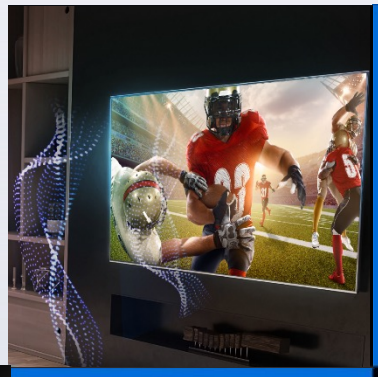
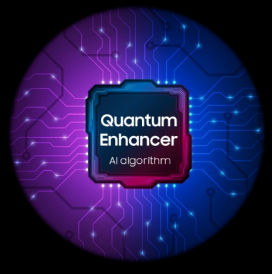
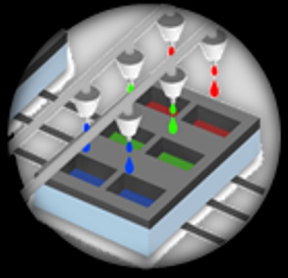
SAMSUNG DISPLAY

Ver. Jan 2024 EN

All New
QD-OLED 2024







SAMSUNG DISPLAY

Contents

1. QD-OLED 2024

1-1. Most advanced technology

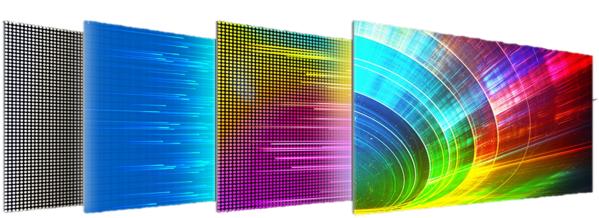
In December '23, the Nobel Prize in Chemistry was awarded to Professor Barwendi, Professor Brus, and Dr. Yekimov. They were recognized for their contributions to various fields such as display and medical use through research on the characteristics, structure, and synthesis technology of nano-sized materials so called Quantum Dot.[1)] It took time from academic research to be used in life on displays. Initially, it was added to LCD in the form of films to enhance color expression. Samsung Display has continued to study the use of Quantum Dot materials on the panel itself, and was able to introduce its first product in January 22.

Despite lots of concerns that it would take several years to reach commercialization, in '22 the yield rate exceeded 90%. In next year, the luminance was improved by more than 30% and the reliability was doubled through Hyperefficient EL and Intelligence2.0. Then the '24 products are not only improved luminance by 3000nit(Max) under higher lifetime through Quantum Enhancer technology but also increased the refresh rate to 360Hz. And resolution can be increased with more sophisticated Pico Inkjet technology.

After CRT TVs developed in the 1930s, LCDs in the early 2000s appeared. And OLED TVs came out with OLED as light sources in the 2010s. QD-OLED was developed by Samsung Display with Quantum Dot technology. Unlike conventional OLED, which substitute LED light sources into OLEDs, make colors through color filters (C/F), QD-OLED convert light energy from OLEDs into colors spontaneously. So we can tell it is the most advanced display technology.

1-2. Judgement of picture quality

The ultimate goal of the display is the same reproduction as the original. Therefore, the technology of the display panel should be evaluated as the reproduction ability of the content. First, it is important how much "Vividness" has in the reproduced screen. Vividness is about naturalness and reality. It should look continuous and smooth such as that are perceived by the human eye. The second will be "Fidelity" for that the reproduced screen should be as same as the content creator made. Even if a famous artist's masterpiece is impressive, it is difficult to have its feeling properly unless painting is shown as the same with original. Finally, it should also be considered whether it is "Suitability" for consumers to use. A display is like a window that conveys the world. These windows should not give inconveniences to use in real life. QD-OLED will explain later in detail that it is the best performance in these Vividness, Fidelity, and Suitability.



1) https://www.nobelprize.org/prizes/chemistry/2023/press-release/

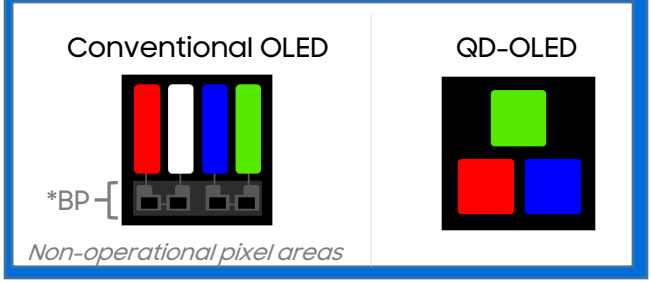
2. Vividness

2-1. High resolution : 140ppi (31.5" UHD)

Consumers have continued to demand OLED monitors for UHD resolution because excellent picture quality of OLED monitors are already well known. In 20"~35" gaming monitor market, the proportion of UHD monitors increased from 0.5% in Q1'21 to 3.3% in Q2'23[1], which clearly tells the biggest contribution of it to increase the market size of the gaming monitor. This shows that consumers who enjoy gaming are expecting more sophisticated picture quality and more realistic screens. Especially QD-OLED, which provides the best picture quality, must be developed for UHD product. Moreover, UHD monitors were essential not only for game but also for work such as designers, editors, and content creators who place importance on image quality.

