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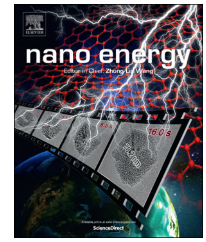

REVIEW

Single-electrode-based rotationary triboelectric nanogenerator and its applications as self-powered contact area and eccentric angle sensors

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Abstract
We introduce a single-electrode-based rotationary triboelectric nanogenerator (SR-TENG) formed by two wheels and a belt for harvesting mechanical energy. The fundamental working principle is studied by conjunction of experimental results with finite element calculation. The continuous discharging (CD) mode and the instantaneous discharging (ID) mode have been demonstrated for the SR-TENG. The systematical experiments indicate that the short-circuit current increases with the rotating speed for SR-TENG with CD mode, but the open-circuit voltage maintains constant. The short-circuit current and open-circuit voltage decrease nearly linearly with the friction contact area, which provides an application as a self-powered surface area sensor of transmission wheel and gear. For SR-TENG with ID mode, the electric outputs are greatly enhances. The current peak is about 20 μA at variation rotating speeds even if the external load is 10 MΩ, which is 33 times higher than that of the SR-TENG with CD mode without external load. The SR-TENG with ID mode has also been demonstrated as a self-powered misalignment sensor.

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Contents

Introduction

Over the past half century, the development of electronic devices is toward miniaturization, lightweight, and portable. In addition, the worldwide energy consumption is growing rapidly. Therefore, new technologies that can harvest energy from the environment as sustainable and low-cost power source are highly desirable [1,2]. There are various forms of mechanical energy existed in our living environment, such as rotation, vibration, walking and so on. Many ways to harvest mechanical energy has been developed that are based on electromagnetics [3,4], piezoelectrics [5-9], and electrostatics [10,11] effects, which have been extensively developed for decades. Recently, triboelectric nanogenerator (TENG) [12-21] has been developed based on the universally known triboelectric effect as a cost-effective and robust energy technology, which can efficiently convert mechanical energy into electricity for self-powered applications without reliance on traditional power supplies. Various applications have been demonstrated, such as micro-patterning [22], powering portable electronics [23-25] and self-powered sensors [26,27]. In all kinds of TENGs, the rotating TENG can harvest rotational energy through a periodic in-plane sliding displacement between two friction surfaces [18,21,28]. While, these rotating TENG also has limitations for application, for example, it is needed to be fixed on a rotating machine. In practical applications, some rotating machines consist of two rotating wheels and belt, such as transfer machine and engine. By combining the inherent structure of these rotating machines and the working mechanism of rotating TENG, novel TENG and self-powered sensors can be developed.

In this paper, we developed a single-electrode-based rotating (SR)-TENG which contains two rotatable wheels and a polytetrafluoroethene (PTFE) belt. Two working modes, the continuous discharged (CD) mode and the instantaneous discharged (ID) mode have been demonstrated for the SR-TENG. For SR-TENG with CD mode, the short-circuit current and open-circuit voltage decrease nearly linearly with the friction contact area, which provides an application as a self-powered surface area sensor of transmission wheel and gear. For SR-TENG with ID mode, the instantaneous electric outputs are greatly enhances. The SR-TENG with ID mode has also been demonstrated as a self-powered misalignment sensor. This study extends the potential application of SR-TENG as multi-functional self-powered sensors.

Experimental section

Fabrication of the nanostructured PTFE film

First, microstructures were fabricated by blasting an Al foil with sand particles using compressed air. The sand-blasted Al foil was further anodizing in a 0.3 Moxalic acid solution to obtain an anodic Al oxide (AAO) template with nanometer-sized holes, and the average diameter of the holes in the AAO template is about 42 nm. Then the PTFE solution was poured into the AAO template and a conventional vacuum process was applied to remove the air remaining in the nanoholes. After the curing at ambient temperature for one day, the solvent was evaporated and leaved a PTFE thin film with nanostructures. Finally, the PTFE thin film was peeled off from the AAO template using a double-sided tape.

Fabrication of the TENG

First, Four 1″-thick PMMA sheets were processed by laser cutting (PLS6.75, Universal Laser Systems) to form the two wheels. One wheel was connected to the rotational motor. On one wheel surface, a layer of PDMS is coated, and the elastic property of PDMS enables a complete contact of two tribo-surfaces. On the top of PDMS layer, half of the wheel is covered by Al film and half overlay is PTFE film. The wheel with PDMS is rotatable wheel and a PTFE belt. The PTFE belt acts as a triboelectric polymer, while the Al film plays dual roles as a triboelectric layer and an electrode.

Electric output measurement of TENG

In the electric output measurement of the TENG, the current meter (SR570 low noise current amplifier, Stanford Research System) and voltage meter (6514 system electrometer, Keithley) were used to measure the electric outputs of the TENG.

Results and discussion

The main structure of the SR-TENG is composed of two rotatable wheels (with a same radius of 5 cm) and a PTFE belt (with a width of 5 cm), which schematically illustrated