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A REVIEW ON ORGANIC LIGHT EMITTING DIODE (OLED) TECHNOLOGY AND APPLICATIONS

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ABSTRACT

With the sweeping down of time the display technology has advanced through much of its high levels. Display technology plays out an important role in our lives in wide spectrum. Various stages have evolved in the tiny world of display technology and today it's the widest and yet a gloomy area to discover a lot. First cathode ray tube, then LED, LCD, and then we reached at a bright terminus where we have discovered the future of display technology that is OLED. OLED's display is really uncommendable and even there is no angle related issues or contrast or backlight related issues. It's almost defect less or we may say it's almost the perfect discovery, finding in unclear world of display technology. It is basically a paper where we basically put our earnest effort to bring out the display qualities of OLED in lime light. We have basically focused on all it's quality like it's HDR, backlight, motion blur, refresh rate etc in much brief. Unlike other flat panel displays OLED has a wide viewing angle (up to 160 degrees), even in bright light and the power consumption is only up to 2 to 10 volts. This low consumption of power provides maximum efficiency and helps to minimize heat and electricity interference in electronic devices.

KEYWORDS: Oleds, OLED Panel, TTF, Fluorescence OLED, LED, LCD.

INTRODUCTION

Organic opto-electronic devices OLEDs have formed a tremendous area of research in chemistry and physics. OLED stands for "organic light-emitting diode" and is a relatively new technology part of recent innovations in display monitors, lighting, and more. OLED technology as the name suggests is next generation advancement upon regular LED or light-emitting diode technology, and LCD or liquid crystal display technology. They're super-light, almost paper-thin, theoretically flexible enough to print onto clothing, and they produce a brighter and more colourful picture. It is a one side emitting device (left) and a transparent one which emits light both upwards and downwards (right). There are several organic layers deposited maintaining a strict order. ITO is presented over as a coating on the glass substrate.

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The electrodes are basically very thin and thickness may vary up to 1 micrometer. Passing of electricity through them may lead to emission of light from carbon based OLED panels. They are more simpler to be constructed and they are even highly efficient since they don't use backlight and filters. OLEDs structures are basically a emissive layer sandwiched between a cathode and anode. Keeping the basic functionality same the modern OLEDs are designed with more number of layer. Beautiful and brilliant colours, uncommendeble contrast, fast responding rate and the worty point that it has wide viewing angle makes the OLED a noteable display technology to be brought down under the lime light. Not all but some OLEDs are soluble.

HISTORY OF OLED

OLED diode technology was invented by researchers at the Eastman Kodak company in 1987. The first efficient OLED was described as "a novel electroluminescent device constructed using organic materials as the emitting elements" was developed by Ching Tang and Steven VanSlyke, then working in the research labs at Eastman Kodak, in 1987. There are basically two technology to make flexible oleds: first, Flexible Glass an engineered substrate that provides a flexible surface, and second, a Barixthin film coating that protects a flexible display from harmful air and moisture. Their work, though novel, built on earlier research into electroluminescence, which was first reported in organic molecules by a French physicist named André Bernanose in the 1950s. By 1970, Digby Williams and Martin Schadt had managed to create what they called "a simple organic electroluminescent diode" using anthracene, but it wasn't until Tang and VanSlyke's work, in the 1980s, that OLED technology became truly practical.

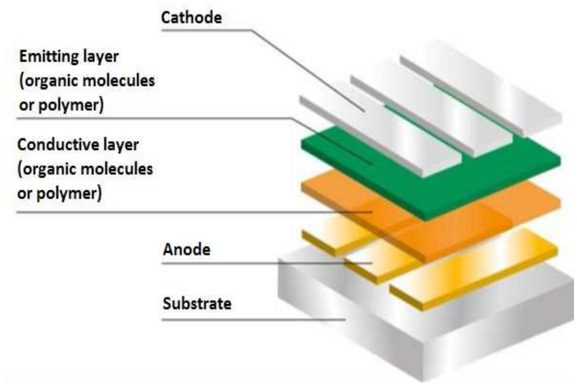

Figure 1.Fundamental Structure of OLED

WORKING OF OLED'S

OLEDS are basically made from ORGANIC semiconductor materials that emit light when electricity is passed through it. OLEDs works by passing electricity through one or more incredibly thin layers of organic semiconductors. These layers are sandwiched between two electrodes – one positively charged and one negatively. The "sandwich" is placed on a sheet of glass or other transparent material which, in technical terms, is called a "substrate". When current is applied to the electrodes, they emit positive and negatively charged holes and electrons. These combine in the middle layer of the sandwich and create a brief, high-energy state called "excitation". As this layer returns to its original, stable, "non-excited" state, the energy flows evenly through the organic film, causing it to emit light. OLEDs work in a similar way to conventional diodes and LEDs, but instead of using layers of n-type and p-type semiconductors, they use organic molecules to produce their electrons and holes. A simple

