done in three ways:

A. Vacuum deposition or vacuum thermal evaporation (VTE)

This is most commonly used for depositing small molecules. In a vacuum chamber the organic molecules are gently heated (evaporated) and allowed to condense as thin films onto cooled substrates. As the heating method is complicated and the strictness of parameters should be highly accurate, this method is more expensive and of limited use for large-area devices than other processing techniques. Vacuum deposition is not a suitable method for forming thin films of polymers. However, contrary to polymer-based devices, the vacuum deposition process enables the formation of well controlled, homogeneous films, and the construction of very complex multi-layer structures. This high flexibility in layer design, enabling distinct charge transport and charge blocking layers to be formed, is the main reason for the high efficiencies of the small molecule OLEDs.

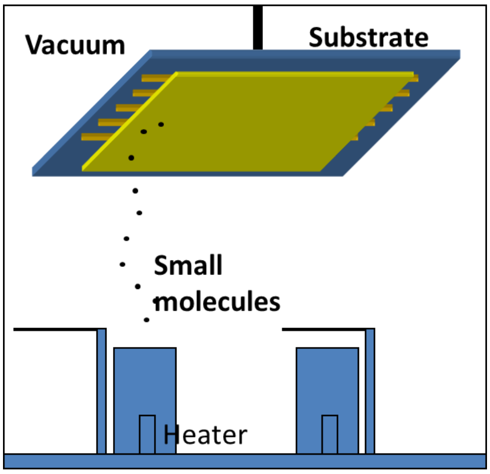

Figure 15. Vacuum deposition

B. Organic vapor phase deposition (OVPD)

This is an efficient technique which can be carried out at a low cost. In a low-pressure, hot-walled reactor chamber, a carrier gas transports evaporated organic molecules onto cooled substrates, where they condense into thin films. Using a carrier gas increases the efficiency and reduces the cost of making OLEDs.

C. Inkjet printing

This is the cheapest and most commonly used technique. Inkjet technology is highly efficient and greatly reduces the cost of OLED manufacturing and allows OLEDs to be printed onto very large films for large displays like big TV screens and electronic billboards. This method is same as the paper printing mechanism where the organic layers are sprayed onto the substrates.

D. Transfer-printing

This is an emerging technology with the capability to assemble large numbers of parallel OLED and active matrix OLED (AMOLED) devices under efficient conditions. Transfer-printing takes advantage of standard metal deposition, photolithography, and etching to create alignment marks on device substrates, commonly glass. Thin polymer adhesive layers are applied to enhance resistance to particles and surface defects. The anode layer is applied to the device backplane to form bottom electrode. OLED layers are then applied to the anode layer using conventional vapor deposition processes, and covered with a conductive metal electrode layer. Transfer-printing is currently capable of printing onto target substrates up to 500mm x 400mm. Expansion on this size limit is needed in order for transfer printing to become a common process for the fabrication of large OLED/AMOLED displays.

VII. DRAWBACKS OF OLED

A. Lifespan

The biggest technical problem for OLEDs was the limited lifetime of the organic materials. One 2008 technical report on an OLED TV panel found that "After 1,000 hours the blue luminance degraded by 12%, the red by 7% and the green by 8%". In particular, blue OLEDs historically have had a lifetime of around 14,000 hours to half original brightness (five years at 8 hours a day) when used for flat-panel displays. This is lower than the typical lifetime of LCD, LED or PDP technology. Each currently is rated for about 25,000–40,000 hours to half brightness, depending on manufacturer and model. Degradation occurs because of the accumulation of nonradioactive recombination centers and luminescence quenchers in the emissive zone.

B.Color Balance

Additionally, as the OLED material used to produce blue light degrades significantly more rapidly than the materials that produce other colors; blue light output will decrease relative to the other colors of light. This variation in the differential color output will change the color balance of the display and is much more noticeable than a decrease in overall luminance. This can be avoided partially by adjusting color balance, but this may require advanced control circuits and interaction with the user, which is unacceptable for user.

C.Water damage

Water can instantly damage the organic materials of the displays. Therefore, improved sealing processes are important for practical manufacturing.

D.Production

Water can instantly damage the organic materials of the displays.

VIII. CONCLUSION

OLED technology is the future. It is a new display technology used to create thin, efficient and bright displays and lighting panels. OLED is without doubt superior to both LCD and plasma. It combines the best from both worlds and has none of the major downsides. It not only raises that upper bar but also the lower bar, enabling even cheap manufacturers to create great picture quality because of the stunning OLED picture characteristics. Excellent OLED picture characteristics are perfect black, perfect viewing angles, extremely fast response time, true color depth, extremely slim frame and low energy consumption.

