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# An Overview of Latest Display Technologies and their Usage for Various Special Applications

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***Abstract***

*In the new world of technology, due to its volatile nature there had been immense changes in the display technology since the past few years. Now it is that when portability plays an important role, the electronic displays of various electronic devices have changed their trend from being heavy and thicker in size to more light and thin in dimensions. This significant change in the dimensions of the electronic displays is due the adoption of AMOLED and Active QLED technology. AMOLED [Active Matrix Organic Light Emitting Diode] is a display technology used in smartphones, mobile devices, laptops and television. A* ***Quantum Dot Display*** *is a display device that uses Quantum dots (QD), semiconductor nanocrystals which can produce pure monochromatic red, green, and blue light. Hence, with the use of these display technologies the manufacturing and usage of flexible and foldable electronic displays have come into existence with low power consumption and low cost, brighter colors with wide color gamut. Also by using this AMOLED and AQLED technology in the latest electronic displays, it is possible to control each and every pixel of the particular display so that, the possibility of manipulating the saturation, brightness, contrast and especially sharpness of the image or the picture increases. But still implementation of AQLED (Active Quantum Dot Display Light Emitting Diode) display is under Research and development process as there are various aspects like optimization and implementation with existing display technologies. This paper proposes a brief idea about the latest display technologies i.e., AMOLED & AQLED and their special applications in various contemporary devices and its possible usage in various other fields in modern devices.*

***Keywords****: AMOLED, OLED, AQLED, QLED, TFT, HOMO, LUMO.*

## INTRODUCTION

The term AMOLED stands for Active Matrix Organic Light Emitting Diode. As the name suggests this technology is dependent on its parent technology i.e. OLED which uses matrix of pixels which are deposited on TFT layer by which control of current through each individual pixel can be achieved. The TFT works as series of switches for completing this job. One TFT is used to start and stop the charging of a storage capacitor and the second one to provide a voltage source at the level needed to create a constant current to the pixel, thereby eliminating the need for the very high currents required for passive-matrix OLED operation. This feature has made the possibility of adjusting the brightness levels, contrast levels, etc., at the pixel level.

Coming to the 2nd part of display technology i.e. AQLED which stands

Active Quantum Light Emitting Diode is also one of the latest and upcoming trends of display technologies. In these technology nano crystals of semiconductor which serve as quantum dots helps in conversion of back light into pure mono chromatic light of red, blue and green. The difference between AQLED and AMOLED is that AMOLED possess self-luminescence feature but the latter possess electro luminescence dependent feature i.e. it depends on the backlight for production of display

In this paper, the details about the AMOLED technology under the electronic display technologies are discussed and a brief introduction to operation of these display units is mentioned. The rest of the paper is organized as follows: Section II gives the details about the related work. The detail about the existing technology in electronic displays is mentioned in Section III. The complete details about the proposed display technology are illustrated in section IV. Next, Section V gives the conclusions and future scope of this modern technology.

## RELATED WORK

The authors Jong hyuk Lee, Hye Dong Kim, Chang Ho Lee, Hyun-Joong Chung, Sung Chul Kim and Sang Soo Kim in their publication "**The Technological Trends of Future AMOLED**" ,in the year 2009 from Technology Center, Samsung Mobile Display Co, LTD ,review the technological trends for the future AMOLED ,especially the unique applications to small and medium sized displays as well as large sized AMOLED TV. The unique characteristics of AMOLED enable paper thin, foldable, bendable and transparent displays which the other display technology can't easily realize. For large sized AMOLED TV, TFT backplane, color patterning and encapsulation are the key technological issues and the new technologies should be developed for the mass production of AMOLED TV. With the aid of certain Auxiliary technologies manufacturing of AMOLED T.V's are also taken into view.

The authors Moon Kee Choi, Jiwoong Yang, Taeghwan Hyeon & Dae-Hyeong Kim in their publication "**Flexible quantum dot light-emitting diodes for next-generation displays",** in the year 2018 discuss about the QLED technology and future scope of QLED in implementing flexible displays. In contrast with various other display technologies the AQLEDS have their upper hand when it comes to various technical parameters such as brightness, wide colour gamut, low voltage consumption and ultrathin dimensions. As mentioned by the authors many issues like cutting edge quantum dot technology, flexible and wearable QLED and colour patterning are discussed.

