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A flexible large-area triboelectric generator by low-cost roll-to-roll process for location-based monitoring

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ABSTRACT

This paper discusses a flexible large-area power floor developed based on the effect of triboelectrification and electrostatic induction. Facilitated by a simple roll-to-roll fabrication method, this device can be fabricated at a very low cost of $2/m^2 with large-area micro patterns. As a normal adult walks across the floor, it can produce more than 480 V peak voltage and over 75 μA peak current. The obtained peak instantaneous power was about 4.6 mW. It also showed favorable charging ability, as demonstrated by charging a 1 μF capacitor to 1.6 V in one step, corresponding to a surface charge density of 53.3 μC/m^2. The spacer distance was systematically investigated and optimized by finite element simulation method. Therefore, this device can produce a pressure sensitivity of 7.1 V/KPa in the pressure range from 2.5 KPa to 30 KPa experimentally, which is about 4.67 times higher than similar devices using the same mechanism. A novel triboelectric generator (TEG) array was proposed based on this large-area TEG (LTEG) for position monitoring. Integrated with the function of power generation and position monitoring, the proposed device is directly applicable to LED-based alarm signals. Generated electricity can be stored in capacitor for use by low-power electronics. Employing a simple signal-processing circuit, the generated signal can also be used to control certain house-hold appliances. In effect, the proposed LTEG has considerable potential for application in harvesting walking energy as well as monitoring human motions.

1. Introduction

Energy crises are a well-accepted and increasingly serious worldwide problem, and researchers are responding by making concerted effort to establish new methods of harvesting energy. Rapid advancements in energy harvesting technology have created alternatives to traditional batteries, for example, to supply power for micro-scale devices [1,2]. Among all types of energy alternatives that exist naturally in our environment, mechanical energy has attracted particular research attention [3,4]. In the last ten years, many attempts have been made to convert mechanical energy from our environment to usable energy for wireless sensor nodes and wearable electronics [5–7]. The most commonly adopted mechanisms are electromagnetic induction [8], electrostatic induction [9–11] and piezoelectric effect [12], while different mechanisms show particular advantages to specific applications.

TEG, as one type of electrostatic energy harvester, has undergone rather extensive research in recent years [13–17]. It has garnered much interest due to its high power density and power conversion efficiency [14,17] as well as its potential applications in wireless systems [18,19], portable electronics [20,21], active sensors [22–24] and biomedical systems [25]. By far, these devices' output performance is mainly enhanced by nano, micro, or micro-nano dual-sized structures [20,25–27]. In many cases, such as power floor, an LTEG is preferred. Unfortunately, these structures are too challenging to fabricate and too expensive for large-area applications. Furthermore, work remains to be done to effectively fabricate TEG arrays suited to large areas with sufficient sensitivity to accurately detect motion.

This paper presents an LTEG-based power floor that converts human energy (i.e., walking) into electricity. We employed a roll-to-roll method to fabricate main structure from commercially available, low-cost material. High-output performance was obtained under one's normally walking on it. Output performance at varying spacer distances and pressures were systematically analyzed after a series of experiments; we found that by optimizing the spacer distance, a high sensitivity between voltage and pressure

