Fabrication of IZO/IGZO-Based Vertical Thin-Film Transistor and Its Integration with OLEDs for High-Density Display

Nahyun Kim[1], Seok Hee Hong[1], Jun Hyeok Lee[1], Ho Jin Lee[1], Tae Geun Kim[1*]

[1] *School of Electrical Engineering, Korea University, Seoul, Korea*

*Email: tgkim1@korea.ac.kr

The rising demand for next-generation applications, such as augmented reality (AR), virtual reality (VR), and wearable devices, has made ultra-high-resolution displays with pixel densities reaching thousands of pixels per inch (PPI) essential. Achieving such high resolutions requires innovative driving circuits and advanced structures for the driving units. Conventional planar thin-film transistors (TFTs) face significant challenges at nanoscale channel lengths, including short-channel effects and threshold voltage (Vth) instability, which reduce reliability and performance [1]. Therefore, planar TFTs are inadequate as drivers for high-resolution displays, positioning vertical channel TFTs (VTFTs) as a promising alternative [2]. Conventional VTFTs feature spacers between the top and bottom electrodes, with a channel layer formed along the spacer sidewalls. However, sidewall interface conditions can result in unstable channel characteristics and lower carrier mobility compared to planar TFTs [3],[4].

Herein, we propose a novel VTFT architecture utilizing a dual-layer metal oxide channel structure, as depicted in Figure 1(a). To further enhance integration, the top electrode of the VTFT is employed as the reflective electrode in OLED devices, enabling a VTFT-based top-emitting OLED integration. We address channel stability by implementing an HfO_X-based dual-layer oxide spacer, which generates a quasi-2D electron gas at the oxide interfaces with high electron density, as shown in Figure 1(b). This concentrated electron layer facilitates main channel formation at the interface, while optimizing the dual-layer thickness maximizes carrier mobility along the channel path. Additionally, pulsed Joule heating enables localized activation of the active layer without external thermal processing, allowing low-temperature processing by avoiding direct substrate heating. This supports flexible display applications compatible with various substrate materials. Experimental results indicate high performance with a mobility of 16.34 cm^2/Vs, Vth of 0.2 V, subthreshold swing of 0.4 V/dec, and an on/off ratio exceeding 10^5 (Figure 1(c)).

Finally, based on these results, we propose an integrated VTFT/OLED structure, realizing a high-integration display component. The integrated VTFT/OLED solution not only offers superior mobility and stability but also supports low-temperature processing for diverse substrates, contributing significantly to advancements in next-generation display technologies. This approach shows substantial potential for applications in AR/VR, wearable devices, and high-resolution monitors, advancing new possibilities in display technology.

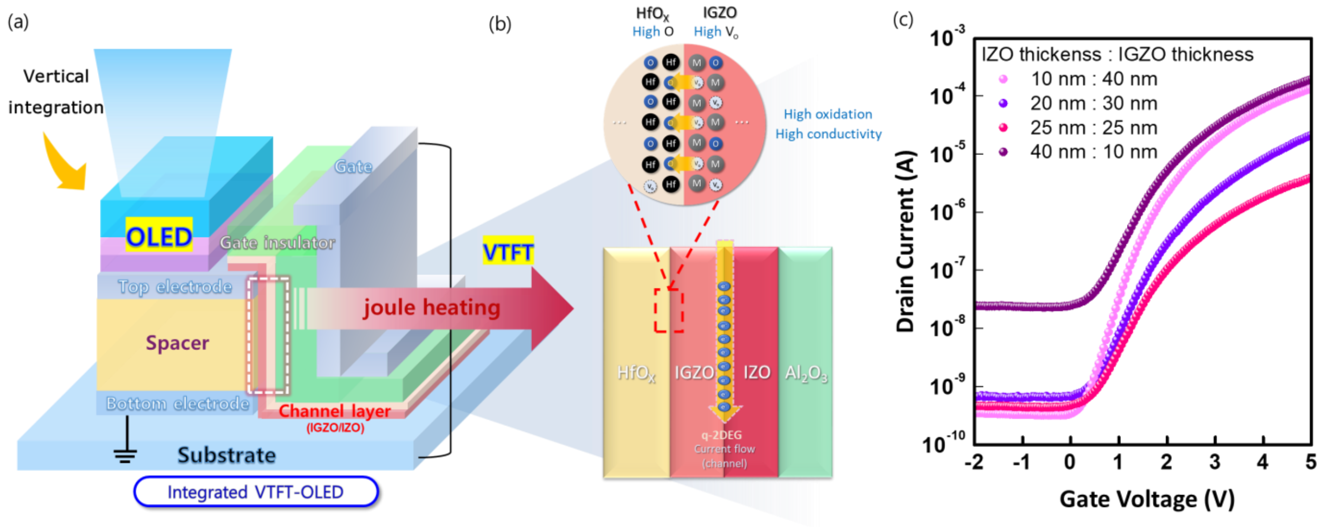

Figure 1 (a) Schematic of a vertical stacked integrated-OLED device with VTFT, (b) Schematic diagram of the formation of quasi-2D electron gas at the interface using HfO_X spacer and oxide double layer channels and the related mechanism, (c) Transfer curves with different IZO/IGZO thicknesses.

References

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