LED'S EXPLAINED

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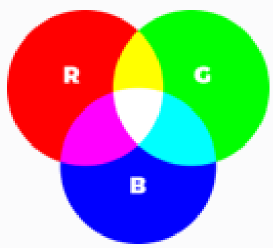
WHITEPAPER

Ever wondered how LED works, and about their variations? Let the LED Experts Group find the "perfect fit".

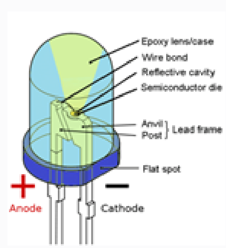
What is an LED?

An LED or light emitting diode is a tiny component that is used to emit light when current flows through it. It has a noticeable appearance where its epoxy shell has a hemispherical or cylindrical-shaped dome.

Until the mid-90s LEDs had a limited range of colors, and in particular commercial blue and white LEDs did not exist. The development of LEDs based on the gallium nitride (GaN) material system extended the palette of colors and opened up many new applications. Red, green, and blue LEDs replicate the primary colors of light and can be added together in varying amounts to produce the color spectrum we see.



Technically speaking an LED is a semiconductor device, which can emit light when an electric current passes through it. Light is produced when the positively charged particles that carry the current (known as electrons) fall into negatively charge empty spaces around the atoms in the physical material (called holes), where the energy lost by the electron falling to the hole is emitted away as a photon or light from within the semiconductor material.



LEDs are emissive technologies meaning they produce their own light, used in many ways replacing traditional light sources. When dealing with display technologies, LEDs can be used as backlighting for an LCD, or a lamp replacement for a projector, but they are especially suited for a specific category of display, known as an emissive display. For emissive displays, each pixel in the display screen is an emitter—an element that outputs light when electric current is applied. Emissive displays include multiple types, where each LED (light emitting diode) is a pixel:

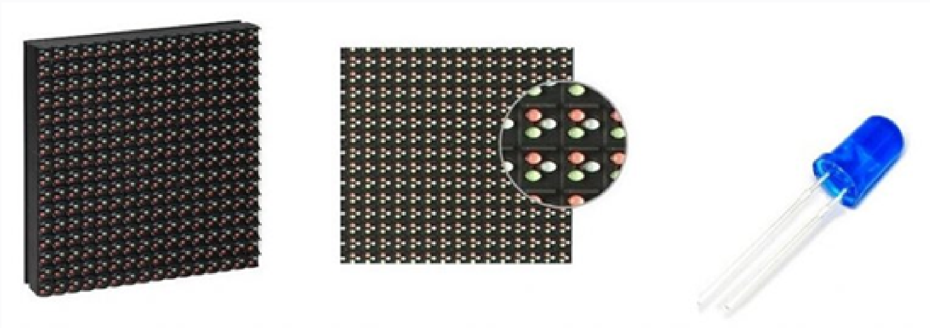
- Direct View LED (dvLED) displays such as large-format outdoor signage and indoor video screens
- MicroLED displays (a specific type of dvLED) are emerging into the market primarily in high-end, ultra-high-resolution displays but gaining ground due to visual performance.
- Organic Light Emitting Diode or OLED displays have become a common technology for today’s computer and smartphone display screens due to their brightness, vivid colors, and energy efficiency.

The five LED configuration types that are widely used in dvLED displays are:

1. DIP LED (Dual In-line Package)
2. SMD LED (Surface Mounted Device)
3. GOB LED (Glue-on-Board)
4. COB LED (Chip-on-Board)
5. Mini and MicroLED

DIP
DIP is one of the oldest types of LED packages used in direct view displays. The DIP LED display is manufactured with traditional (discrete) LED lamps.

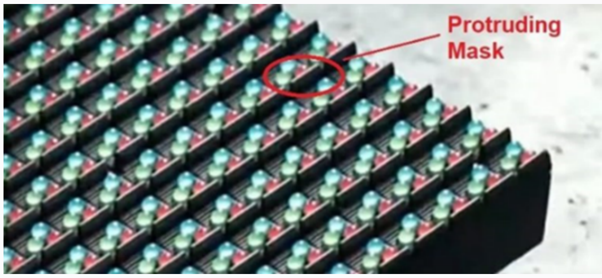
On the surface of a DIP LED display module, you will see that each LED pixel is made of 3 LEDs – a red, a green, and a blue LED. RGB LED shapes the foundation of any color dvLED display. Since the three colors (red, green & blue) are the primary colors, they can be combined to produce nearly all possible colors including white. This is ultimately how all displays create color.



