

Electroluminescence Fiber Network for Motion-Sensing Textiles

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Abstract

Here, we present a type of AC electroluminescence (ACEL) fibers to create a strain sensor textile that can instantly visualize human motion. The proposed ACEL fibers are designed to operate at low voltage by using an elastomer with a high dielectric constant. A woven network of ACEL fibers exhibits brightness changes corresponding to levels of stretch or deformation, thereby functioning as a motion sensor.

Author Keywords

AC electroluminescence; luminescent fibers; strain sensor; wearable displays

1. Objective and Background

Recently, attention has been focused on the development of wearable devices and flexible electronic display devices capable of sensing human body information. These human motion monitoring electronic devices hold significant potential for personal health management, making it essential for users to visualize real-time signals during daily activities to make immediate and informed decisions.^[1,2] Existing flexible human activity monitoring devices primarily utilize methods based on piezoresistive, capacitance, triboelectric and piezoelectric technologies.^[3-6] These sensors operate by converting received electrical signals through a microprocessor, which then transmits the data to a physically connected display unit.^[7-9] However, this complex physical connection often fails to provide accurate real-time information about the human body efficiently and is not well-suited to handling various environmental factors.^[10] Therefore, there is a need to enhance the effectiveness and accuracy of monitoring by simplifying complex digital processing. It can reduce system complexity and minimize signal transmission delays to provide users with more intuitive and immediate feedback.

In this work, we offer a concept of wearable strain sensor textiles that visually indicate strain by employing AC electroluminescence (ACEL) fiber technology. By utilizing composites with high dielectric constants in the emissive medium, we address the drawbacks of existing ACEL displays, particularly the high driving voltage. Additionally, we implement a variety of display colors, including green, orange, and white. The proposed system is designed for feasibility through reasonable engineering and an easy solution-based fabrication process. This approach is expected to enhance the flexibility and comfort of sensor wear and contribute to advancements in the field of wearable strain sensors.

2. Results and Discussion

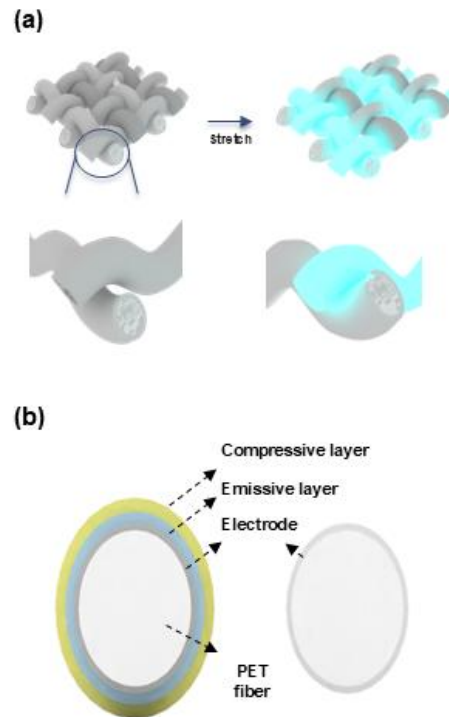


Figure 1. Schematic illustrations of (a) woven network of ACEL fibers and (b) cross-sectional fiber designs.

Figure 1 shows schematic illustrations of the proposed motion strain sensor textile. This strain textile consists of ACEL fibers interlaced with transparent conducting fibers. The ACEL fiber is designed with a stack of an emissive layer and a compressive layer. When the woven textile is stretched, the thickness of the compressive layer decreases due to the compression of the elastomer. As a result, the electric field strength between the two electrodes becomes stronger, an increase in the intensity of light.