## EXISTING TECHNOLOGY

The following are few display technologies used:

1. Cathode ray tube display **(CRT)**
2. Light emitting Diode **(LED)**
3. Electroluminescent display **(ELD)**
4. Plasma Display Panel **(PDP)**
5. Liquid Crystal Display **(LCD)**
6. High performance Addressing Display **(HPA)**
7. Digital Light Processing Display **(DLP)**
8. Field emission display **(FED)** etc.,

### Introduction of each individual display technology

### CRT (CATHODE RAY TUBE) Display

The cathode ray tube display uses vacuum tube, phosphorescent screen and electron guns for the purpose of display. The CRT was basically used in oscilloscopes, old television's etc. By controlling the electron beam intensity which is emitted from electron gun the image can be produced, these beams are influenced the magnetic deflection which is one of the

consequences of magnetic field around electronics circuits.

**LED (LIGHT EMITTING DIODE) DISPLAY**

The LED display is one of the commonly used electronic displays where in the light emitting diodes act as pixels to laminate various colors of light. The LED consumes less power for illumination of the pixels in order to display the image. Thus they are widely used in sign boards, Stage lighting, T.V displays, Etc.,

**ELECTRO-LUMINESCENT DISPLAY (ELD)**

In this display technology electro luminescent material like gallium arsenide is sand witched between 2 layers of conducting material which upon electrical activation produces light.

**PLASMA DISPLAY (PLD)**

The plasmas are the electrically charged ionized gases which upon electrical activation produce visible light making it possible to use it in the displays. These ionised gases are placed in small cell like structures.

**LIQUID CRYSTAL DISPLAY (LCD)**

The **Liquid Crystal Display (LCD)** is one of the flat panels' displays which are dependent on back light to produce images. The LCD's are used widely in 7 segment displays, displays of digital clock and computer screen displays, etc. The LCD displays are the successor of the old CRT displays hence, reducing the dimensions both in appearance and weight. LCD's have more advantage over CRT displays with low possibility of image burn- in. They consume less power and can be used efficiently for producing display.

**HIGH PERFORMANCE ADDRESSING (HPA)**

The High-Performance Addressing display is an improvement of LCD with passive matrix display analyzes the incoming video signal and refreshes the image by modulating the frequency making it the high responsive rate display technology which can produce to a 16 million colours. This phenomenon is referred to as **"multi line addressing".**

**THIN FILM TRANSISTOR (TFT)**

In the TFT (Thin Film Transistor) which is a kind of an FET (Field effect transistor) made by deposition of layers semi-conductors and di electric over a substrate. The substrate is generally made out of glass but in other transistors the semi-conductor material itself acts as substrate. The TFT generally serves as series of switches for making the light produced from the active region of semi-conductor on or off.

**ORGANIC LIGHT EMITTING DIODE (OLED)**

In the organic light emitting diode, the electro luminescent layer is made using an organic compound through which the light is emitted with the application of electric current. The organic compound is placed between 2 electrodes with one electrode made completely transparent. The OLED has been helping factor for development of next generation display technologies such as AMOLED. OLED' S are basically used in T.V, mobile display, Etc.

**PROPOSED AMOLED & AQLED DISPLAY TECHNOLOGIES**

**INTRODUCTION to AMOLED**

Before having an overview about AMOLED and AMQLED displays, it is mandatory to have some basic information its parent display technology i.e., **OLED (ORGANIC LIGHT EMITING DIODE**) and **QLED (QUANTUM DOT DISPLAY LIGHT EMITTING DIODE**) respectively.The term AMOLED stands for Active Matrix Organic Light Emitting Diode. As the name suggests this technology is dependent on its parent technology i.e. OLED which uses matrix

