ViP™ Technology Empowered OLED Total Solutions

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Abstract

Visionox intelligent Pixelization (ViP™) technology stands out as a unique and novel RGB patterning technique that offers numerous performance advantages due to its FMM-free nature. Since its introduction in 2023, ViP™ has achieved significant breakthroughs in core technologies and is steadily moving toward mass production. This paper elaborates on recent advancements in ViP™ technology, with a focus on performance enhancement and process optimization.

Author Keywords

ViP; OLED; metal mask-less; FMM-free; photolithography patterning.

1. Introduction

In recent years, the rapid development of OLED technology has significantly driven innovation within the display industry. With its superior visual quality and outstanding device performance, OLED has garnered widespread market acceptance. In 2024, AMOLED accounted for over one-third of global smartwatch panel shipments and reached 51% of total smartphone panel shipments, establishing itself as a mainstream display technology[1]. Currently, Fine Metal Mask (FMM) evaporation is the dominant patterning method for OLEDs. However, due to its inherent process limitations, FMM-OLED faces challenges in fully unlocking the intrinsic advantages of OLEDs and is difficult to scale up for large-size display applications[2,3]. As market demand continues to expand, achieving a unified platform that supports diverse product categories, from wearables to large IT and TV displays, has become a key industry objective.

The ViP™ (Visionox intelligent Pixelization) technology, a mask-less photolithographic OLED patterning process, was developed to address these challenges. By employing photolithography to pattern R/G/B sub-pixels, this approach preserves the intrinsic characteristics of OLEDs while eliminating the limitations imposed by FMM, thereby maximizing the performance potential of the device. While our previous studies have outlined the general benefits of ViP™[4,5], this paper provides a more detailed discussion on recent technical advancements. Specifically, we focus on independent RGB device performance, EL power consumption, higher transmittance, and pixel arrangement optimization. Furthermore, we analyze the advantages of ViP™ technology for medium-to-large product applications.

2. Verification Platform

To assess the mass production readiness and overall performance of ViP™ technology, Visionox has developed multiple verification platforms across different application categories, including smartwatch, smartphone, tablet and laptop sizes. These samples were fabricated utilizing LTPO or LTPS as driving backplanes, and pixel patterning was achieved through the ViP™ process flow. All of these products were designed and fabricated at Visionox's Gen 6 facility in Hefei, China, using a dedicated evaporator tailored for ViP™ technology (mother glass size: 1850 × 1500 mm; half glass size: 925 × 1500 mm).

3. Results and Discussion

2.1 Performance improvement: ViP™ technology employs a 2D mesh-like isolation structure positioned between adjacent sub-pixels. This design effectively reduces power consumption while simultaneously enhancing image quality and visual performance. Furthermore, the unique photolithographic process utilized in ViP™ offers numerous advantages unattainable by FMM. These aspects will be elaborated upon in the following sections

2.1.1 OLED device: The core advantage of ViP™ lies in its ability to break the "common layer" constraint. In conventional FMM OLEDs, the hole-transport layers (HTLs), electron-blocking layers (EBLs), and other common functional layers must be identical across red, green, and blue pixels to ensure the minimum usage of expensive FMM (Figure 1). This one-size-fits-all approach often leads to suboptimal performance because the charge transport requirements and exciton recombination dynamics differ significantly between colors. By leveraging the precision of photolithography, ViP™ technology enables the fabrication of fully individualized RGB devices. This unprecedented design freedom opens a vast parameter space for maximizing intrinsic efficiency.