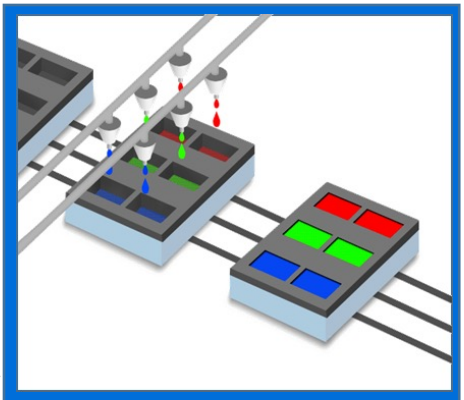
Current OLED technologies have different levels of difficulty in making high-resolution products depending on the stacked structure. BP (Back plane), the switch that drives the pixel, does not transmit light. Conventional OLED technology has a structure called 'Bottom emission', and its BP blocks the light that passes through the C/F from the light emitting layer.

【 BP impact on the same pixel size 】



The switch for each pixel occupies a certain area. When the size of each sub-pixel is reduced for high resolution, the area blocking the light becomes relatively larger, results luminance loss. On the other hand, the 'Top emission' structure of QD-OLED does not have blocked area, so there is no effect of BP even if the pixel size is reduced.

Understandably, it was a very difficult to make 140ppi for QD-OLED. So called 'Pico Inkjet', it requires very fine control to pitch QD ink to the right spot. It may be like the free throw in basketball. Three players in R, G, B uniforms get score all of them, shoot 25 million times and the scoring rate must be 99.9999999% or more. And if it falls, the panel is scrapped as a defective panel. For your reference, Tyler Herro had the best free throw percentage in the NBA 22-23 season with 93.4%, followed by Kevin Durant with 91.9% and Stephen Curry with 91.5%. Additionally, In addition to probability, And all progress should be finished within the limited time.



【 Pico Inkjet process 】

In the actual process, there are numerous environmental factors, such as equipment moving and continuous processing. Many experts predicted that it would take a long time to commercialize this highly sophisticated process. However, with Samsung Display's long-standing know-how of manufacturing and tenacity to achieve, it was able to introduce QD-OLED 31.5" UHD monitor to the world in only two years since January 2022, when QD-OLED monitors were first introduced.

1) IDC, Quarterly Gaming Tracker ('23.8.28)

The QD-OLED 31.5" UHD by Pico inkjet, provides the best performance thanks to the high response time of a self-emitting display and the high color expression of QD, which is difficult to express with conventional OLED. Gamers can now enjoy games with greater vividness in higher resolution. In addition, we expect that it will be actively adopted not only by gamers but also in other business fields such as content production and design that are waiting for a high-resolution monitor with premium specifications..

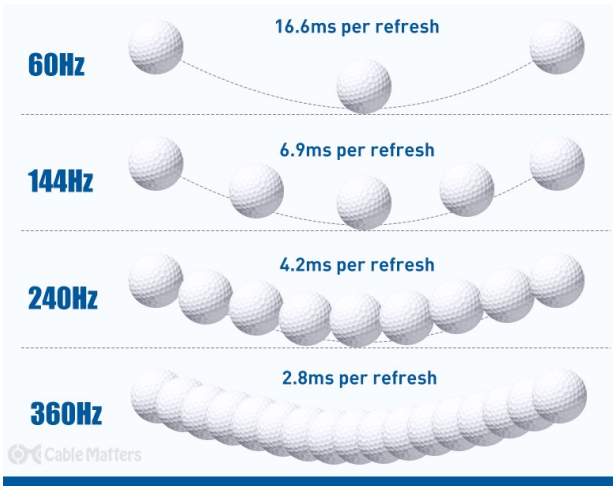
QD-OLED, which added the world's first 140ppi 240Hz product lineup as an OLED monitor, is already invited from many brands, starting with Dell in '24, and will continue to expand to other brands. We will continue to make efforts to improve resolution, and aim to bring products with even improved resolution to the market within 2 to 3 years.

2-2. High refresh rate : 360Hz (27"QHD)

Among gaming monitor's required performances, the refresh rate is very important to users and evaluation agencies also look at with a high weight[1]. Accordingly, along with the expansion of 144Hz monitor since '15, 240Hz monitors are increasing after '17. And the demand for higher refresh rate such as 360Hz appeared at the end of '20 and it is increasing[2].

OLED monitor has 0,03ms response time because of not using liquid crystal, so even with the same refresh rate, the user's actual perceiving is more than twice that of LCD. This is because the dragging of object is much smaller than that of LCD, so is displayed more clearly and can be easily observed in display. As you can see in the picture on the right, as the refresh rate increases, you can feel smoother screen transitions, and OLED displays, which can display clearer picture quality in each frame through fast response speed, provide more vivid and continuous picture quality than LCD. So the 175Hz OLED monitor, which is introduced in '23, already can make to feel the performance of over 300Hz LCD monitor.

【 Image quality on refresh rate 】



* Source : www.cablematters.com

The 360Hz QD-OLED, which was commercialized OLED monitor for the first time in the world, applies an upgraded algorithm that combines the optimized design of OSG (Oxide Silicon Gate) and a driving technology that minimizes pixel resistance, making it more improved refresh rate than in '23. The 360Hz QD-OLED is the first OLED monitor-dedicated product that was not found in conventional OLED products. We can propose precisely 360Hz QD-OLED monitor from now on for premium gaming monitor users who want real premium performance. We believe that it will make users can have more stable and clear screen at a reduced cost with the best gaming experience.