of pixels which are deposited on TFT layer by which control of current through each individual pixel can be achieved. The TFT works as series of switches for completing this job. One TFT is used to start and stop the charging of a storage capacitor and the second one to provide a voltage source at the level needed to create a constant current to the pixel. The OLED'S are mainly categorized depending of accessing of pixels present. If each row of pixels is controlled sequentially, then these types of OLED are called "**PASSIVE OLED**". But coming to its counterpart i.e., **ACTIVE OLED,** the electric current through each individual pixel can be controlled making it more reliable for usage in the general and special applications. This mechanism in AMOLED of controlling each pixel has become possible by placing the TFT backplane behind the pixels with not only allows easy switching of pixels but also allows improvement of resolution and sharper images. Overcoming the disadvantage of LCD, CRT displays etc., AMOLED displays due to **self-light*** emitting property perform well even in ambient day light than their counterparts by improving high contrast ratio of display.

**INTRODUCTION AQLED (Active Quantum Dot LED)**

The abbreviation of AQLED is **Active Quantum Dot Light Emitting Diode.** Before discussing about AQLED, a brief idea about QLED is needed. The QDLED basically works on the principle that the recombination of electron-hole from organic material takes place in Quantum Dots thereafter emitting visible monochromatic light of more efficiency reaching 100% colorgamut. When this technology is collaborated with Active organic layer then sensitization of electric up to sub pixel level is can be achieved. The basic Quantum Dot structure consists of Cadmium Selenide. One more added advantage of AQLED technology is more efficient power consumption, sharper display and more vibrant colour saturation levels.

**Materials Used**

Coming to the materials used in production of OLED's much more complex analysis of electro chemistry and physics is needed. Number of materials is used making of OLED for various internally developed functions like transport of charge. Using thermal evaporation process for production of OLED consisting of minute molecules is an expensive task. But when compared to Polymer based display devices, the vacuum deposited organic OLEDs facilitate the formation of Homogeneous layers and multilayer structures which allow efficient charge exchange. Generally small molecules of Alq3 are used in OLED. If the properties of these small molecules are analyzed carefully then production of molecule sized devices binding the optical, electrical properties can be accomplished. Coming to the design architecture of OLED layer of organic material is placed between two electrodes. This arrangement is placed on the substrate and the organic material is electrically conductive. The organic material consists of High Occupied Molecular Orbitals and Low Unoccupied molecular orbitals. From cathode, electrons are injected into LUMO region and holes are injected at HOMO region from anode. The hole movement in OLED is more hence, decay of excited state results in relaxation energy levels. The recombined electron-Hole pair at the emissive region is called as **EXCITON**. Indium Tin oxide is generally used as Anode as it has high electron injection property at HOMO junction and is transparent to visible light since the Anode in OLED are selected based on their chemical stability, optical transparency and electrical conductivity.

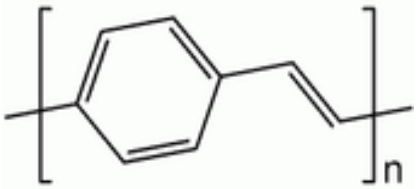


***Fig: 1.*** *Light Emitting Diodes using Polymers*

***Poly (p-Phenylene vinylene)***

In these types of diodes the light is emitted from the electroluminescent conductive polymer when an external voltage is applied and the required voltage for the polymer LED is activate and function is very less. These polymers LED due to flexible nature can be used in a wide variety of applications as their film is thin layer. These polymers can be formed using spin coating method. To achieve the formation of multilayer polymer light emitting diodes which are used in many display applications vacuum deposition method. The first Polymer Light Emitting Diode developed using Poly (p-Phenylene vinylene).

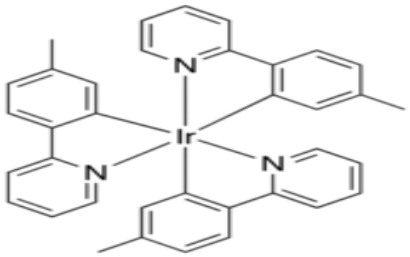


***Fig: 2.*** *OLED using Phosphorescent materials*

Iridium complex Using Phosphorescent materials in OLEDs the electrical energy can be efficiently converted into light energy using the principle of **Electro phosphorescence**. Also the Internal Quantum efficiency of the device is enhanced by decay of singlet and triplet exactions by usage of Electro phosphorescence materials. In general poly N-vinyl carbazole is used as main hosting material. To This host material an organic metallic complex such as ***Iridium complex*** is added as a Dopant. The metal atom at middle of dopant allows transfer of singlet and triplet states by spin-orbit coupling.