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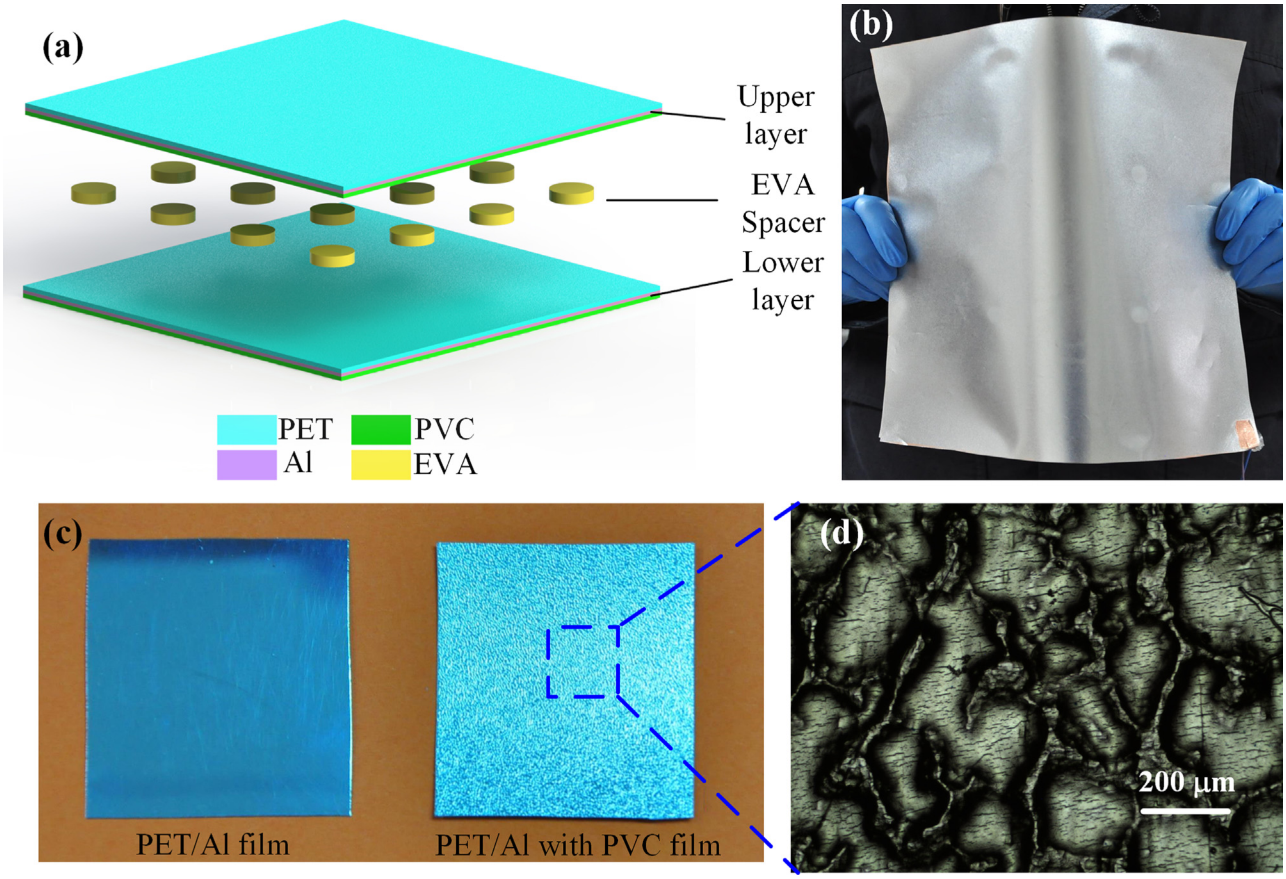

Fig. 1. Schematic diagram of the LTEG. (a) Explosive 3D view of this device. (b) Photograph of the LTEG to exhibit its flexibility. (c) Comparison of photographs of the PET/Al film with PET/Al/PVC film. (d) Microphotograph of the surface structure of PVC film.

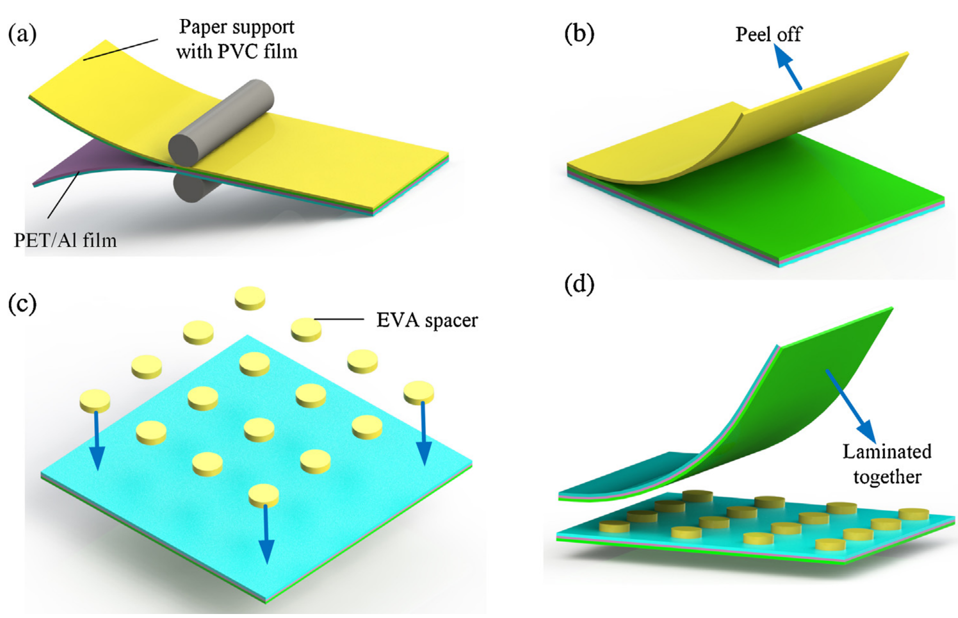

Fig. 2. Fabrication process of the LTEG. (a) Roll-to-roll laminating PET/Al film with PVC film together. (b) Peeling off the protecting layer of PVC. (c) Placing the EVA spacers array. (d) Laminating two layers together.

was obtainable. The device also showed high charging ability and capability to drive commercial LEDs, suggesting that it can serve as a smart floor for detecting motion and target locations to produce alarm signals.

2. Design of the device

Fig. 1a shows the explosive 3D diagram of the proposed LTEG. Both the upper and the lower part consist of a 100 μm polyethylene terephthalate (PET) film, a 100 nm aluminum (Al) layer on the