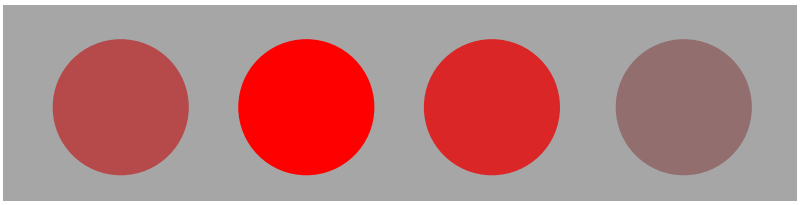
1) Rtings allocates 30% of the total points to refresh rate among the evaluation items of gaming monitors, considering it as the most important performance.
2) IDC, Quarterly Gaming Tracker ('23.8.28)

2-3. Perceived Brightness : XCR

When we say how much bright in everyday life, we often use the two terms Luminance and Brightness interchangeably. "Luminance" is a value measured by a instrument of the luminous intensity of light emitted from a light source, and the unit is cd/m2 (nit). "Luminance" has been used to show the brightness capabilities of a display because it is familiar and easy to compare to CRT. It has been mainly used as one of the representative specifications of a display. "Brightness" refers to what a person feels when light hits the retinal rods and cones. Since it is usually a subjective evaluation, it is difficult to measure (quantify) like luminance, but it represents the degree of brightness and darkness that a person actually feels.

As shown in below picture, even on a screen with the same brightness, the human feels brighter and more vivid as higher saturated colors. There have already been existing research results[1),2)] on the phenomenon that colors with high saturation appear clearer and brighter at the same luminance. Based on this, Samsung Display proposed XCR(eXperienced Color Range) and SEMI adopted this measurement method[3)] as an international standard through long-term discussions with the display industry, manufacturers, related academia and organization.

【 Same luminance & Different brightness 】



XCR, which quantifies perceived brightness, specifies a method to calculate the level of brightness that a person actually feels with his or her eyes considering the influence of color along with luminance. So, a higher XCR means that user can feel brighter even at the same luminance.

As results of evaluating through the XCR measurement method at Samsung Display, the XCR at 400nits of 65" TV were QD-OLED 258 and Conventional OLED 223, which QD-OLED can give perception about 20% brighter. In other words, even with the same luminance, if you look at the screen of QD-OLED, you will feel brighter and more lively vivid image. As shown in below picture, vivid colors make you feel brighter.

【 Perceived brightness with color differences at the same luminance 】

1) Hyeyoung Ha, et al, 'Image-brightness prediction model for wide-colorgamut displays based on Helmholtz-Kohlrausch (H-K) effect', JID 2022, vol.23, no.2, pp. 115-120

2) YungKyung Park, 'Measuring Color Strength for Wide Color Gamut OLEDs', SID Vol53, Issue1, pp1172-1175

3) SEMI D61

2-4. Response time

QD-OLED is a display optimized for watching movies and content as well as playing games. For gamers, the display is also important part that can affect winning or losing, and Response time is one of the important factor that decide the display. While LCDs that display screens by moving liquid crystals have a response time of about 1ms only when overdrive technology is applied, QD-OLED can play satisfactorily and realistically without dragging even in fast-moving games with a response time of 0.1ms (IDMS, Box pattern) / 0.03ms (Line), which is more than 10 times faster than LCDs without overdrive. Unlike LCDs, where the response time is limited by liquid crystal, QD-OLED have the best response time because each pixel can be reacted immediately by current. These characteristics of QD-OLED also work with the high refresh rate characteristics introduced above, showing clearer movement without attraction at the same refresh rate.

VESA proposed CMR that distinguishes the degree of video clearness as shown in the table on the right, which includes the refresh rate along with the response time, and in particular, self-emitting display products can receive the highest tier. The final set with self-emitting monitor panel have already been certified and the monitor with '23 QD-OLED has already acquired the highest tier of CMR13000. '24 QD-OLED panel also provides performance to get CMR13000

【 VESA CMR Classification 】

VESA CERTIFIED ClearMR

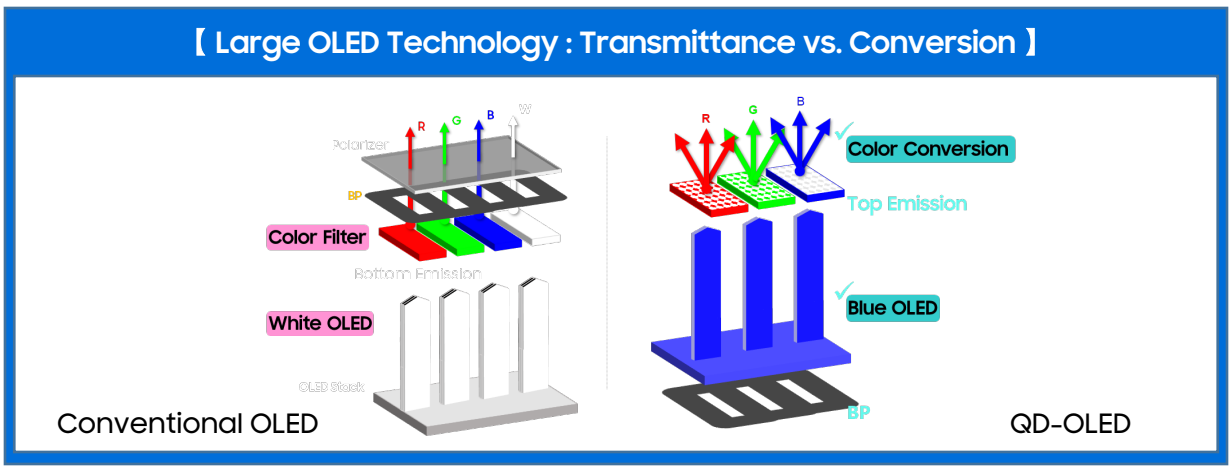
ClearMR™ TIER	CMR RANGE
ClearMR *3000*	2500 ≤ CMR < 3500
ClearMR *4000*	3500 ≤ CMR < 4500
ClearMR *5000*	4500 ≤ CMR < 5500
ClearMR *6000*	5500 ≤ CMR < 6500
ClearMR *7000*	6500 ≤ CMR < 7500
ClearMR *8000*	7500 ≤ CMR < 8500
ClearMR *9000*	8500 ≤ CMR < 9500
ClearMR *10000*	9500 ≤ CMR < 10500
ClearMR *11000*	10500 ≤ CMR < 11500
ClearMR *12000*	11500 ≤ CMR < 12500
ClearMR *13000*	12500 ≤ CMR

