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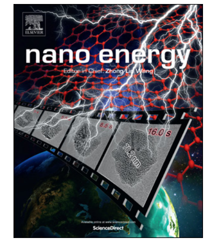

RAPID COMMUNICATION

Self-powered velocity and trajectory tracking sensor array made of planar triboelectric nanogenerator pixels

Chang Bao Han[a], Chi Zhang[a], Xiao Hui Li[a], Limin Zhang[a], Tao Zhou[a], Weiguo Hu[a], Zhong Lin Wang[a,b,*]

[a]*Beijing Institute of Nanoenergy and Nanosystems, Chinese Academy of Sciences, Beijing 100083, China*
[b]*School of Material Science and Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0245, USA*

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KEYWORDS
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Resolution

Abstract
We report self-powered velocity and trajectory tracking sensor (VTTS) array for detecting object motion, velocity, acceleration and trajectory based on single-electrode triboelectric nanogenerator. The VTTS was fabricated by a cost-effective and simple-designed grid, which obtained the electric signals by the charge transition between the electrodes and the ground according to the electrostatic induction of objects. A self-powered VTTS arrays (9×9 pixels) with low-node mode was prepared and realized the real-time tracking of position, velocity, acceleration and trajectory for a moving object by visual observation. Using the simply electrode weave technique, a high-resolution VTTS with 41×41 pixels on an active size of $1 \times 1\ cm^2$ was obtained and it only needs the $41+41=82$ output ports. The device can detect a tiny displacement and trajectory for the high resolution of 250 μm. This work may provide a innovate design for preparing VTTS with ultrahigh pixels and low-cost.

Introduction

A fast development of mobile electronics desperately needs the development of miniaturized power sources [1-3]. Even with a high-density energy storage unit, they will be drained out as a matter of time. Given this, the “self-powered” technology presents a possible approach for sustainable

*Corresponding author at: Beijing Institute of Nanoenergy and Nanosystems, Chinese Academy of Sciences, Beijing 100083, China.
E-mail address: zlwang@gatech.edu (Z. Lin Wang).

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operation of mobile electronics [4-6]. The device with self-powered system provides an independent, sustainable, maintenance-free operation and has a promising application in wireless sensor network [7,8], such as enzyme-based biosensors [9], condition monitoring system [10], or robot system [11]. Displacement tracking sensor is frequently used in today's smart phone and human tracking systems. However, a general design for this type of sensors is based on capacitive [12], optical [13,14], or magnetic [15], effects; a common characteristic of all these sensors is that they do need an external power source.

Recently, nanogenerators (NGs) [16-19] relying on the piezoelectric and triboelectric effects have been developed that convert mechanical energy in our living environment into electricity for powering gas sensor [20], liquid sensor [21], temperature sensor [22], skin sensor [23], speed sensor [24], and so on. The triboelecric nanogenerators (TENGs) offer not only a practical solution for self-powered devices [25,26], but also active sensors. For example, the detection of object motion inside of an one-dimensional (1-D) tube and in limited directions of a plane had been successfully realized based on single-electrode TENG [27,28]. A TENG array ($7 \times 7\ cm^2$) with the 8×7 pixels showed a real-time tracking of the movement location [29].

In this work, a 2-D velocity and trajectory tracking sensor (VTTS) was fabricated by an ingenious electrode design based on an array of single-electrode TENGs [28,30]. The constructed active matrix of VTTS, combined with light-emitting diodes (LEDs), can achieve a self-powered, real-time position and trajectory tracking in 2-D plane. A device ($1 \times 1\ cm^2$) with pixels of 41×41 pixels was prepared and demonstrated exhibited high sensitivity. This work may provide a novel design for preparing self-powered VTTS with ultrahigh resolution.