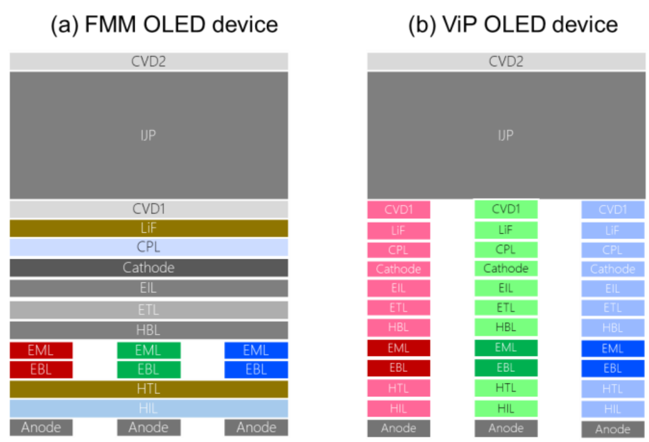

Figure 1. R/G/B OLED device structure in FMM and ViP™ OLED displays[6]

Recent experimental results demonstrate that this individualization directly translates into tangible performance gains. For example, by independently optimizing the hole-transport materials (HTMs) for devices, we have successfully suppressed exciton quenching mechanisms, achieving near-zero efficiency roll-off at high brightness levels. Furthermore, the ability to fine-tune the thickness of all layers for RGB color has yielded cumulative white efficiency improvements exceeding 7%. Beyond material selection optimization and optical optimization, the decoupling of microcavities allows for the integration of diverse emission mechanisms within a single display. While FMM-based mass production struggles to combine highly efficient green phosphor-assisted TADF sensitized fluorescence (pTSF) devices with red and blue TADF sensitized fluorescence (TSF) devices due to energy level mismatches, ViP™ technology facilitates this integration by allowing distinct energy level engineering for each sub-pixel (Figure 2). This capability paves the way for the implementation of even more advanced architectures such as tandem OLEDs, where the mechanisms and materials of first and second EMLs can be precisely adjusted to maximize device efficiencies. These findings underscore the transformative potential of ViP™ technology, positioning it as a critical enabler for the next generation of high-performance, energy-efficient OLED displays.

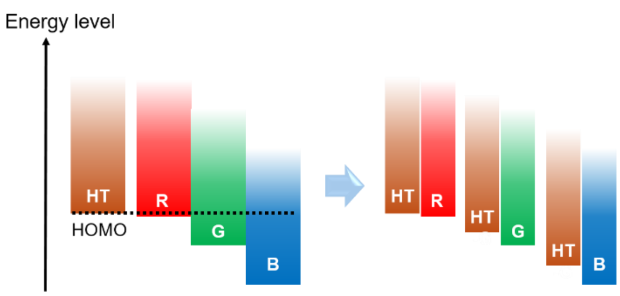

Figure 2. Illustration of individual energy level matching for RGB devices

2.1.2 Higher transmittance: The integration of under-display cameras and sensors represents a novel approach to mobile device design. In this architecture, high panel transmittance is critical for ensuring recognition precision, minimizing fingerprint response time, and optimizing overall under-display performance. Figure 3 illustrates the difference in layer stack-up between conventional FMM and ViP™ products. In FMM designs, the high-transmittance area still contains multiple light-blocking layers, such as the cathode. Conversely, ViP™ technology utilizes photolithography to remove all unnecessary layers in this region without incurring additional mask or process costs. Consequently, ViP™ achieves superior light transmission for under-display applications.

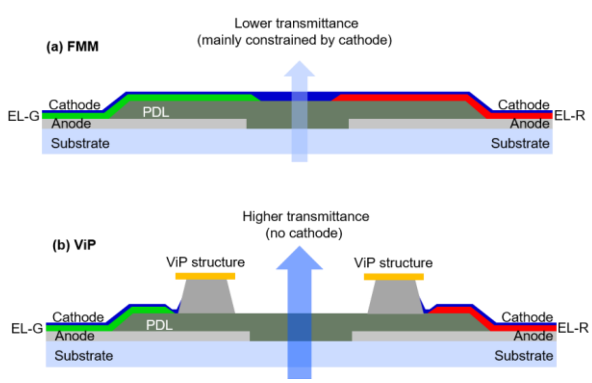

Figure 3. Layers stack-up of (a) FMM and (b) ViP™ in high-transmittance zone[6]

Table 1 presents transmittance measurements for FMM and ViP™ technologies derived from a mobile phone product. ViP™ demonstrates a transmittance improvement of at least 30% over FMM across both visible and infrared wavelengths. These experimental findings align with previous simulation results, confirming that the increased light throughput provided by ViP™ will significantly enhance under-display performance.