3. Fidelity

3-1. Color Accuracy

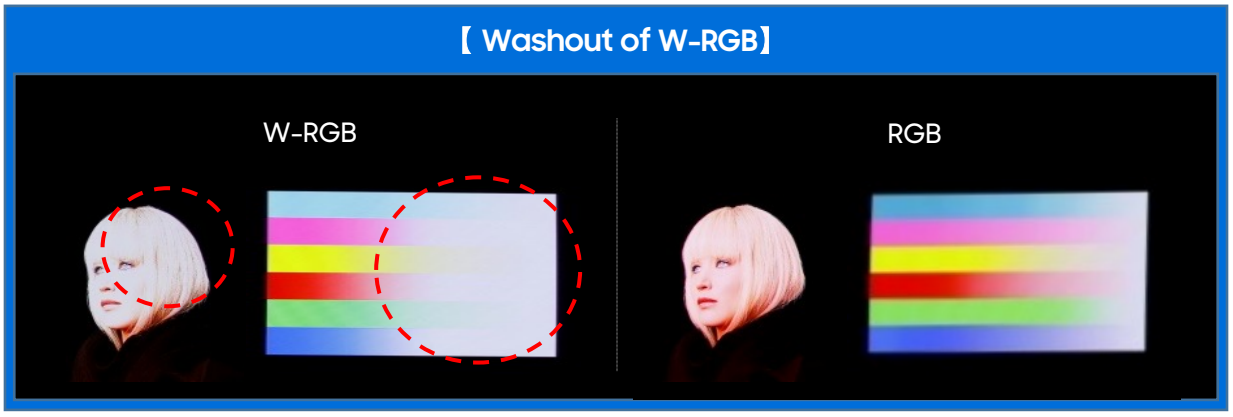
Since QD-OLED reproduce images only with three primary colors of light(R, G, B), white maximum luminance and the sum of R, G, and B peak luminance is the same. In other words, the exact color can be displayed at any luminance.

【 Large OLED Technology : Transmittance vs. Conversion 】



1) Philips 49M2C8900, 49"DQHD 240Hz

Conventional OLEDs, on the other hand, use white subpixels to compensate for insufficient luminance, so as the luminance increases, the proportion of white increases, and the colors expressed are inaccurate or limited. Due to the influence of white, a "Washout" appears in which the saturation of pure color decreases and appears to be bleached. Therefore, conventional OLED in high luminance makes color with not pure RGB but washout-RGB.



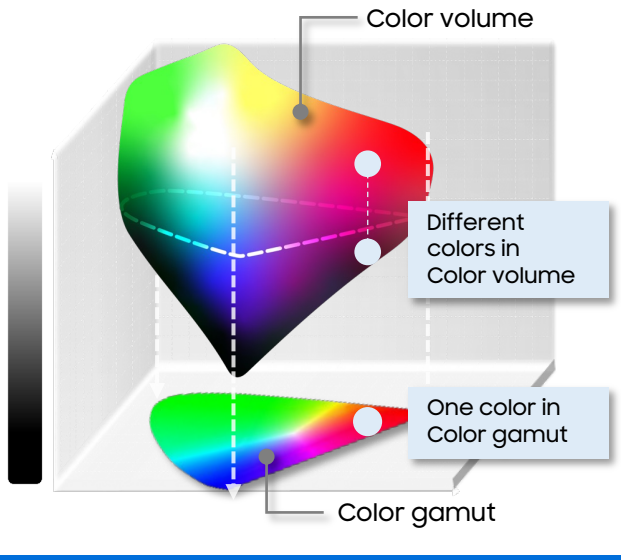
The ability of QD-OLED's color accuracy has been validated by Pantone, which leads the world's color standard. Pantone validation has completed for the first time in the world as a panel ('23.June). This shows that it accurately expresses more than 2,100 colors of the Pantone Matching System (PMS) developed by Pantone and more than 110 colors of Pantone Skintone, confirming once again that it is the world's best display technology in color accuracy.

3-2. Color Volume

In the past, the display industry used 'Color Gamut' to indicate color expression ability, which indicates the coverage of the color area that can be expressed with luminance fixed. At that time, there were standard dynamic range (SDR) images mainly, so two-dimensional color gamut alone was enough to display's performance. Recently, however, content has been developing to show realistic images at various luminance, and the representative technology used here is High Dynamic Range (HDR). The number of contents applied with HDR technology is increasing and it is certain that the trend will continue in future. Therefore, the display also requires more performance to represent accurate colors in a wide range of luminance levels and color gamut alone can be limited in indicating the capabilities required by HDR for the display's color expression capabilities.

