Mini-LED BLU Technology and Mini-LED TV Market

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3.1 LCD Evolution

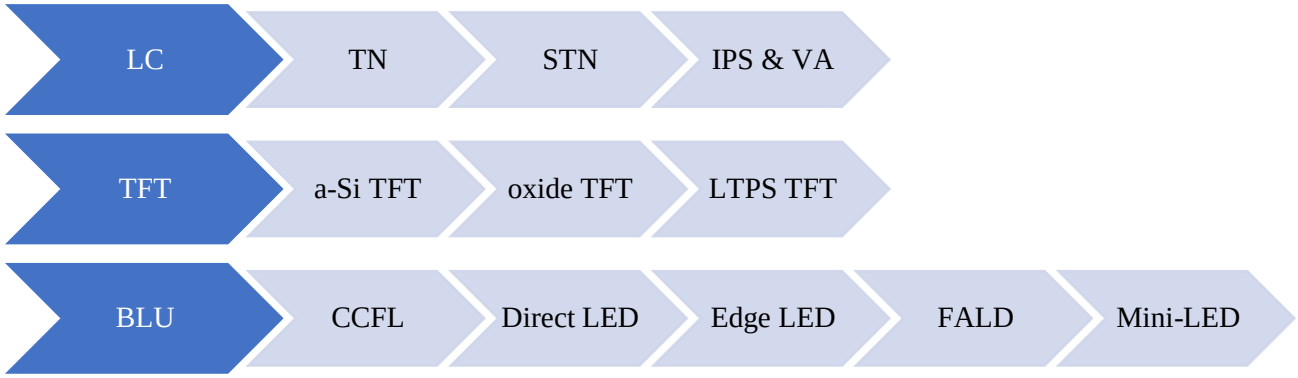
- **Is it the last stage of evolution?**

LCD, which has been used for more than 40 years, is entering the market by once again upgrading its performance.

Liquid crystal displays that started with TN (twisted nematic) LC (liquid crystal) changed to IPS (in-plane switching) type and VA (vertical alignment) type liquid crystals through super twisted nematic (STN). IPS and VA types are used in LCDs for TVs, monitors and smartphones.

Passive matrix (PM) driving was mainly used when TN and STN LCDs were used until the early 1990s, but as the resolution increased, a-Si TFTs began to be applied to LCDs for notebook computers. Oxide TFTs are used in high-resolution large TVs. LTPS TFT is applied to high-resolution smartphones.

There have also been many changes in the backlight unit (BLU). A CCFL (cold cathode fluorescence lamp) similar to a fluorescent lamp was used, but LEDs without standby power consumption began to be used as a light source for BLU in order to prevent an increase in power consumption of BLU due to an increase in TV size. Initially, LED lamps were used on the edge of four sides, but recently only one LED is arranged due to the improvement of LED efficiency. In order to improve the contrast ratio, which is a disadvantage of LCD TVs, the FALD (full array local dimming) method, which improves the contrast ratio by local dimming by placing LEDs under the liquid crystal panel, is being applied to premium LCD TVs. Recently, in order to maximize the contrast ratio of LCD, BLUs with mini-LEDs placed directly under them have begun to be released on the market.