Building upon these findings, a high-transmittance ViP™ device was designed and fabricated at Visionox's Gen 6 facility in Hefei, China. Figure 4 shows the transmittance measurement data in the module form at different wavelengths. A transmittance of 23.5% was achieved at 940 nm, ensuring compatibility with more IR sensors. Furthermore, the device maintains a transmittance of approximately 9% even within the visible light spectrum (400–780 nm), confirming the ability to support more under display camera sensors.

Table 1. Transmittance measurement results in high transmittance area

Wavelength	Transmittance in high transmittance area		ViP™ improvement
	FMM	ViP™	
450 nm	6.02%	9.48%	57.48%
550 nm	17.96%	23.71%	30.01%
650 nm	19.80%	29.05%	46.72%
940 nm	22.58%	60.39%	167.44%

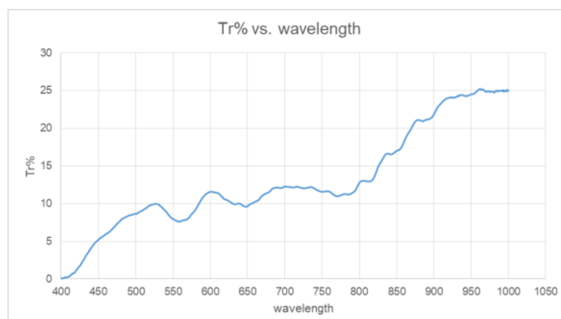

Figure 4. Transmittance measurement results in module form

2.1.3 EL power consumption: The unique VSS routing design of ViP™ technology also contributes to significant power savings within the panel. In conventional FMM products, the ELVSS signal is routed through a full-surface cathode layer across the display area. Due to the high sheet resistance of the cathode, a substantial voltage drop (IR-drop) occurs, leading to excessive energy dissipation, particularly in medium-to-large size products. In contrast, ViP™ utilizes a mesh-like metal structure for ELVSS routing. This design features significantly lower sheet resistance, maintaining a minimal IR-drop even in larger applications such as tablets and desktop monitors. Consequently, the power consumption associated with ViP™ is far lower than that of FMM products.

Furthermore, the cathode layer in FMM devices is formed via full-surface evaporation, which precludes mesh patterning; consequently, sub-pixels of different colors are compelled to share a common signal. In contrast, ViP™ enables individual ELVSS signal routing for each color channel through its flexible VSS layout design. By applying distinct ELVSS voltages to R, G, and B sub-pixels, ViP™ achieves reduced power consumption across various brightness levels and display scenarios, thereby further enhancing power efficiency. Although individual ELVDD design for different colors is technically feasible in FMM products, its potential for reducing power consumption is limited compared to ViP™, largely due to constraints on ELVDD voltage settings and their critical impact on display performance.

Figure 5 illustrates a comparison of power efficiency gains between conventional VDD/VSS designs and individual ELVDD/ELVSS architectures. As shown in Figure 5a, in a conventional design, sub-pixels of different colors share common ELVDD and ELVSS voltages. During normal operation, the required voltage difference ($\Delta V = V_{ELVDD} - V_{ELVSS}$) follows the order: B > G > R. When voltages are calibrated to meet the requirements of the B sub-pixel, the R and G sub-pixels are subjected to an excessive voltage difference, leading to unnecessary power consumption. This phenomenon persists across both high- and low-brightness scenarios.

To mitigate this issue in FMM products, the concept of individual ELVDD design was introduced, as depicted in Figure 5b. However, this approach has inherent limitations. Since display luminance is highly sensitive to ELVDD variations, dynamic voltage adjustment is unfeasible despite the individual architecture. For instance, if ELVDD is optimized for low-brightness conditions, the R and B sub-pixels require a more negative ELVSS to achieve high brightness. Consequently, similar to the conventional design, the excessive voltage difference across the B sub-pixel increases the overall panel power consumption.