To overcome this, a method of displaying color reproducibility in three dimensions by adding a luminance level to a two-dimensionally defined color gamut is used, which is a 'color volume'. As shown in the figure on the right, in a two-dimensional color gamut, it is expressed in one color, but from the perspective of a three-dimensional color volume, there may be cases where it can be divided into different colors.

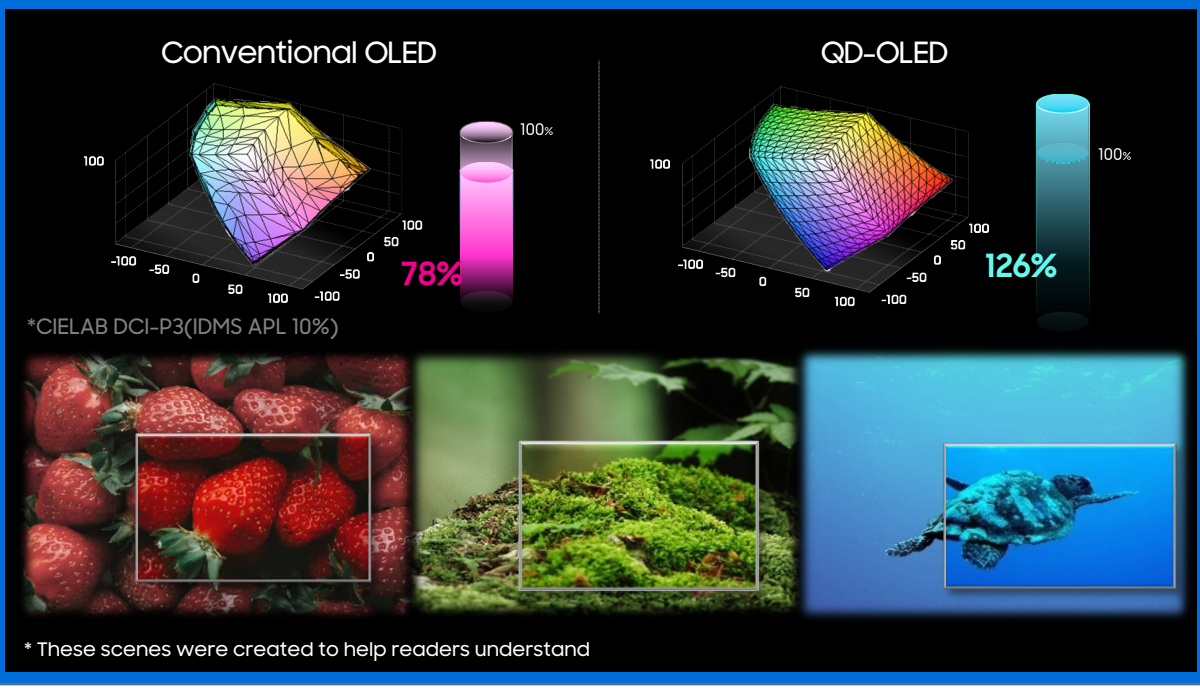
Therefore, color volume will be one of major specifications of display in the near future in order to determine the display's ability to accurately express realistic and HDR images.



【 Color gamut & Color volume 】

As described above, while conventional OLED has a washout phenomenon when luminance increases, QD-OLED that makes colors and luminance only with R, G, B. So it has no change in color expression due to changes in luminance. As many experts and consumers' reviews already say, it proves that QD-OLED's color expression ability at high luminance is excellent. Eventually, there is a greater difference in the 3D color volume reflecting the change in luminance than the difference in the 2D color gamut. Color gamut shows values of 90% QD-OLED and 76% Conventional OLED based on BT.2020 , Color volume is 126% QD-OLED and 78%[1] conventional OLED, indicating that the gap is much larger, which shows QD-OLED's richer color reproduction ability.

【 Color volume 】

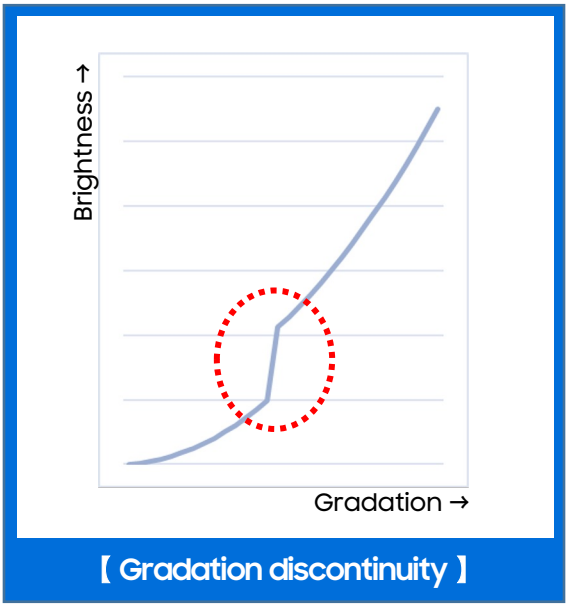


1) IDMS 1.2 APL 10%, DCI-P3 CIELAB

3-3. Shadow detail

Recently produced content is carefully reviewed in more detail, and each scene contains the producer's intention, and consumers' emotions are also expecting to do so. There will be no disagreement that the demand for higher completeness of content will increase in the future. Therefore, not only consumers but also producers want better performance for ability of displays, which were not recognized in the past though. In other words, people want to feel the same on screen as they see the landscape with their eyes in nature, and producers try to produce and deliver it that way as well.