Design and analysis

Theoretical analysis and working mechanism

When an object moves on a 2-D plane, it can be regarded as a plane rectangular coordinate system and whatever it locates in, as characterized by corresponding coordinates, (x, y). Conversely, provided that we had detected the coordinates of the object in real time, its velocity and trajectory was able to be obtained by X–Y data at the corresponding time. By further simplification, firstly the calculation of position and speed in 1-D direction were analyzed by the current signals at different x coordinates. Based on the single-electrode TENG, the working principle of the 1-D VTTS for location tracking is shown in Figure 1. The metal (Al) strips were fixed in parallel and each of the strips serves as an electrode of the single-electrode TENG and was connected to the output port. The width of PTFE (object), metal electrode and the spacing between the two electrodes are w, l and d, respectively. Each of the electrodes corresponds to the fixed location x_1, x_2, x_3, ... In the original position, the negative charges will be distributed on the surface of PTFE as a result of triboelectrification after a contact with Al. When the PTFE slides outward and approaches the electrode, the positive charges will flow from ground to the electrode and produced a negative current pulse (Figure 1(a)). Subsequently, it slides away from another edge of the electrode and a positive current peak will be generated. Therefore, the current signals indicate the location (x), from which we can know when and where the object moves to in 1-D direction, this is because that the object is electrostatically charged due to triboelectrification. Figure 1(b) displays the measured current change at different time when PTFE moves through different location (here, $w=l=10$ mm, $d=20$ mm).

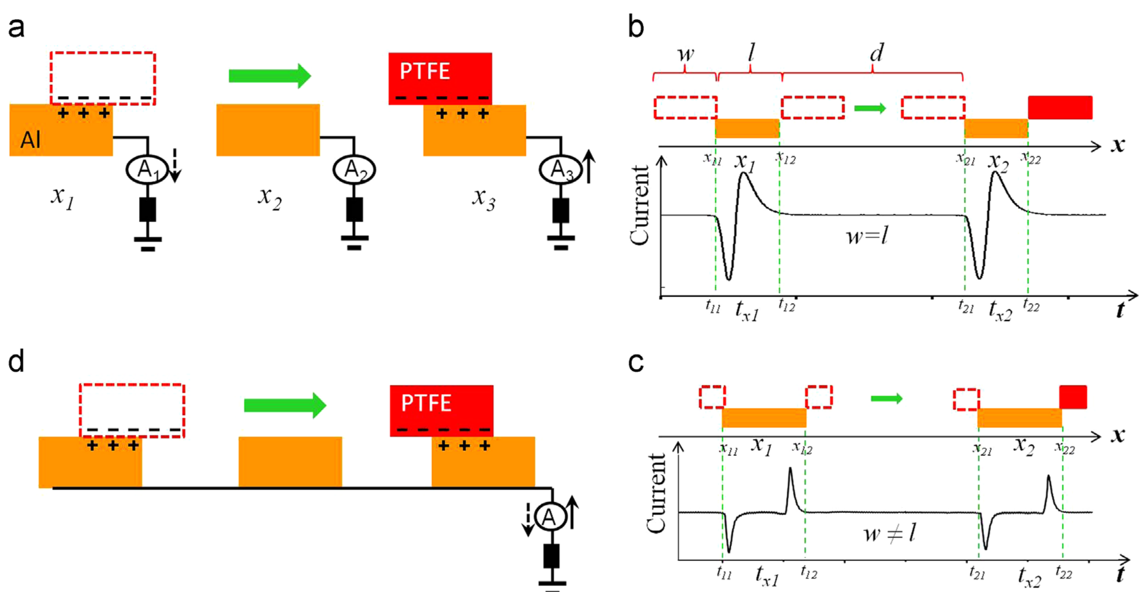

Figure 1 (a) and (d) are schematic diagrams of electricity-generation process in the 1-D direction for different types of electrode arrangements: individually grounded, and commonly grounded. (b) and (c) are the relationship among the movement, time and measured current signal of the sliders with different sizes in comparison to the width of the electrode, and the expected output signal shape.