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OLED is made up of six different layers. On the top and bottom there are layers of protective glass or plastic. Seal and substrate are the top and bottom layers respectively. Emissive or light emmiting layer is present just after cathode and conducting layer is present just after anode.

Organic light-emitting diode based on EML: Tang and VanSlyke in 1987 1st proposed the structure of the OLED display and it consisted of organic stacks sandwiched between anode and cathode. The emitting layer (EML), which is used for light emission, consists of dopant and host materials with high quantum efficiency and high carrier mobility. Basically each layer is quite thin and most probably the thickness of the whole device is <1µm . The EML is the core of an OLED. Based on the emitters inside, OLED devices can be categorized into four types:

1. **FLUORESCENT OLED:** 25% singlets and 75% triplets are formed with higher and lower energy, respectively by electrical excitation. Only singlets decay radiatively through fluorescence with an ~ns exciton lifetime in fluorescent OLED which sets the theoretical limit of the internal quantum efficiency (IQE) to 25%.
2. **TRIPLET-TRIPLET FLUORESCENCE (TTF):** One singlet exciton is formed by the fusion of two triplet excitons & hence called triplet fusion process. TTF improves the theoretical limit of the IQE to 62. 5%.
3. **PHOSPHORESCENCE OLED:** The triplet lifetime greatly reduces to ~µs with the introduction of heavy metal atoms (such as Ir and Pt) into the emitters, which results in efficient phosphorescent emission. Now the triplet may interact with other trplet and triplet-polaron due to the long radiative lifetime (~µs) in a phosphorescent OLED. The singlet exciton experiences intersystem crossing to the triplet state for light emission, and thus achieves IQE to 100%.
4. **THERMALLY ACTIVATED DELAYED FLUORESCENCE (TADF):** By minimizing the exchange energy the energy between the singlet and triplet can be reduced by (<0. 1 eV). This enables the triplets to jump back to the singlet state by means of thermal energy (reverse intersystem crossing) for fluorescence emission, which is called TADF. So basically without a heavy atom in the organic material in the TADF emission it is possible to achieve a IQE to 100%.

DISPLAY METRICES

To evaluate the performance of display devices, several metrics are commonly used, such as response time, CR, color gamut, panel flexibility, viewing angle, resolution density, peak brightness, lifetime, among others. Here we compare LCD and OLED devices based on these metrics one by one.

1. **RESPONSE TIME AND MOTION PICTURE RESPONSE TIME:** To mitigate the motion image blur and boost the optical efficiency we need to have a fast time response. Motion Picture Response Time (MPRT) is highly important while quantifying the visual performance of a moving object. MPRT can be represented as :

   MPRT= $\sqrt{\tau^2 + (0.8\,Tf)^2}$ where Tf is the frame time (e. g., Tf=16. 67 ms for 60 fps). More over MPRT is calculated as the LC response time is fast enough, i. e. , $\tau \ll Tf$.

2. **CR AND ACR:** In order to achieve supreme image quality image high CR is greatly required. Since OLEDs are emissive, their CR could approach infinity to one. However, this is true only under dark ambient conditions as in most cases ambient light is inevitable. So we tend to calculate a more meaningful parameter for practical applications called the ACR:

$$ACR = \frac{Ton + A}{Toff + A}$$

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3. **COLOR GAMUT:** For all displays vivid colour is the critical requirement. Severalcolour standards have been proposed to evaluate color performance including sRGB, NTSC, DCI-P3 and Rec. For conventional LCDs employing a WLED backlight, the yellow spectrum generated by YAG (yttrium aluminum garnet) phosphor is too broad to become highly saturated RGB primary colors.
4. **LIFETIME:** TFT LCDs are a fairly mature technology. They can be operated for >10 years without noticeable performance degradation. OLEDs' are basically effected by moisture and oxygen so, especially for blue OLEDs, is still an issue. There are basically two types of Lifetime 1. Storage: (The water vapor permeation rate and oxygen transmission rate for an OLED display should be <1 × 10−6 g (m2-day) −1 and 1 × 10−5 cm3 (m2-day) −1, respectively) and 2. Operational (Due to material degradation, OLED luminance will decrease and voltage will increase after long-term driving.
5. **POWER EFFICIENCY:** Power consumption is an important parameter as to look upon. The power efficiency of an OLED is generally limited by the extraction efficiency (ηext~20%). To improve the power efficiency, multiple approaches can be used, such as a microlens array, a corrugated structure with a high refractive index substrate.
6. **PANEL FLEXIBILITY:** Flexible displays have a long history and have been attempted by many companies, this is one of the considerable parameter to count.
7. **VIRTUAL REALITY AND AUGMENTED REALITY:** Two emerging wearable display technologies are VR/AR. VR head-mounted displays require a resolution density as high as >2000 ppi to eliminate the so-called screen door effect and generate more realistic immersive experiences. As for AR applications, lightweight, low power and high brightness are mainly determined by the display components.
8. **THRILLING IDEAS OF USING THE SCINTILISING DISPLAYS:** Age old idea of using displays in televisions or mobile phones have been totally discarded instead we are now trying to use them in more advanced and smarter way just like a magic touch in washing machines, fridges etc.

TYPES OF OLED'S

1. PASSIVE MATRIX OLEDS

PMOLEDS have organic layer along with stripes of cathode and anode, arranged perpendicular to each other. The intersections of the cathode and anode make up the pixels where light is emitted. Current is applied through External circuitry that determines which pixel will get turned on and with how much of brightness and which pixels are going to be turned off. Moreover the brightness of each glowing pixel is proportional to the amount of applied current.

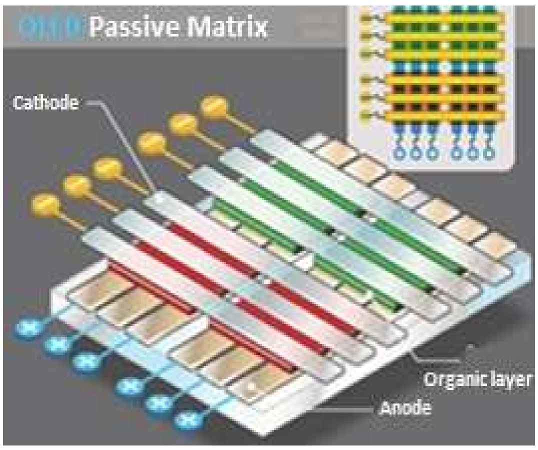

Figure 2.Passive Matrix OLEDs

Though external circuitry of PMOLEDs require more power but yet it is the most sorted choice for low dimensional screens.

2. ACTIVE MATRIX OLEDS (AMOLEDS)

These are full layers of cathode and anode along with organic molecules, however there is a thin film transistor (TFT) which forms a matrix on the anode layer. This array sets pixels on or off state/mode to generate an image. Large screen monitors, TV's and billboards are the products where this type of OLED is well suited and well fitted. Power consumption in AMOLEDs is comparingly less than PMOLEDs because the TFT array requires less power than external circuitry, and hence they become more efficient for large displays. AMOLEDs also have faster refresh rates suitable for video.

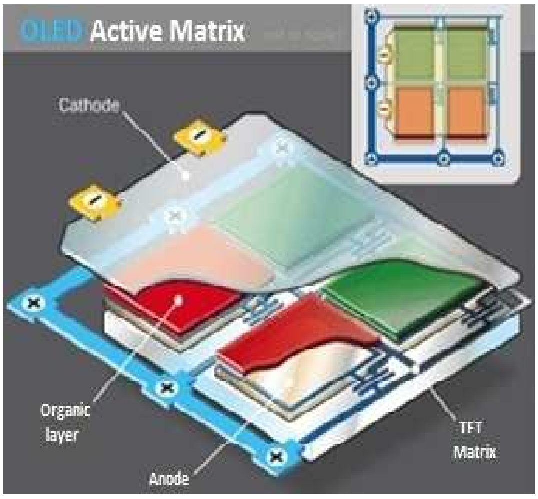

Figure 3.Active Matrix OLEDs

3. TRANSPARENT OLEDS

Turning on these types of OLED leads to bidirectional emmision of light. They are only comprised of transparent components. They are either Passive or active matrix.