In order to express this 'natural screen', it is more advantageous for the display to have continuous changes in brightness. When there is a discontinuity, a screen that feels unnatural or strange is displayed. The best way to achieve a natural change in brightness is to express the change continuously or to make it as fine as possible so that it cannot be felt. However, in the current display operated by digital signals, it can only be expressed in 256 (8bit) and 1,024 (10bit) steps called 'gradation'. Therefore, it can be evaluated by how uniformly the difference in brightness for each gray level is expressed.



【 Gradation discontinuity 】

When only three primary colors of light are used for sub-pixels, the brightness is displayed in the same step as the given signal, so it is possible to express exactly what the creator intended. However, in the case of W-RGB structure using white sub-pixels, luminance is expressed with RGB without white pixels in low gradation only, which is a dark part. But when a specific luminance is reached, white sub-pixels begin to turn on to add insufficient luminance, so the conditions for generating the color or luminance become discontinuous and the screen may become unnatural. In particular, human eye is more sensitive to dark than bright, such a phenomenon can be recognized easily in low gradation areas.

As in the case of the actual conventional OLED's screen on the right, when it is condition for white sub-pixel to turn on at the boundary between dark and bright areas, the change in brightness is expressed abnormally, contrary to the creator's intention. Sometimes it appears in form of a band. In previous conventional OLED, the level was reduced through dithering, but there are user opinions that it began to appear again in the new product in 2023 after a lens-shaped layer was added for increasing brightness.[1)]

1) www.avsforum.com

【 Band in conventional OLED by gradation discontinuity】

* Source : https://www.avpasion.com/lg-oled-g3-tecnologia-mla-magnifica-fallos-oled/

4. Suitability

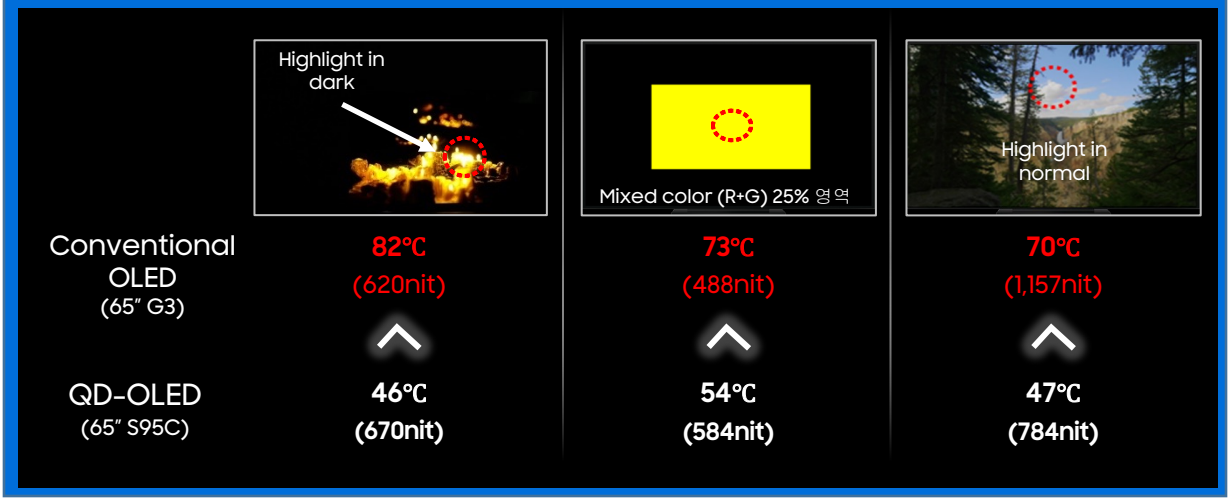
4-1. Heat

All electronic goods inevitably generate heat during operation. The display can be touched by users, such as TVs or monitors, and users may feel uncomfortable depending on the level of heat generated. Therefore, it should never be enough to burn users. Burns can be divided into high-temperature burns and low-temperature burns. Low-temperature burns occur when the contact time is prolonged even though the temperature is relatively low. According to the International Standards Association (ISO), if the temperature is above 55 degrees Celsius, a burn occurs for more than 17 seconds, and if the temperature is above 60 degrees Celsius, a burn occurs in about 8 seconds.[1] Even if you don't get burned, you can't help but be surprised or anxious when an unexpected high temperature occurs.

Since the self-emitting display is loaded in the process of turning on/off each pixel, heat generation is concentrated when a bright part is expressed on a part of the screen. Increasing the efficiency of OLED, a light source, can create the same brightness with a small load and is the most ideal way to reduce the risk of heat generation. However, if the efficiency is low, a higher load is required to create the same brightness, and the possibility of heat generation increases.

As measured by Samsung Display, the surface temperature of two OLED set currently available in the market were observed as bellows. QD-OLEDs remained below 55 degrees Celsius, while conventional OLEDs exceeded 70 degrees Celsius and exceeded 80 degrees Celsius.

【 Surface temperature of actual screen 】



If the Average Picture Level (APL), which refers to the ratio of the area of the white screen among the entire screen, is high, that is, if the overall screen has a large proportion of white, the conventional OLED can reduce the load of each pixel with the help of white sub-pixels. But if the color saturation is high or the color luminance must be increased without the help of white subpixels, the load increases and the temperature goes up. As will be explained later, this phenomenon of heat generation is expected to be linked to Burn-in or image sticking, one of the main interests in OLED displays.