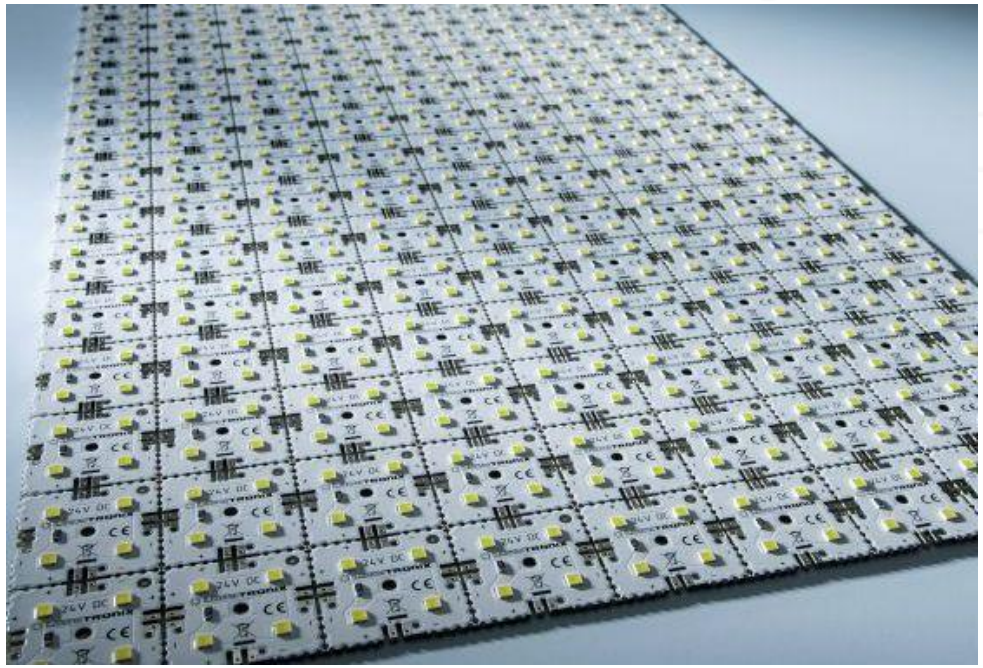
3.2 BLU Type and Structure

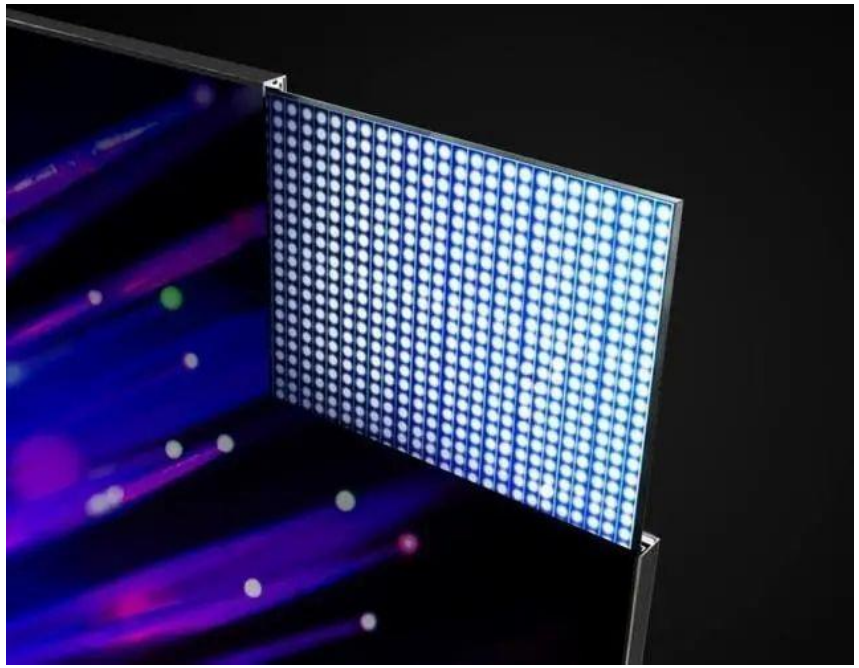
- **Mini-LED BLU**

Mini-LED BLU is a method developed by FALD BLU. In order to increase the contrast ratio, the local dimming zone is over 1000 blocks, and there are many LEDs, so mini-LEDs around 100um are used.

There is no optical lens used in FALD BLU, so the BLU thickness is thin.

Mini-LED BLU is classified into a passive matrix (PM) and an active matrix (AM) according to the driving method. The PM method is a structure in which LEDs are integrated on the PCB board, and the AM integrates the LEDs on the TFT substrate.





