Oxide-TFT-Integrated OLED Fibers for High-Performance Self-Powered Textile Displays

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Abstract

This research presents oxide thin-film transistor (OxTFT)-integrated organic light-emitting diode (OLED) fiber interlaced with organic photovoltaic (OPV) non-luminescent fiber, forming highly reliable textile displays with a self-powering system. To form solid and reliable OLED fibers, they are fabricated on a planar substrate and subsequently transferred. This OLED textile exhibits high luminance and mechanical flexibility. Furthermore, it has a display system capable of self-power generation.

Author Keywords

Organic light-emitting diodes (OLED); oxide thin-film transistor (TFT); self-powered; transfer

1. Introduction

Electronic textiles (e-textiles), a fusion of textiles and electronics, have emerged as a promising future industry,[1] representing the ultimate goal of wearable devices. Beyond the simple function of clothing, e-textiles can perform complex electrical functions such as biomonitoring through interactions with the body and environment.[2,3] Initially, e-textiles were fabricated by simply attaching light-emitting devices to fabrics.[4,5] However, the technology has evolved to integrate and print/coat these devices directly onto the fabric. Recently, there has been significant interest in applying OLEDs to textiles. With excellent form factors and a high level of technological maturity, OLEDs offer stable luminescence characteristics, making them suitable for woven textile displays.[6-8] Moreover, as self-emitting devices, OLEDs do not require external light sources, facilitating their integration into textiles.[9] However, luminescent fibers present several challenges that hinder the development of highly reliable textile-based OLEDs. Notable challenges include improving low luminous efficiency, developing transparent and flexible electrodes, and implementing effective encapsulation techniques to protect OLED devices from oxygen and water.[10-12]

In this study, we propose a novel approach that significantly enhances the performance of conventional textile displays, thereby contributing to the advancement of wearable display technology (Figure 1). To address the limitations of existing textile displays, such as low luminance and difficulties in fine control, we have developed a method that involves transferring high-performance OLEDs fabricated on planar substrates onto fibers comprised of polyethylene terephthalate (PET) or polyurethane (PU). This approach ensures uniform film formation and stable OLED operation, enabling the realization of high-resolution displays. Furthermore, by integrating driving oxide thin-film transistors (OxTFTs) within the fibers, we can precisely control individual OLED pixels. This lays the foundation for developing active-matrix OLED textile displays. Moreover, we have demonstrated a self-powered textile display by integrating organic photovoltaic (OPV) fibers that generate electricity from light. The non-luminescent fibers, which are interconnected with the luminescent OLED fibers, supply power to the TFT gates, driving the OLED pixels.

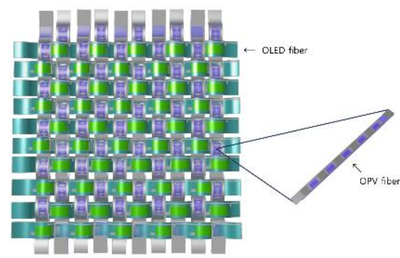

Figure 1. Schematic illustration of the proposed woven textile display consisting of OxTFT-integrated OLED fibers and OPV fibers.

2. Design and fabrication of Woven Textile Displays

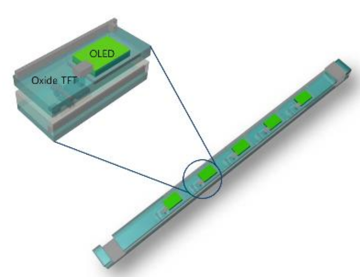

Figure 2. Structure of an OLED fiber incorporating OxTFTs.

Figure 2 presents a schematic diagram of the OxTFT-integrated OLED fiber proposed in this study. A gate contact pad was formed at the bottom to receive gate signals from a conductive fiber. OxTFTs and OLED pixels were arranged 1-dimensionally, where the drain of OxTFT was connected to the OLED cathode. To protect the OLED pixels from oxygen and water, a transparent

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thin-film encapsulation (TFE) consisting of 2-dyadic aluminum oxide (Al2O3)/parylene-C was formed on both the top and bottom. 20 nm-thick indium gallium zinc oxide (IGZO) served as an active channel material of OxTFT, demonstrating reasonably high levels of mobility and on/off ratio. High-efficiency top-emitting phosphorescent green OLEDs were employed, where their layer structure was optimized for cavity-enhanced light extraction. The fabricated array of OxTFT-connected OLEDs was successfully transferred onto a PET strip fiber (width = 3 mm) or a PU cylindrical fiber (diameter = 1 mm).