1) ISO 13732-1:2006 Methods for the assessment of human responses to contact with surfaces
2) APL 100% means that the entire screen is the same color, and APL 25% means that only 25% of the screen is turned on in the same color

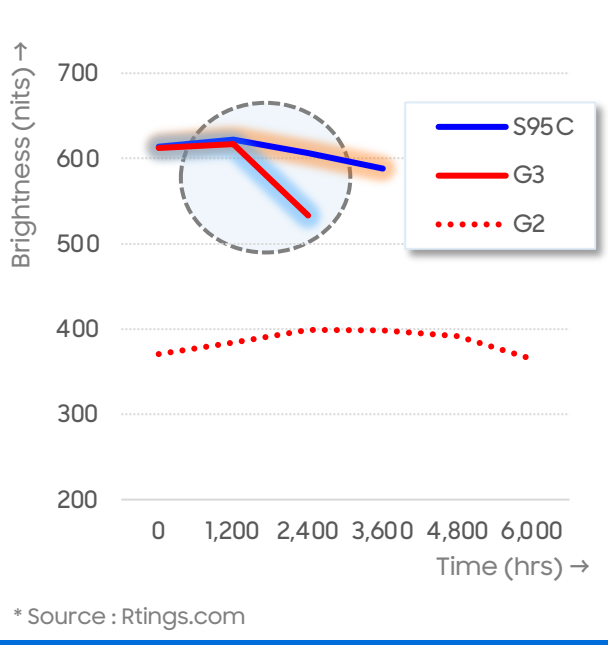
4-2. Burn-in

The burn-in problem is one of the most concerning issue with OLED displays. This is because OLED displays that use organic matter as a light source have a inherent risk that they may be vulnerable to heat. In fact, it is true that until a few years ago, there were complaints about image sticking occurring in usage environments.

The risk of burn-in has continued since the release of OLED displays, and display manufacturers have also made efforts to minimize burn-in occurrence. They have applied methods such as limiting the maximum brightness of displays or using white sub-pixels. In order to reduce the load of each pixel, QD-OLED has already been used the technology to find optimal conditions by measuring the load of each pixel in real time to the '22 product. It has improved not only the burn-in of the screen but also the uniformity of the screen with IntelliSense2.0 applied in '23. And using Hyperefficient Blue OLED helps to minimize burn-in as well as improve luminance.

Rtings, well-known for its evaluation of consumer electronics, is conducting burn-in evaluations of many available sets in the market[1], including OLED displays. Rtings evaluates particular screens by inspecting at changes in display brightness over time under SDR conditions and whether there is visible burn-in. Burn-in evaluation is still ongoing as it takes a very long time.

Looking at the results so far (E/Oct.'23) of Conventional OLED and QD-OLED released by Rtings, it is as shown on the right. Until 1200 hours, neither product shows much difference from the initial state, but changes can be seen after 2400 hours. Regarding the results as of now, it is difficult to say that there is a big change in QD-OLED, but conventional OLED has a decrease in luminance of about 14%. Along with the results of QD-OLED, which has already been evaluated for 3,600 hours, the results of conventional OLEDs will be known more accurately in near future, but the results of at least 2,400 hours alone show that they are different from QD-OLEDs and that even there have been some changes in G2 and G3.



【 Burn-in test result of Rtings (APL10%) 】

In other words, in the case of Conventional OLED, when compared to existing products at the same APL, a decrease in luminance is observed from the product that apply the micro lens patterned layer in addition to boosting technology to improve luminance in Rtings test results. It can be assumed that added layers and its boosting technology might be a factor causing vulnerability to burn-in has arisen.

1) Rtings, https://www.rtings.com/tv/tests/longevity-burn-in-test-updates-and-results

4-3. Harmful blue light

Harmful blue light is no longer an unfamiliar term. As consumption of digital content such as OTT, gaming, and streaming increases, consumers' awareness of harmful blue light is increasing. Due to concerns about eye fatigue and vision deterioration, more and more consumers are looking for displays that are comfortable on the eyes even after long-term use. QD-OLED products have been able to prove that they contribute to the protection of consumers' eyesight by obtaining Eye Care certification from SGS, a global certification company, and EyeSafe2.0 certification from EyeSafe, an eye health organization.

	Eye Care		Eye Safe 2.0	
Organization	SGS		EyeSafe, TUV	
Meaning	Harmful blue light portion out of visible ray		Effectiveness of protection from harmful blue light	
Evaluation result	LBL %		RPF (Radiance Protection Factor)	
	QD-OLED	LCD (Gaming)	**QD-OLED**	Others
	11.3%	18~20%	**≥ 40**	N/A
Logo				

Through SGS certification, it can be seen that the proportion of harmful blue light in the overall average screen has been reduced by about 40 to 50% compared to LCD. In EyeSafe 2.0 certification, which was upgraded to the latest method in '22, QD-OLED obtained more than 40 RPF in the similar sense as SPF to show how much protect. This is due to the characteristics of QD-OLED that technically optimizes and applies each RGB.