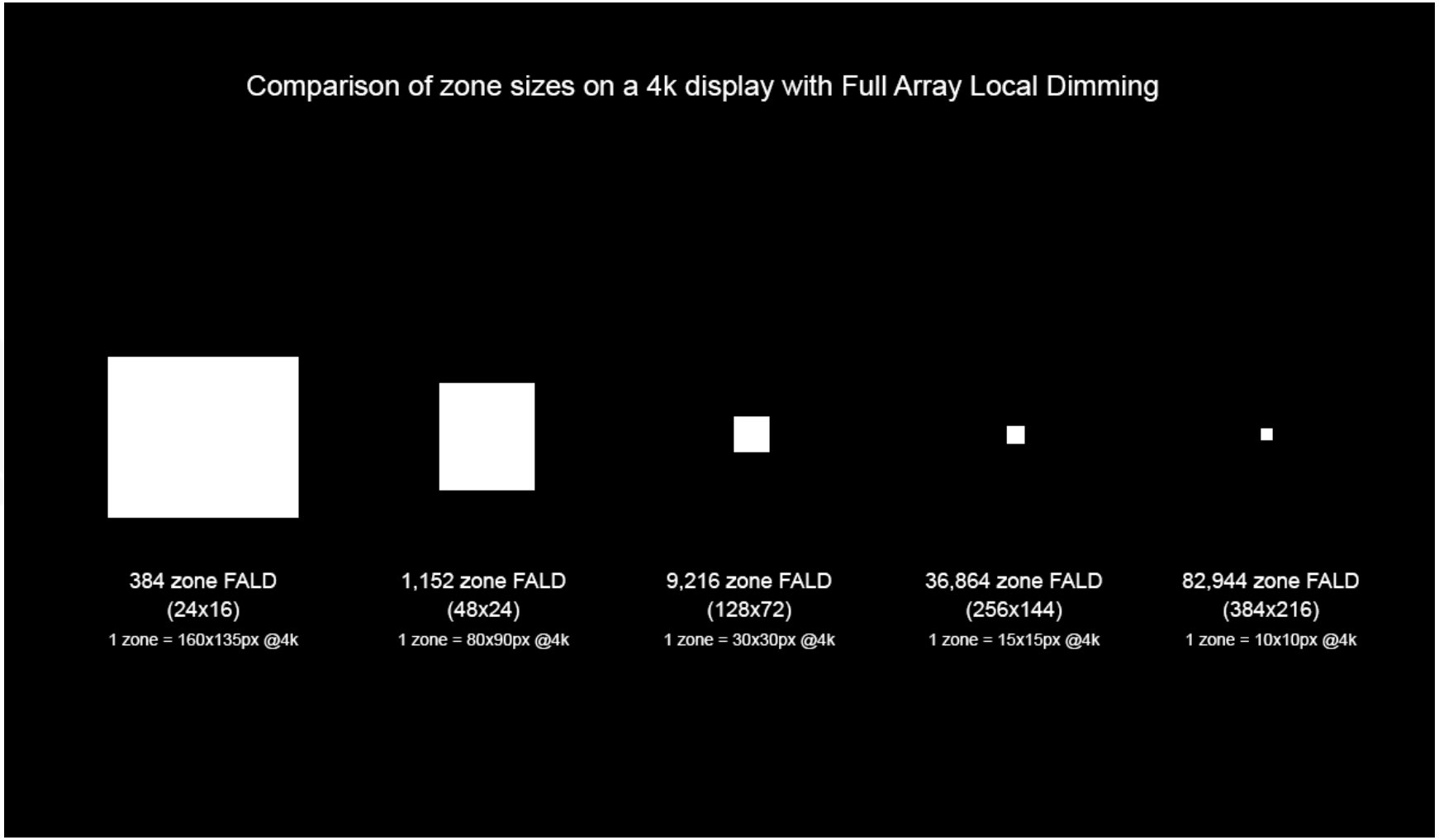
Nichia LED Backlight Module Matrix Mini 126 segments

4.3 Local dimming zone

In order to minimize the halo effect and increase the contrast ratio, there should be as many local dimming zones as possible.

The figure on the right shows the driving area size according to the number of local dimming zones of a 4K display in the FALD method.

The 384 zone FALD has 21,600 pixels per zone, and the 9,216 zone FALD has 900 pixels in 1 zone. Therefore, as the number of zones increases, the number of screen divisions increases, thus increasing the contrast ratio and reducing the halo effect.