**Bottom or top emission**

The main difference between top emitted and bottom emitted OLED's lies in the direction of emission of light which comes out of the device. If the light is emitted through the transparent or semi transparent layer electrode and substrate on which the panel is placed, it is called bottom emission. In top emission devices the light exits the device from the lid i.e. placed during the fabrication process of the device. In practice top emission devices are widely used for AMOLED displays because integration of the pixels with immobile TFT back plane can be made. But in bottom emissive devices the blockage of light transmitted can take place due to interfacing of TFT array with bottom substrate.

**Transparent OLEDs**

Using transparent OLED's Top and bottom emitting TOLED's can be made which can improve the contrast levels to have better display in day light. These transparent OLED's use semi-transparent or transparent contacts on both sides of the device.

**Graded heterojunction**

The reduction of ratio of electron-holes to electron transporting chemicals is made using graded hetero junction OLED's which increase the quantum efficiency of contemporary OLED's to 2x times.

**Stacked OLEDs and Inverted OLED**

Stacked OLEDs use a pixel architecture that stacks the red, green, and blue sub pixels on top of one another instead of next to one another, leading to substantial increase in gamut and colour depth, and greatly reducing pixel gap. Currently, other display technologies have the RGB (and RGBW) pixels mapped next to each other decreasing potential resolution. In contrast to the OLED in which the anode

is placed on the substrate, in the inverted OLED cathode is placed on the substrate to connect to drain end of N channel TFT basically for amorphous silicon TFT back plane. Using the above techniques, materials a new concept has been developed which is addressing of pixels in the display screen.

**Designing of AMOLED and AQLED display**

**Design of AMOLED display**

An AMOLED display consists of an active matrix of OLED pixels generating light (luminescence) upon electrical activation that have been deposited or integrated onto a thin-film transistor (TFT) array, which functions as a series of switches to control the current flowing to each individual pixel. The AMOLED display in order to function, use two TFTs backplanes one for applying a proper voltage across the individual pixel and the other TFT backplane for Starting and Stopping the charging of Storage capacitor

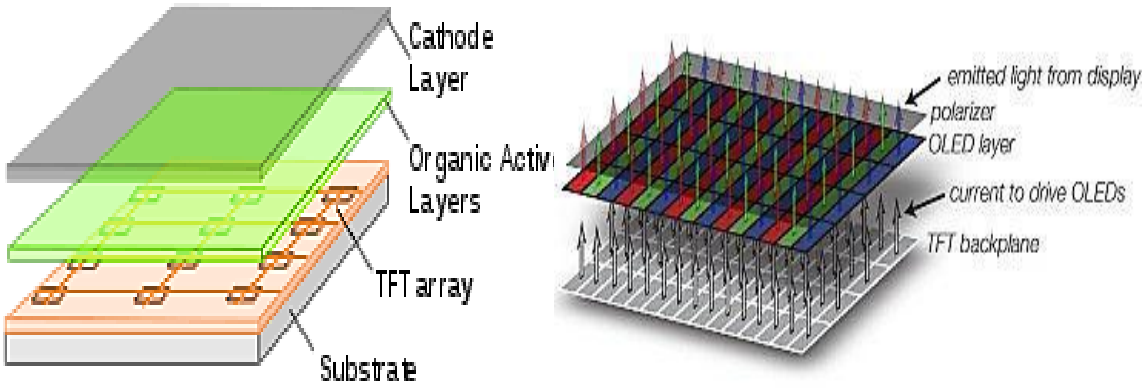


***Fig: 3.*** *Design of AMOLED display*

**Schematic of active matrix OLED**

A transparent substrate is used in the construction of AMOLED display in order to manufacture Flexible displays. Polycrystalline Silicon (Poly-Si) & Amorphous Silicon(a-Si) are two generally used TFT backplanes for allowing the formation of Active Matrix planes.