The only downside of the OLED technology at the moment is the price and lifetime. Right now OLED displays are just entering the market so their production costs and hence their prices are still very high. Plasma and LCD displays have been around for many years, so they are much cheaper as well. This factor along with the long life of Plasma displays gives them the edge in the current market, but OLED technology is coming. As the prices of OLED displays will fall, their popularity will increase and they will slowly cause plasma displays to be extinct. As you can see, in technical terms, OLED technology has great potential and suggests a very wide range of applications. In terms of technology OLED technology has a significant cost advantage compared with the production technology of liquid crystal matrices. OLED devices is much less rich in materials, they require a significantly smaller number of manufacturing operations.

Figure 16. Wall format display

In addition, the production of OLED will be used by the infrastructure of liquid crystal indicators, which will reduce the time to organize issue. In the future one of the possible markets for OLEDs is wall format displays as we can see in Fig. 16 [17], cars, as it shown in Fig. 17 (a) [18], and mobile phones, as it shown in Fig. 17 (b) [9]. In the future, but even today, we can see several interesting usages for OLED displays or lighting in cars such as dashboard displays, windshield transparent OLEDs, internal lighting, external lighting, back-window alerts and messaging (as seen on the EDAG prototype). OLED seems to be the perfect technology for all types of displays but challenges are still ahead including high production costs, longevity issues for some colors (blue organics currently have much shorter lifetimes), sensitivity to water vapor (water can damage OLED displays easily and perfect sealing of the display is warranted, and it can also affect the longevity). When displaying an image with a black background OLEDs are 34% power saving compared to polarization film ; however OLEDs can use more power than LCDs to display an image with a white background such as a document or a website. A great deal of progress has been made in organic electroluminescent materials and devices in terms of synthesis, development, and application of electron transport materials as a means to improve OLED performance.

a) b)

Figure 17. OLEDs in cars and mobile phones

IX. REFERENCES

[1] http://thetechjournal.com/electronics/lg-brings-worlds-largest-55-inch-oled-hdtv-panel-in-ces-2012.xhtml, accessed: February 2012

[2] http://www.konicaminolta.com/about/research/oled/development/index html, accessed: February 2012

[3] http://www.agasonia.com/index.php?prm=40200, accessed: Mart 2012

[4] http://tech.ebu.ch/events/Electro-optic Displays for Television /Michael E. Backer /display- metrology.com, accessed: Mart 2012

[5] http://www.oled.si/tv/oled-history/, accessed: April 2012

[6] http://www.oled-info.com/history, accessed: April 2012

[7] http://www.ledtransformations.com/page5.html, accessed: Mart 2012

[8] http://www.docstoc.com/docs/74013021/An-Overview-of-OLED-. Display-Technology, accessed: April 2012

[9] http://www.oled-info.com/my-samsung-galaxy-s-photo, accessed: April 2012

[10] http://pluggedin.kodak.com/pluggedin/post/?id=2270207, accessed: Mart 2012

[11] http://electronics.howstuffworks.com/oled3.htm, accessed: April 2012

[12] http://www.computerworld.com/s/article/9215043/Display_ tech_to_watch_this_year_OLED_s_future_looks_bright, accessed: April2012

[13] http://www.freepatentsonline.com/6753655.pdf, accessed: April 2012

[14] http://www.sony.co.uk/res/attachment/file/55/1133797572855.pdf, accessed: April 2012

[15] http://www.hd2line.com/index.php?eID=tx_nawsecuredl&u=0&file=uploads/media/HD2line_Brochure.pdf&t=1338017529&hash=2a9fb4690523d9832d5fb5493a8307afb8c8af39, accessed: Mart 2012

[16] http://tech.ebu.ch/events/display09/cache/off?id=14083, accessed: Mart 2012

[17] http://www.oled-info.com/tags/videos/transparent-oled-videos, accessed: February2012

[18] http://www.oled-info.com/oled-cars, accessed:February 2012

[19] http://www.pcmonitors.org/news/further-advances-in-solution-coating-technology-for-oled-monitors, accessed: April2012

[20] Karazi Y.,Cornil J.,Bredas J.L.,J.Am.Chem.Soc., 123(2001)10076.

[21] Karzazi Y., Cornil J., Bredas J. L., *Nanotechnology*, 14 (2003) 165.

[22] Hamilton M. C., Martin S., Kanicki J. *IEEE Trans. Electron Devices*, 51 (2004) 877.

[23] Li G., Shrotriya V., Huang J. S., Yao Y., Moriarty T., Emery K., Yang Y., *Nature Mater.*, 4 (2005) 864.

[24] Peumans P., Yakimov A., Forrest S. R., *J. Appl. Phys.*, 93 (2003) 3693.

[25] https://en.wikipedia.org/wiki/OLED