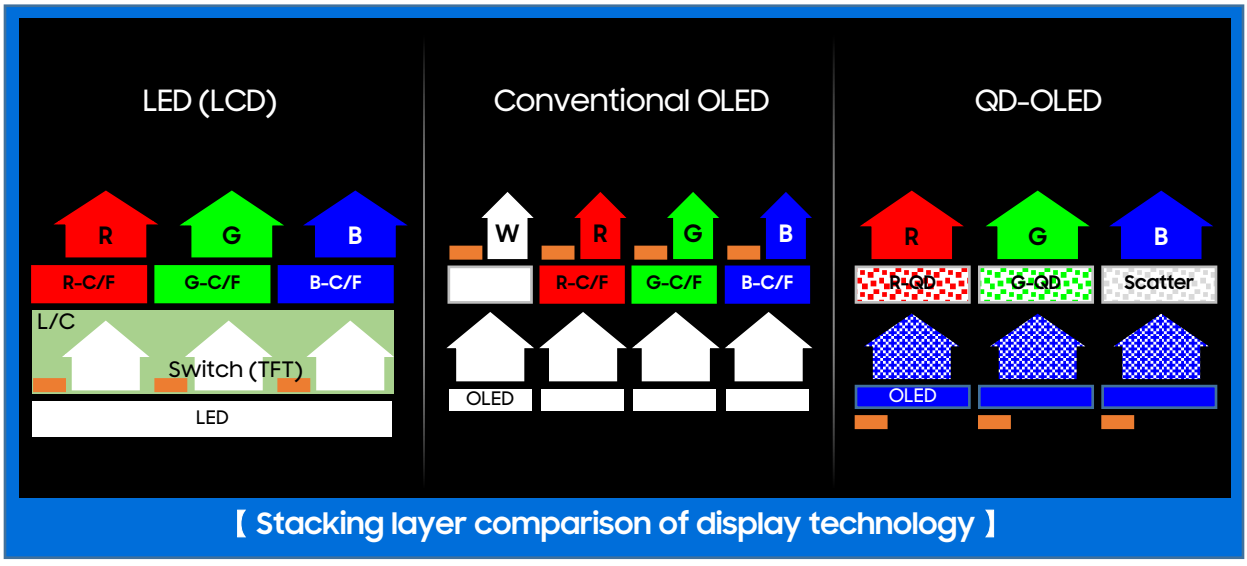
5. Historic QD-OLED

5-1. Best picture quality

It is no exaggeration to say that LCD displays have pushed CRTs out of history. And now the public is waiting for premium technologies that provide better picture quality by more advanced technologies. Under these expectations, self-emitting OLED technology, which runs pixel by pixel, appeared in the large display market more than a decade ago. It has been accepted as a groundbreaking technology in the market because it is the first pixel-based self-emitting technology for large displays and used OLED as a light source. However, in order to avoid obstacles such as brightness, life time, etc., a W-RGB structure using white subpixels was used at that time. And the method of implementing color is the same as the LCD, which is transmissive method of passing white light through a color filter.

As described above, QD-OLED is a method in which QD particles located on the front of the display receive energy from the blue OLED layer and emit light on their own in each single subpixels, so excellent off-axis visibility and high resolution products can be made earlier than expected. Above all, QD-OLED, which consists of only the three primary colors of R, G, B without white subpixels, has already been evaluated as showing the best picture quality in various media by many display experts and consumers who have actually used the product over the past two years. Even if conventional OLED technology removes white subpixels and changes them to RGB structures, it can not be predicted exactly whether it will be able to maintain the current brightness, but it may be expected that new investment such as time and cost will be required. As such, the difference between conventional OLED and QD-OLED is very clear, and the difference in picture quality is inevitably large.

Some people say that it is a same OLED display with self-luminous black light. But QD-OLED is using QD material and has a different mechanism of producing colors. It must be a different technology from conventional OLED and can be said the best technology so to reproduce accurately for the best picture quality.



【 Stacking layer comparison of display technology 】

5-2. Leap of display technology

In addition to the excellent HDR expression and high response time of existing OLEDs, QD-OLEDs show clearer and more vivid picture quality with QD's accurate and wide color expression that cannot be followed by other technologies else. This is the display that can deliver what content producers intended to consumers. Therefore, those who have experienced QD-OLED at least once will feel that it is the best display for its picture quality level. Just as consumers who have used LCDs have not returned to CRTs, consumers who have experienced QD-OLED once will no longer be able to step back.

Just as there was a big jump from CRT to LCD, QD-OLED will be making a quantum jump by presenting a new standard of image quality for the future display. You saw the birth of QD-OLED in January '22, and you are sharing a monumental moment in display history that is divided before and after QD-OLED.

5-3. New size for everyone

- End -

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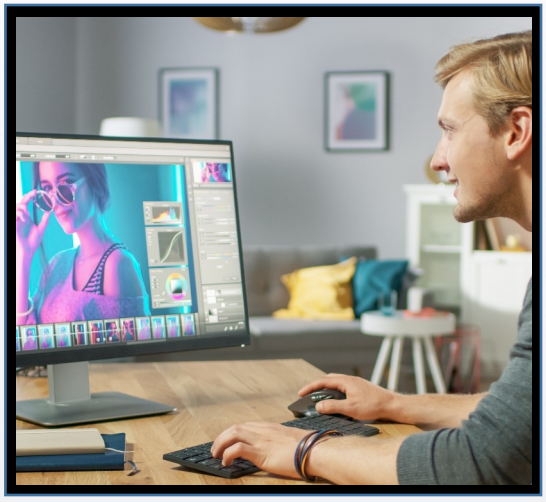

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