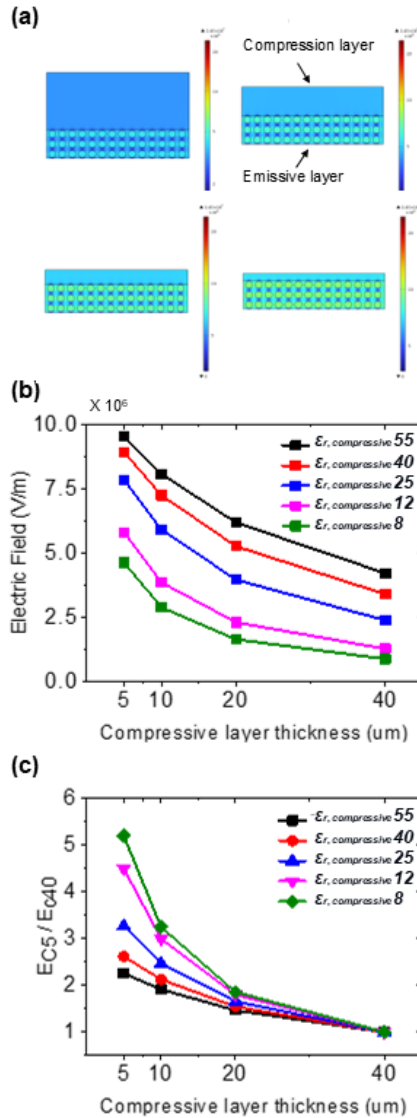


Figure 2. (a) Calculated electric field distribution according to compressive layer thickness changes. (b) Calculated electric field intensity at the phosphor position at various compressive layer thicknesses and dielectric constants. (c) Normalized electric field intensity by its initial value as a function of compressive layer thickness.

To calculate the electric field intensity concentrated on ZnS phosphor according to the dielectric constant difference between the emission layer and the compressive layer, a simulation was conducted using the COMSOL Multiphysics program. The matrix of the emission layer was calculated assuming PVDF-TrFE-CFE, high dielectric constant ($\epsilon_r = 55$) elastomer. In Figure 2(a), both the emissive and compressive layers were assumed to be a PVDF-TrFE-CFE material, because it exhibited a stronger electric field intensity near the phosphors. In Figure 2(b), it was observed that as the thickness of the compressive layer decreases, the electric field concentrated on the phosphor becomes stronger due to the electric property of layers connected in series, meaning that the electric field tends to concentrate in the layer with the lower capacitance value. Figure 2(c) shows the ratio of electric

field change at various compressive layer thicknesses relative to the initially thick layer case (i.e., uncompressed state, compressive layer thickness = 40 μm). This result demonstrates that if the dielectric constant of the compressive layer is reduced, the electric field change becomes significant. The difference in the dielectric constant of the compressive layer is proportional to the electric field change due to thickness variation, but inversely proportional to the amount of electric field in the phosphor

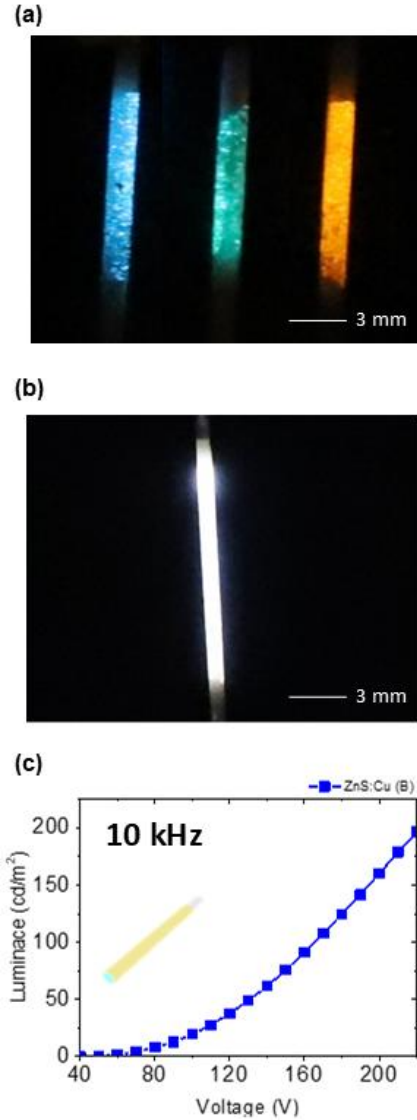


Figure 3. (a) Photographic images of the working blue, green and orange single ACEL fiber operating at 10 kHz. (b) Photographic images of the working white single ACEL fiber operating at 2 kHz. (c) Luminance performance of blue single ACEL fiber at 10 kHz.

Figure 3 shows the single fiber using both the compressive layer and the emissive layer based on PVDF-HFP ($\epsilon_r = 12$). It successfully implemented blue, green, and orange at a frequency of 10 kHz, and achieved white at (x, y) = (0.3207, 0.3204) in the CIE 1931 space at a frequency of 2 kHz. In Figure 3(c), the fabricated device exhibits a threshold voltage of 40 V and achieves a brightness of 197 cd/m^2 at 220 V.

3. Impact

We have demonstrated a sensor that can visualize human movement in real-time using an ACEL display. This addresses the drawback of existing systems, which struggle to provide accurate real-time body information due to complex physical connections, while offering the advantages of being lightweight and wearable. We have successfully implemented various colors, contributing to the advancement of future wearable displays.

4. Acknowledgements

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5. References

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