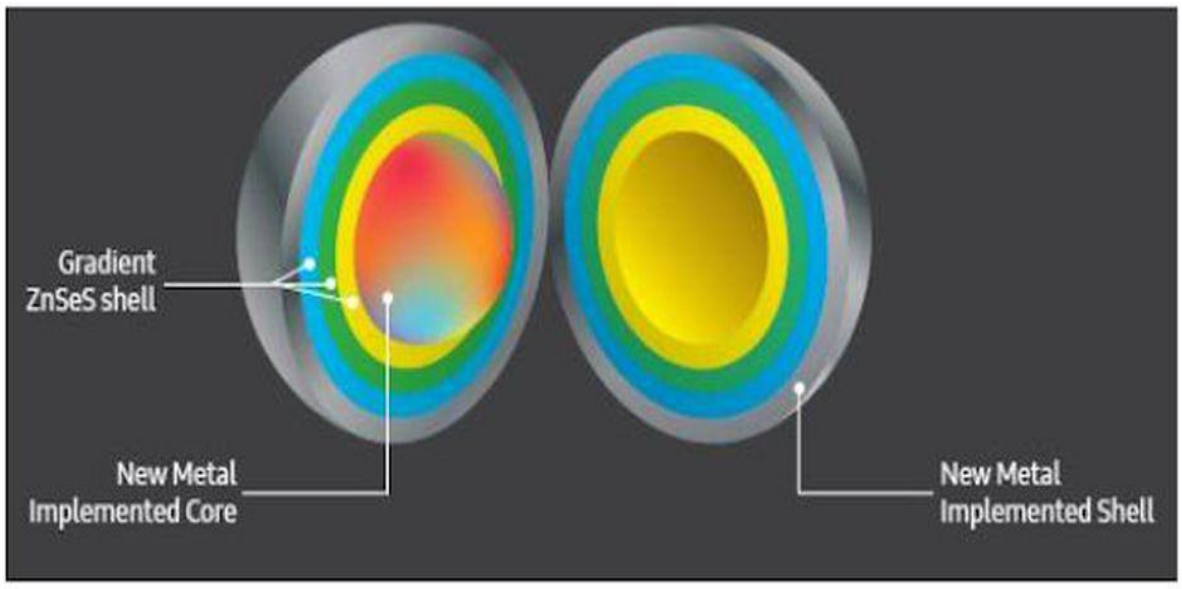


***Fig: 4.*** *Design of AQLED display*

Quantum Dot Design by Samsung technologies Here in the AQLED design, the Quantum Dot nanoparticles are arranged in from of active array of matrix which allows the reduction in response time of each individual sub pixel and eliminating the usage of Liquid Crystal layer. There are basically two approaches of the Quantum Dot. They are photoluminescent and electroluminescent approaches. The photoluminescent approach used by all current commercially available QLED displays, including Samsung's new QLED TVs, uses an external light to stimulate the QDs. The electroluminescent approach applies electricity individually to each QD to deliver a self-emitting image where essentially every pixel creates its own light. Clearly the ability of this approach to combine LCD's brightness and color advantages with perfect black levels makes it a hugely exciting proposition for the future. The main innovative approach is the cladding of the QDs in a new metallic sheath. It matters for various reasons.

First, it makes the QDs much less susceptible to oxidation, meaning that their performance will erode much less rapidly over time than normal QDs. Second, the metal sheath means that the QDs can be positioned differently on the preliminary display structure.

In the AQLED design ,the Quantum Dot layer is placed in-between the electron and hole transporting organic materials when the electrons and holes recombine in the Quantum Dots they emit visible light. The Quantum Dot layer is generally made of **Cadmium Selenide nanocrystals.** For the fabrication of AQLED display the two basic methods are,

1. Phase separation method
2. Contact printing method

**Phase separation**

The Phase separation process is mainly used to produce Quantum Dot monolayers layers of larger size. In this process the solution of Quantum Dots and Organic semiconductors are mixed with the help of spin casting process. The formed monolayers of QD are placed on top of the co-deposited contact. During the drying of solvent, the formed QD layer disassembles from the Organic material and move towards the surface of the film. The organic layer generally used is N,N'-Bis (3-methylphenyl)-(N,N'-diphenylbenzidine). In phase separation process lateral patterning of different QDs which in turn disable to form multi-colour Quantum LEDs'. Few parameters that affect the formed Quantum Dot structure are solvent and solution concentration, purity of the solvent used, QD size distribution and aspect ratio etc.