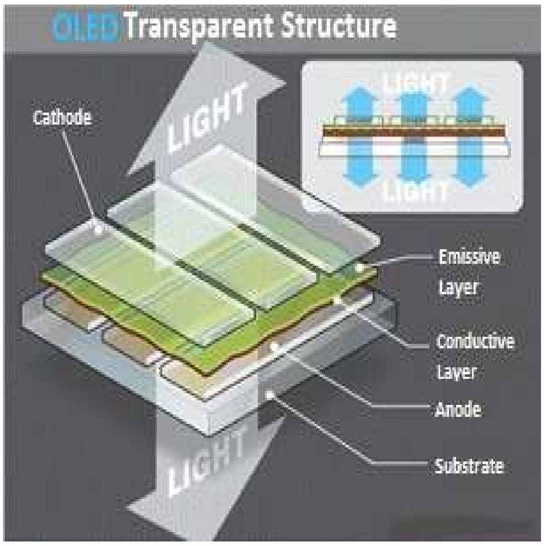

Figure 4.Transparent OLEDs

4. TOP-EMITTING OLEDS

Substrates used in this particularize of oled is either opaque or reflective. They are best suited to active-matrix design. Manufacturers may use top-emitting OLED displays in smart cards.

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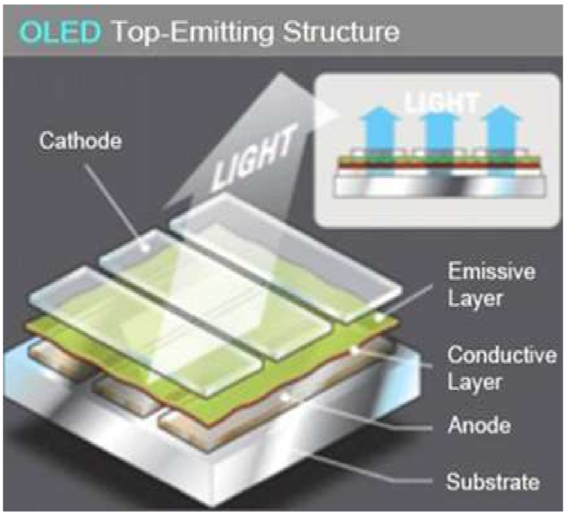

Figure 5.Top- Emitting OLEDs

5. FOLDABLE OLEDS

Folded oleds are quite strong and light. Very flexible metallic foils or plastics are used on the substrate of foldable OLEDs. They are basically used in cell phone to avoid the issues of breakage a major cause for return or repair. Potentially, foldable 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.

6. WHITE OLED

A compararable brighter light is emmited in this type of OLED with more uniformity and more energy efficient than that emitted by fluorescent lights. White OLEDs also have the true-color qualities of incandescent lighting. Because OLEDs can be made in large sheets, they can replace fluorescent lights that are currently used in homes and buildings, which potentially reduces energy costs for lighting.

LED, LCD VS. OLED: TV DISPLAY TECHNOLOGIES COMPARED

In today's modern world of grooming technology displays based on plasma have come to an extinct and their positions have taken over by LEDs and LCDs.

1. LIGHT OUTPUT (BRIGHTNESS)

When the question of light output comes then LCD scrawls over OLEDLCD gets the nod here specifically because the whole screen can be brighter, a function of its backlight. OLED can't do a full screen with as much brightness. Light output also plays a big part in High Dynamic Range (HDR), which we'll discuss a little later.

2. BLACK LEVEL

At the other side of light output is black level, or how dark the TV can get. OLED wins here because of its ability to turn off individual pixels completely. It can produce truly perfect black. LEDs isn't quite as good as per-pixel control because the black areas still aren't absolutely black, but it's better than nothing. The best LCDs have full-array local dimming, which provides even finer control over the contrast of what's onscreen but even they can suffer from "blooming, " where a bright area spoils the black of an adjacent dark area. An OLED TV has perfect black levels and bright whites, for an infinite contrast ratio.