DIP LED is mainly used for outdoor LED screens and digital billboards. Since it can produce a high brightness level, DIP LED can mean display visibility is possible even in bright sunlight.

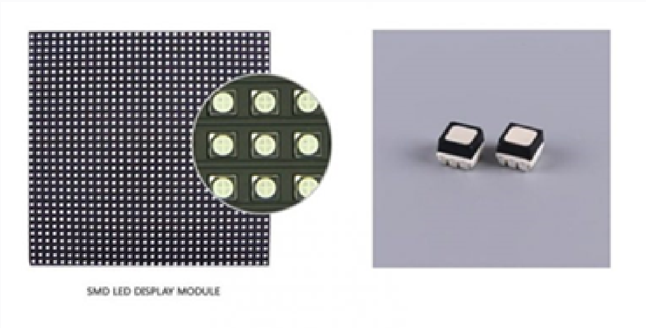
DIP LEDs are more durable and have a high degree of impact and environmental resistance. The hard epoxy shell or encapsulation of the LED semiconductor effectively protects most of the internal components from potential damage.

DIP LEDs are soldered directly onto the surface of the dvLED display module, meaning the LEDs are exposed. Without any extra protection, the protruding LEDs increase the risk of damage. Hence, some form of protection or a protruding mask is used.



SMD
In an SMD (surface mounted device) dvLED display module, there are three LED chips (red, green, and blue diodes) that are miniaturized, and combined into a single package. The long LED “pins” in a single (or discrete) LED are removed, and the LED chips are now directly mounted into a single encapsulation.

SMD allows manufacturers to place more LEDs on a single display module, since SMD LEDs are smaller, meaning higher visual resolution can be easily achieved. More LEDs ultimately contribute to a display module with a smaller pixel pitch and a higher pixel density. The SMD dvLED display is the most popular choice for any indoor application, due to its high-quality image and wider viewing angle.



SMD LED has some disadvantages too. SMD dvLED displays are more prone to damage because the LEDs are smaller and more delicate. Also, the SMD LED does not disperse heat as quickly as other types, which can result in higher maintenance costs over the long term.

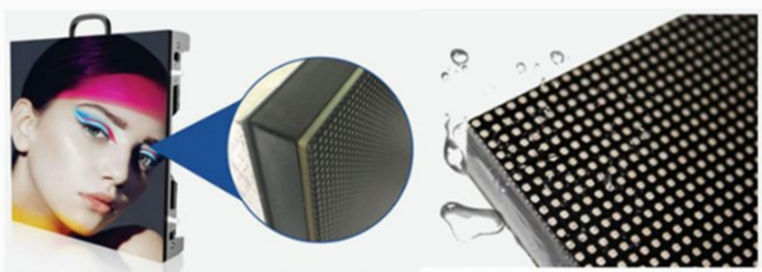
GOB
GOB is an dvLED display module using glue on board (GOB) technology. This is ultimately a manufacturing technique that seals the display module surface with a transparent epoxy glue, covering the module’s PCB to protect the thousands of SMD lamps soldered on it. This makes the display module impact resistant, water and dust proof, and anti-UV.

GOB technology also protects the dvLED module from breaking as a result of accidents such as dropping during installation or delivery. Since it’s shock resistant, most accidents won’t cause breakage. This technology allows ultra-high transparency, improving efficiency (less power required) and ultra-high thermal conductivity extending the life span of the modules.

As pixel pitches get smaller, it becomes much easier to damage the tiny SMD LEDs; since the SMD module is so small, the soldering pads attaching it to the PCB are equally small, and little force is required to detach the LED from the board, especially at the edge of the cabinet, and at the corners of the display (the hardest hit areas during shipping and installation). Once the LEDs are damaged, repair costs can be high.