**Contact printing**

The contact printing method is one such method used for the formation of quantum dot thin films. These films are solvent free water-based suspension. Using this method, the RGB pattern of electro luminescent structure with a resolution of 1000 pixels per inch can be accomplished. In this process the main task lies with separating the solvent's interaction with the charged transport layer of quantum dot LED structures. To overcome this problem the usage of solvent free suspensions is encouraged. Now the process of contact printing is mentioned below stage by stage.

- First Polydimethylsiloxane is moulded using a silicon master and the top side of this PDMS stamp is coated with a thin film of chemical vapour deposited aromatic organic polymer.
- This thin layer is inked through spin casting of colloidal quantum dot suspended solution in organic solvent and after the evaporation of the solvent the resulting single QD layer is shifted on to the substrate using contact printing.
- The matrix of QD's is made by process of spin casting in which the QD's after

being placed on substrate are evenly spun to spread the solution. Using this process QLED of 25 micro meter wide strip can be fabricated of red, green and blue mono layers. The main advantage of this process is effective usage of QD hence reducing the expenditure.

## CONCLUSION

AMOLED and AMQLEDS displays be responsible for greater refresh amounts than passive-matrix, repeatedly decreasing the reply time to a smaller amount than a millisecond, and they devour considerably minus power. By using this property it creates active-matrix OLEDs and QLEDs which is well-applicable for portable electronics, where energy feasting is dangerous near battery life. Various parameters such as the colour production and brightness decide the power consumption of the display for reference and OLED display (QVGA) on an average consumptions 0.3 watts for displaying white text on black background and vice versa of this consumes 0.7 watts but in LCD's, on and average consume 0.35 watts regardless of whatever the case might be one important features in AMOLED display is that the black pixels turn off completely making it produce high contrast levels of image produced. The proposed QLED display also carries all the advantages that an AMOLED display does. The only difference lies in the materials used in their manufacturing. Thus, in conclusion the AMOLED and AQLED display are far ahead in terms of **SIZE, POWER CONSUMPTION, COST AND ESPECIALLY DISPLAY FEATURE.** These display technologies if implemented in the latest electronic gadgets from smartphones to smart watches can be made advantageous and more reliable to future usage.

## A FEW APPLICATIONS OF PROPOSED DISPLAY TECHNOLOGIES IN EXISTING ELECTRONIC DISPLAYS

1. Mostly used in flexible mobiles.
2. Frequently used as mobile chargers.
3. Most of the time used with 60 inches Televisions.
4. Generally used in smart watches.

***Fig: 5.*** *Amoled Display In Samsung's Galaxy Note 8 Edgesamsung Flexible Mobile 7.3" Exhibited At World Mobile Congress*


***Fig: 6.*** *Sony 60 inch TV using QLED display Samsung gear S Smart watch with AMOLED Display*

## FUTURE SCOPE

Thus, using the above discussed technologies such as the AMOLED and AQLED displays bendable, high resolution, better colour saturated displays can be made. These displays can be used at scientific research centres so that effective usage of space can be made. Also, 3D stereoscopic displays that use eye tracking (via stereoscopic front-facing cameras) to provide full resolution 3D visuals can also be developed. These flexible displays can also be used in Defence applications and Medical applications so that mobility and portability of various devices like the monitoring and surveillance systems can be further increased. These AMOLED screens when developed in larger dimensions can be substituted with projectors used for presentations or used in movie theatres.

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 **N. K. Shreyas** is pursuing his B.tech in Electronic & Communication Engineering in CMR College of Engineering & Technology, Hyderabad. His research Interests' include Microwave and RADAR remote sensing systems, Display systems, Micro-electronics and **Digital Forensics**.

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