3. CONTRAST RATIO

Here's where it comes together. Contrast ratio is the difference between the brightest and the darkest a TV can be. OLED is the winner here

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because it can get extremely bright, plus it can produce absolute black with no blooming. It has the best contrast ratio of any modern display. Contrast ratio is the most important aspect of picture quality. A high contrast-ratio display will look more realistic than one with a lower contrast ratio.

4. RESOLUTION

Both OLED and LCD are widely available in Ultra HD 4K form. There are also plenty of 1080p LCDs. Some older OLEDs are 1080p, but new models are all 4K.

5. REFRESH RATE AND MOTION BLUR

Motin blur reduction can be done by refresh rate or the blurring of anything on screen that moves (including the whole image if the camera pans), the current version of OLED has motion blur, just like LCD. OLEDs, and all current 4K TVs, have a 120Hz refresh rate. Cheaper LCDs are 60Hz, while some 1080p LCDs are available at up to 240Hz.

OLEDs and many LCD use black-frame insertion, which is a way to improve motion resolution without resorting to the (usually) dreaded Soap Opera Effect.

6. HIGH DYNAMIC RANGE (HDR)

The latest technologies that can significantly improve picture quality is High Dynamic Range (HDR). It's just an expansion of contrast ratio &improvement of brightness and more. There are both OLED and LCD models that are HDR-compatible.

7. EXPANDED COLOR GAMUT

An extension of HDR, is Wide Color Gamut, or WCG, though technically one can exist without the other. It's an expansion of the colors possible on "standard" TVs. It presents us with more deeperand vibrant colors.

8. VIEWING ANGLE

The main drawback of LCD TVs is a change in picture quality if you sit away from dead center (as in, off to the sides). But fortunately this issue of OFF-AXIS is totally avoided in OLED's its image looks basically the same, even from extreme angles.

9. UNIFORMITY

The consistency of brightness across the screen is technically termed as "Uniformity". Most edge-lit LED LCDs are pretty terrible with this, "leaking" light from their edges. . OLED is much better. Unlike plasma, however, it isn't perfect. The forthcoming flat OLED TV's are thought to come up with better "Uniformity".

10. ENERGY CONSUMPTION

OLED's energy consumption is directly related to screen brightness , the brighter the screen, the more power it draws. But the energy consumption of LCD only varies depending on the backlight setting, the lower the backlight, the lower the power consumption. A basic LED LCD with its backlight set low will draw less power than OLED.

11. LIFESPAN

OLED TVs have a lifespan of 100, 000 hours to half brightness, a figure that's similar to LED LCDs. Generally though, flat panels are very reliable.

12. BURN-IN

"Image Persistence" or what we technically call "Burn in" where a ghost of an image remains on screen. It's really hard to do this with most LCDs. It's slightly easier with OLED.

13. SCREEN SIZE

LCD TVs are available in a vast array of sizes, from less than 20 inches to more than 100 inches.

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OLED TVs only come in three sizes today: 55 inches, 65 inches and 77 inches.

14. PRICE

OLED's are quite cheaper than LED's.

15. PICTURE QUALITY

Picture quality of OLED's are far better than LED's largely due to the incredible contrast ratio.

APPLICATIONS OF OLED'S

1. SINGLE COLOURED OLED'S APPLICATIONS

a. These are mainly used for electronic gadgets which are brought in use by holding them in our hands like mobile phones and all.

2. DI OR TRI OR MULTICOLOURED OLED'S APPLICATIONS

a. These are basically used in hand held computers.
b. They have even found their applications in Global Positioning System.
c. They even finds a place in Power steering /EPAS warning light.

3. FULLCOLOUR APPLICATION

a. LCD backlights (white light).
b. Small full colour displays. To be introduced within a year.
c. Full colour, high-resolution, personal communicators.

ADVANTAGES OF OLED

1. OLED's are biodegradable.
2. OLED's are thinner, lighter and more flexible compared to the crystalline layers in LCD's or LED's.
3. OLED's are flexible, they can be folded and rolled up as in the case of roll-up displays embedded in textiles. This is because the substrate used in OLED is plastic rather than the glass used for an LCD or an LED.
4. OLED's are brighter than LEDs.
5. They have greater artificial contrast ratio Because the organic layers of an OLED is much thinner than the corresponding inorganic crystal layers of an LED, the conductive and emissive layers of an OLED can be multi-layered and does not require glass which absorbs some part of light.