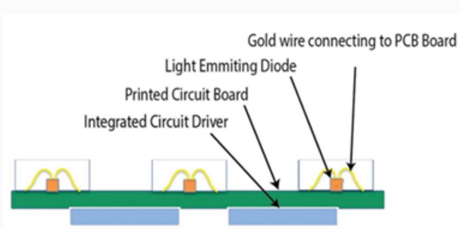
There are Pros and Cons to GOB:

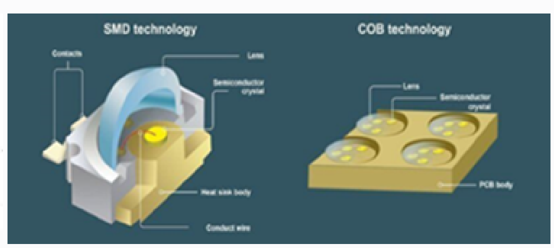
- **Pros**
  - GOB LED displays are shock resistant to external impact or breakage during installation or shipping.
  - The glue on board technology protects the dvLED display from dust, maintaining the quality of the LEDs.
  - GOB LEDs are designed to be waterproof, protecting the LED module from moisture.
  - GOB LEDs are highly reliable. Since they are designed to be safe from most risks such as breakage, moisture, or impact, they can last longer.
- **Cons**
  - One of the cons of GOB technology is that it makes the LEDs difficult to repair. The LED is encapsulated in epoxy, and that increases the effort and time required to perform replacements of individual LEDs.
  - The epoxy is placed onto the LED module under high pressure, which can deform the PCB. This can negatively affect screen flatness.
  - The epoxy is a second, transparent, surface over the top of the LEDs. This can cause internal reflection and may impact viewing quality.



COB

Chip-on-Board or "COB" refers to the mounting of a bare LED chip in direct contact with a substrate to produce LED arrays. All chips are wired directly, integrated, and packaged on a dedicated PCB board.

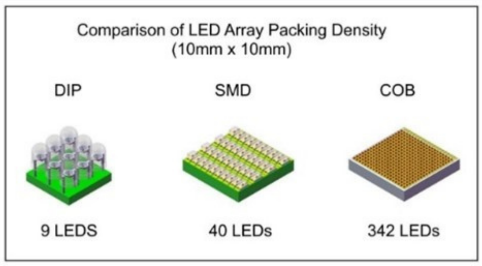




While SMD LED can have up to 3 diodes within a single chip, COB LED can have 9 or more diodes. Regardless of how many diodes are soldered on an LED substrate, a single COB LED chip has only two contacts and a circuit. This has greatly reduced the potential failure rate.

One of the biggest advantages of the COB LED technology is that it can produce more light or higher brightness with lower power consumption per square inch when compared to the DIP and SMD LED technologies. This is made possible because COB LED chips take up less space. Most notably, COB technology allows for a much higher packing density of the LED array, or what light engineers refer to as improved "lumen density". This also results in higher intensity and greater viewing angle and uniformity of light.

As an example, using COB LED technology on a 10mm x 10mm square array results in 38 times more LEDs compared to DIP LED technology and 8.5 times more LEDs compared to SMD LED technology (see diagram below).



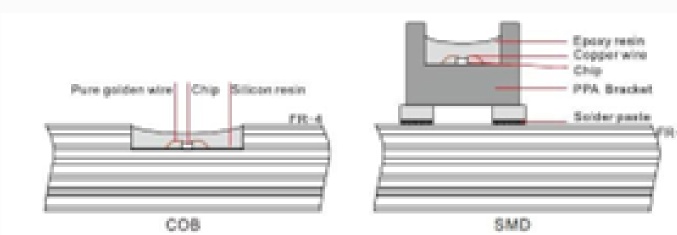
Using COB LED technology can greatly reduce the footprint and energy consumption of the LED array while keeping light output constant. For example, a 500 lumen COB LED array can be many times smaller and consume substantially less energy than a 500 lumen SMD or DIP LED array.

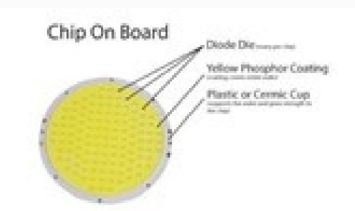
Another reason that COB LED chips can be mounted closely together is the superior performance in heat dissipation. This relates to the aluminum or ceramic substrate of the COB LED chip, and this is a great medium that contributes to higher efficiency in heat conductivity.

In addition, COB dvLED display has a high level of reliability thanks to its coating technology. For the COB LED, it is to encapsulate the LED chip on the PCB board, then solidify with an epoxy resin glue. The technology can protect the LED screen against moisture, liquid, ultra-violet sunrays, and minor impact.

COB LED technology is used commonly in fine-pitch LED screens with pixel pitches that are lower than 1.5mm. At present, P0.4, P0.7, and P0.9 have been mass-produced. Its applications also cover both mini-LED screens and Micro LED screens. COB LEDs are smaller than DIP and SMD LEDs, meaning higher video resolution can be achieved.