As shown in Figure 5c, ViP™'s unique design and process capabilities enable a configuration compatible with both individual ELVDD and individual ELVSS, effectively eliminating the two types of power inefficiencies mentioned above. The individual ELVDD design reduces the ELVDD voltage for R and G sub-pixels while simultaneously lowering the gamma master voltage (VGMP). Concurrently, the individual ELVSS architecture allows for dynamic ELVSS adjustment, where ELVSS levels for different color pixels can be set separately without interference from adjacent pixels, thereby preventing additional power degradation. Using an 11.X-inch product at 200 nits as a case study, we simulated panel power consumption across the three designs. Accounting for factors such as IR-drop. The results indicate that while the FMM individual ELVDD design suffers a power degradation of 12.3%, the ViP™ solution achieves a further power efficiency gain of 12.4%, demonstrating the significant advantage of ViP™ in power saving.

2.2 Process Capability Optimization: In the ViP™ process planning, we developed an overall process solution that balances performance and stability through a well-designed experimental approach by progressively optimizing lithography parameters, layer stacking structures, and etching processes. This solution effectively ensures consistency in electrical conduction and successfully improves low grayscale image quality of ViP™-based products to be compatible with that of FMM-based products.

With the continuous advancement of lithography technology, the precision of the graphic process has been significantly enhanced, and the key dimension fluctuations have been effectively suppressed, promoting further uniformity in both the electrical and optical performance of the product.

Based on the improvements above, the optical and electrical characteristics of the subpixels meet the design specifications, achieving a higher pixel density. The ongoing optimization of the process has steadily improved the yield, while maintaining a low defect density in key processes. This has laid a solid foundation for large-scale mass production and provided ample technical reserves for the future iteration of high-resolution and low-power products.

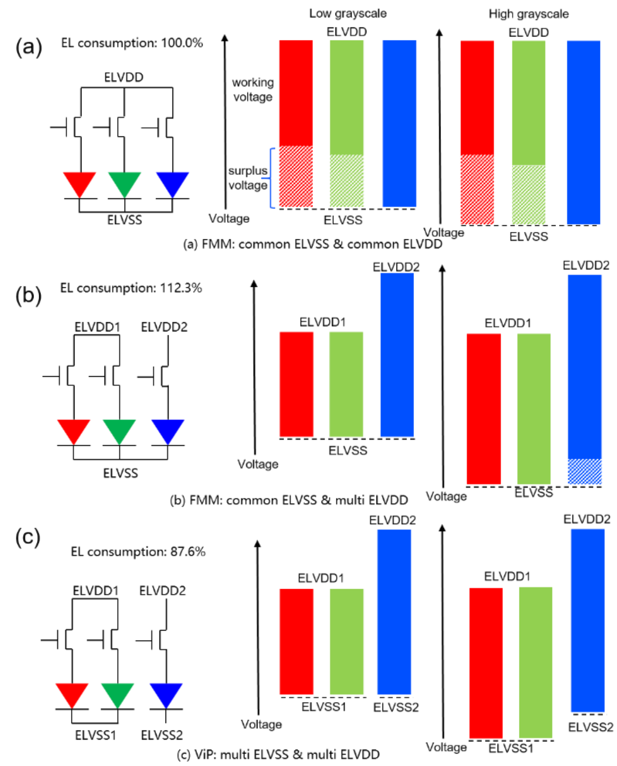

Figure 5. Comparison of power consumption in different designs

4. Summary and Outlook

ViP™ technology has achieved mass production readiness through validations across platforms ranging from wearables to notebooks. By overcoming FMM limitations, it significantly enhances OLED lifetime, power efficiency, transmittance, and reliability. Following the successful Gen6 foundation, the Gen8.6 production line was structurally topped in August 2025. ViP™ is now positioned to provide competitive solutions for all display sizes, particularly high-performance medium-to-large applications. By optimizing cost, lead times, and performance, ViP™ effectively addresses the evolving demands of the next-generation AMOLED market.

5. Acknowledgments

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