DISADVANTAGES OF OLEDS

- **Durability:** Functioning life of LCD exceeds over that of OLED. Differently coloured OLED's have comparitvely varying functioning life durability and Blue OLEDs stands last in the queue.
- Degradation of different types of colour producing elements in OLEDs varies over time that results in reduced luminescence.
- Contact of water with OLEDs may lead to serious problems.

FUTURE CHALLENGES OF OLED'S

Though OLED has a lot of applications but yet we need to face a lot of challenges when we consider OLED's:

1. It is highly expensive (~10/20 times costlier than the same performing LED).
2. It is not so much widely available in the market.

Communication aspect:

1. Light efficiency is low
2. High capacitance thus limiting the device modulation bandwidth (100's kHz).

PAVING NEW WAYS FOR OLED TECHNOLOGY

We are highly privileged to have OLED or more precisely we could say it's really a blessing of advanced technology that we have such a beautiful and flexible display technology. But yet we are trying our best to come up with more

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developed and advanced OLEDs so that we could overcome all it's disadvantages. Like we are on our way of developing OLED with extended durability and long sustainable lifespan, use age of better materials that comprise of the layers. We are trying off to design or built in such a water prone layer that could prevent OLEd to come in contact with oxygen, water and humidity. It's even thaught off to design more thin and more flexible OLEDS. We really hope these ideas to be fruitful and we would very soon have the most eye soothing display amongst us.

HANDLING PRECAUTIONS OF OLED's

1. The display panel is made up of glass we should apply not apply mechanical impacts such us dropping from a high position.
2. We should be careful not to inhale nor lick the organic substance if the display panel is broken by some accident and the internal organic substance leaks out.
3. If pressure is applied to the display surface or its neighbourhood of the OLED display module, the cell structure may be damaged and be careful not to apply pressure to these sections.
4. The polarizer covering the surface of the OLED display module is soft and easily scratched. Please be careful when handling the OLED display module.
5. When the surface of the polarizer of the OLED display module has soil, clean the surface. It takes advantage of by using following adhesion tape- Scotch mending tape no. 810 or an equivalent Never try to breathe upon the soiled surface nor wipe the surface using cloth containing solvent such as ethyl alcohol, since the surface of the polarizer will become cloudy. Also, pay attention that the following liquid and solvent may spoil the polarizer: Water, Ketone, Aromatic solvents
6. Hold OLED display module very carefully when placing OLED display module into the system housing. Do not apply excessive stress or pressure to OLED display module. And, do not over bend the film with electrode pattern layouts. These stresses will influence the display performance. Also, secure sufficient rigidity for the outer cases
7. Do not apply stress to the LSI chips and the surrounding molded sections.
8. Do not disassemble nor modify the OLED display module.
9. Do not apply input signals while the logic power is off.

CONCLUSION

We are yet trying to enter deep in to this dense world of display technology and researchers and scientists are even successful in grasping and finding out more developed, advanced and more innovative display technology where we could feel a kind of reality. We are just trying to improvise the level of OLED by improving the current injection in OLED devices. Most probably after this we going to get more eye soothing display technology like OLET (organic light emitting transistor), then SED, FED are soon going to make the world of display more glamorous.

REWORK

1. Researchers discover a new way to improve the current injection in OLED devices. Researchers from the Max Planck Institute for Polymer Research developed a way to improve the current injection from the positive electrode in OLED panels. To enhance the hole injection the researchers covered the positive electrode with an ultrathin layer of an organic semiconductor as a spacer layer between the electrode and the light-emitting organic semiconductor.
2. Great minds are yet working on to come up with such electrodes that are made up with new transparent items that may overcome the haziness of OLEDs. According to the researchers this idea is based on some kind

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of exposure to a radiation source. This effects the physical properties of the materials. This is even called Colloidal lithography.

3. Scientists have developed more efficient encapsulation layer using magnesium oxide that may even bring down the cost and may effectively be deposited at low tempretures. The refractive index is brought down to a lower scaling and we get a more developed stability of OLEDs. Researchers have confessed that it's for the first time that we are using magnesium oxide based layer.

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