The OPV fiber served as both a power-generating element and a gate signal applier for the interlaced OLED fiber. The OPV structure was primarily composed of flexible electrodes, charge transport layers, and photoactive layers. The defined OPVs were covered with the TFE on both the top and bottom. Similar to OLED fibers, the devices fabricated on a planar substrate were transferred onto a fiber substrate.

3. Results and Discussion

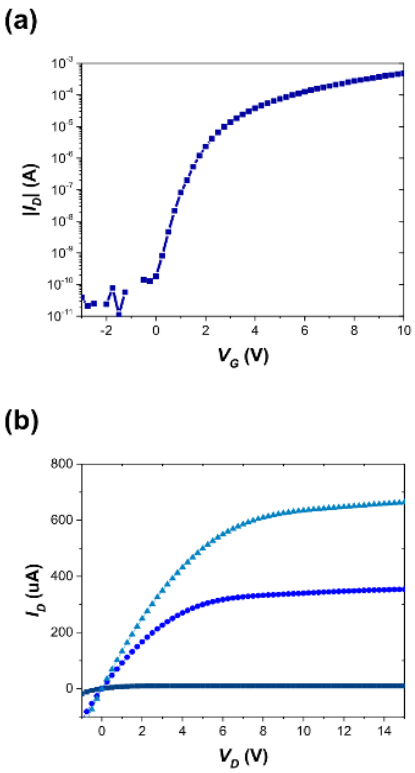

Figure 3. Representative (a) I_D-V_G curve and (b) I_D-V_D curves of OxTFTs

The characteristics of the experimental IGZO-based OxTFTs are presented in Figure 3. Due to the fabrication implementation on a planar substrate, the OxTFT exhibited fully working output characteristics, such as rapidly increased drain current with increasing gate voltage, and stable drain saturation current. The gate threshold voltage (V_{th}) was found to be 1.82 V, and a reasonably high mobility of ~20 cm²/Vs was obtained. High levels of on/off ratio (1.64×10^6) and subthreshold swing indicate excellent switching performance of the fabricated OxTFTs.

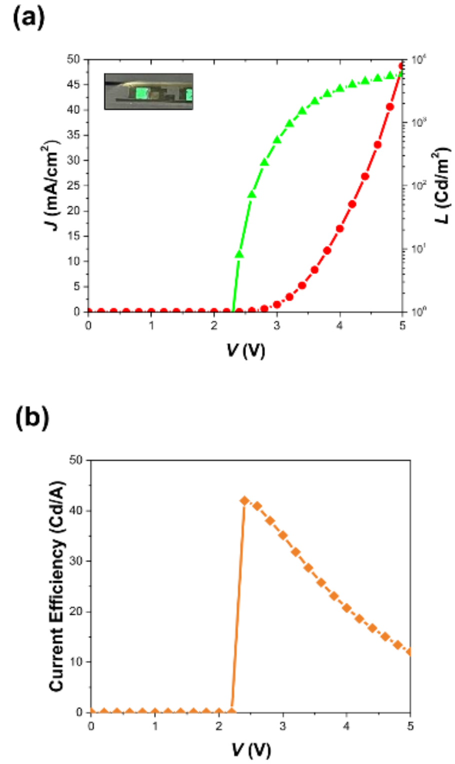

Figure 4. Representative (a) J-V-L curves and (b) current efficiency-V curves of OLEDs

Figures 4(a) and 4(b) show the current density (J) - voltage (V) - luminance (L) curves and the current efficiency curve of the OLED transferred onto a PET fiber, respectively. Owing to the employed fabrication process, the OLED fiber exhibited high electroluminescence (EL) performance comparable to those on a planar substrate. The representative EL parameters demonstrated low turn-on voltage (~2.4 V), high luminance (> 5800 cd/m² at 5 V), and high current efficiency (> 40 cd/A).

4. Conclusions

This study demonstrated a high-performance self-powered textile display using OxTFT-integrated OLED fibers and power-generating OPV fibers. The top-emission phosphorescent OLED fibers, which were capable of being interconnected, were arranged perpendicularly to the OPV fibers. The OLED pixels were integrated with highly uniform OxTFTs, enabling precise EL performance control. The ideas and results presented in this study significantly improve the performance and reliability of OLED textiles, providing a solid foundation for the development of future active-matrix textile displays.

5. Acknowledgements

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