The quality control of COB is more complex than SMD and the production cost is much higher due to a high failure rate. Although COB LED technology has achieved many breakthroughs, SMD LED is still widely applied in 1mm or above pixel densities.





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MiniLED and MicroLED

MiniLED and MicroLED can be confusing to some. These are two names that while sounding similar, generally signify two different things. MiniLED is a better form of traditional dvLED construction, and can be thought of as a transitional technology between traditional LED and MicroLED. The current small-pitch LED displays of around 0.9mm are often referred to as MiniLED displays. These are characterized by a 4 in 1 chip design, encapsulating more (and smaller) diodes into a single package, but otherwise working the same as we have previously described.

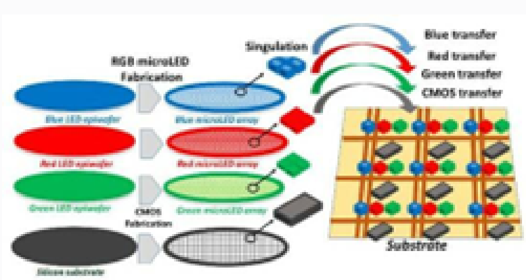
MicroLED is a new generation of display technology that uses a matrix of tiny (almost microscopic) LEDs to create a display. Each pixel is independently addressed and directed to emit light, similar to OLED displays. They share a number of traits with OLED technology, making comparisons a little easier. For starters, both have LED in their name, meaning that they're both constructed from light emitting diodes. The two are "self-emitting" technologies, so each red, green, and blue sub-pixel produces its own light, unlike LCD, which requires a dedicated backlight. Therefore, MicroLED displays will offer very high contrast ratios and deep blacks, just like OLED.

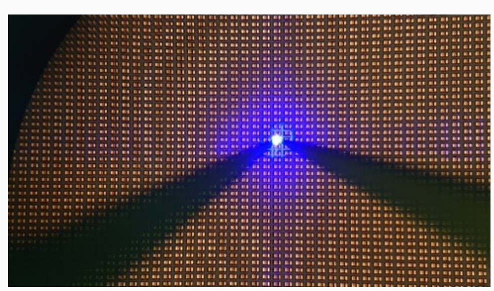
Where MicroLED differs from OLED is in the makeup of the LED materials. The "O" in OLED stands for organic and refers to the organic materials used in light producing part of the pixel stack. MicroLED technology changes this to an inorganic Gallium Nitride (GaN) material, which is typically found in regular LED lighting. This switch also reduces the need for a polarizing and encapsulation layer, making panels thinner. As a result, MicroLED components are tiny, hence the name, measuring less than 100 µm. That's less than the width of a human hair.

Another way of looking at this is that MicroLEDs are simply traditional LEDs shrunk down and placed into an array. The actual LED technology isn't new but manufacturing a panel array using such tiny components is relatively new and currently poses some difficulty.

The unresolved problem for panel manufacturers is how to mass transfer and bond millions of near microscopic LEDs over to the control circuit panel. One potential solution sees the LEDs picked and placed into a larger array, to then be soldered to complete a display. The issue is that the accuracy of current pick and place manufacturing is ±34µm, which doesn't meet the ±1.5µm accuracy requirements to place these tiny LED components.

Flip-chip technology is currently the favored method for producing MicroLED panels. In this method, a wafer carrying the light emitting layer is flip bonded onto the driver circuitry and then soldered. Unfortunately, this method is done one substrate at a time is therefore very slow. Investments are being made to improve yields, which suffer due to thermal mismatching and those pesky alignment accuracy issues.





MicroLED is here and will increase in our future. It offers all the benefits of high contrast ratio, wide color gamut, and potential use in flexible displays that we've come to associate with OLED.

Unfortunately, these next-generation panels are also considerably more expensive, possibly three to four times higher than current flat panel display technologies and even other LED types and configurations. This price gap will undoubtedly fall in time, but it's likely to discourage some immediate investments, especially as many panel manufacturers are still ramping up meaningful OLED and QD-OLED production.

Conclusion

dvLED display technology has been evolving at a rapid pace over the past few years. The technology has introduced various models of dvLED display to the market. These innovations benefit both the businesses and the consumers. While it is safe to say that COB dvLED display is going to be the next biggest thing in the industry, every packaging type of dvLED display has its advantages and disadvantages. There is no such thing as "The Best" dvLED display. The best dvLED display will be the one that fits your applications and requirements perfectly.

Let's collaborate!

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