Source: [H]ardForm

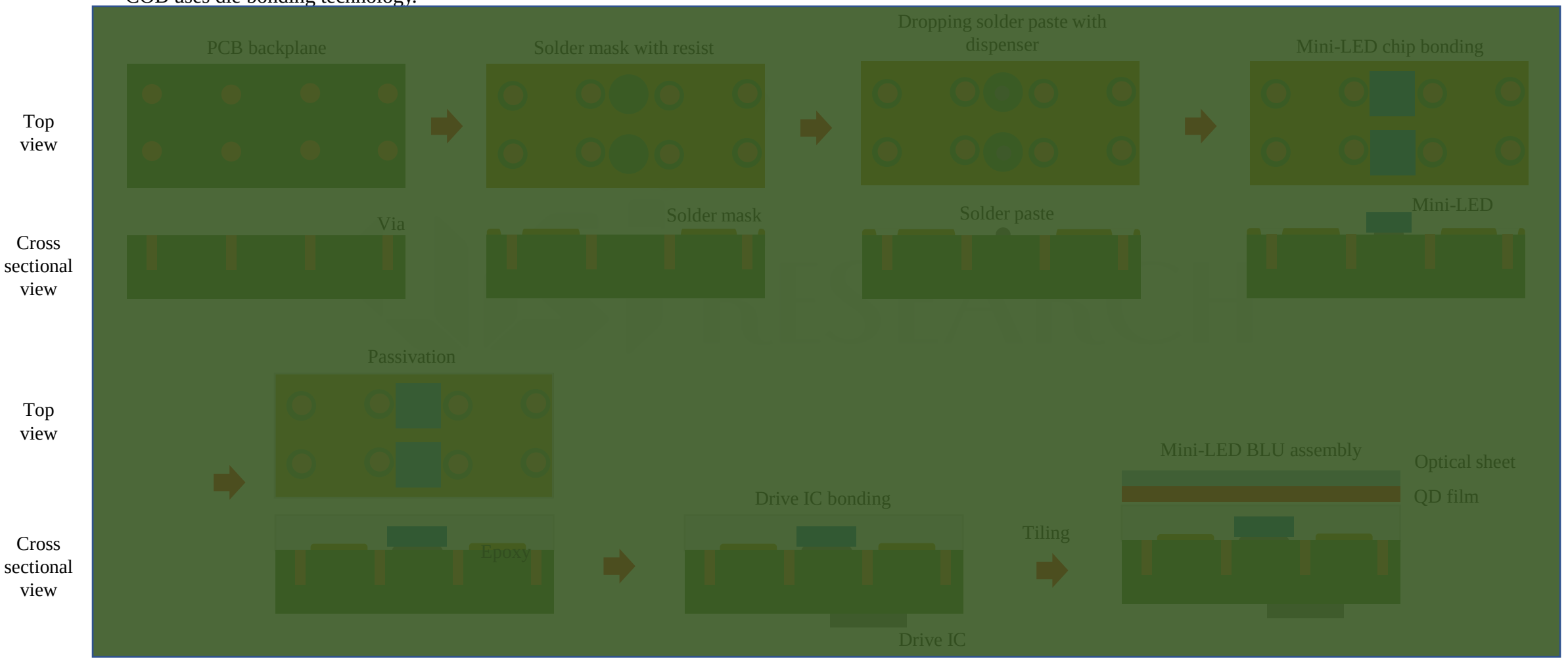
5.4 Mini-LED Type

LED Type	POB (package on board)		COB (chip on board)		COG (chip on glass)
Driving	PM (passive matrix)				AM (active matrix)
Chip size	0.8 ~ 3.5 mm		0.3 ~ 0.6 mm		0.05 ~ 0.3 mm
Color	Blue	White	Blue	White	Blue
QD film	Necessity	Unnecessity	Necessity	Unnecessity	Necessity
Method	SMT (surface mounting technology)		Die bonding		Chip bonding
Board	FR4 (frame retardant type 4) FPC		FPC BT resin (bismaleimide-triazine resin) HDI (high density interconnect) PCB		TFT glass
Application	Mid-end TV Monitor Automotive		Premium TV Notebook PC Tablet PC		Super premium TV

6. Mini-LED BLU Manufacturing Process

6.1 POB/COB Type LED

The Mini-LED BLU manufacturing process that integrates the LED on the PCB board is as follows. POB uses SMT technology to mount LEDs, and COB uses die bonding technology.



9. Cost Analysis of Mini-LED BLU for TV

9.1 Cost Calculation Basis and Method

- **Basis for cost calculation**

In this report, a 65-inch mini-LED BLU for TV was analyzed.
The panel manufacturing line was based on 8.5G.
The substrate was limited to three types: FR4, BT, and oxide TFT. Although a-Si TFT is a suitable technology for voltage-driven LCDs, it is not used for driving OLEDs or LEDs, which are current-driven devices. This is because current control is difficult. The a-Si TFT was excluded from the mini-LED drive.
The number of LEDs per local dimming zone is 6~12. TVs that require higher luminance have more LEDs per zone.
Since the LED size is different according to the number of local dimming zones and the price of TV is different, the local dimming zone and the number of LEDs are assumed for each substrate.
For AM driving, the local dimming zone is assumed to be over 10,000.

	Oxide TFT	BT	FR4
Driving	AM	PM	PM
Bonding	Chip bonding	Die bonding	SMT
Local dimming zone	10,000	3,000	1,000
LED/zone	12	9	6
LED number	120,000	27,000	6,000
Application	Premium TV	High-end TV	Middle-end TV