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Performance Study of Triboelectric Nanogenerator with Laser-Induced Graphene Electrodes

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ABSTRACT

As wearable electronics increasingly demand a continuous power supply, conventional batteries—requiring frequent recharging or replacement—pose both user inconvenience and environmental risks. This study develops a wristwatch - shaped triboelectric nanogenerator that employs solid - state semiconductor laser - induced graphene electrodes patterned directly onto a polyimide (PI) film and utilizes an independent sliding interface to harvest 1 to 3 Hz low-frequency human motion energy. By systematically optimizing laser power 1.25–1.75 W, we precisely control the LIG's microstructure and sheet resistance 52 to 141 Ω/ square. Morphological and structural analyses are performed via scanning electron microscopy (SEM). Electrical characterization uses a four-point probe to map resistance distribution, and a linear actuator applies reciprocal sliding under approximately 110 hPa contact pressure. Under optimized conditions with a laser power of 1.75 W and a scanning speed of 60 mm/s, the device delivers an open-circuit peak-to-peak voltage of 18.3 V, which is significantly higher than that obtained with other parameter sets. To enhance mechanical stability and environmental protection, the nanogenerator is encapsulated in a polydimethylsiloxane (PDMS) film.

Keywords: Laser-Induced Graphene, Triboelectric Nanogenerator, Wearable Energy Harvesting, Low-Frequency Vibration, Self-Powered System

INTRODUCTION

Wearable electronics are limited by battery dependence. This work presents a wristwatch-style triboelectric nanogenerator with laser-induced graphene electrodes and a sliding interface to harvest human motion energy efficiently.

MATERIALS AND METHODS

The wristwatch-shaped device integrates a 40 mm stator with the electron acceptor layer, while nylon-coated rotor blades and a pendulum convert vibrations into rotational motion for energy harvesting.

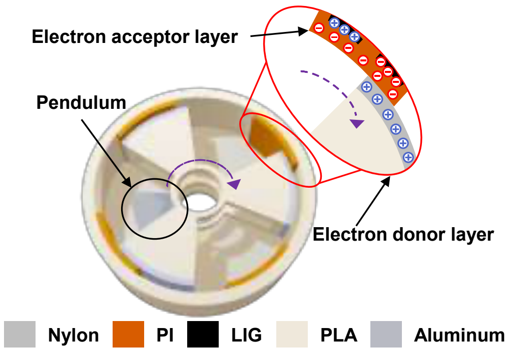

Fig. 1 Schematic diagram of wristwatch-shaped TENG using LIG as electrodes.

The donor layer was formed by laser-induced graphene on PI and coated with PDMS for protection, as illustrated in Figure 2. Two 10 × 10 mm² square pattern was generated at 60 mm/s with horizontal scans followed by vertical scans, shown in Figure 3.

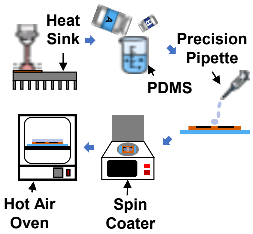

Fig. 2 Fabrication of WS-TENG.

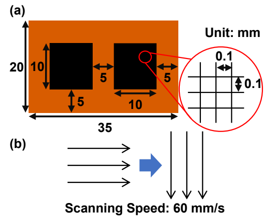

Fig. 3 (a) Laser scanning patterns (b) Laser scanning path.

The WS-TENG principle is illustrated in Figure 4, where sliding nylon on PI transfers charges between LIG electrodes. The experimental setup in Figure 5 uses a linear motor to drive the nylon film, with an oscilloscope recording signals under approximately 1.162 N/cm² apply pressure .

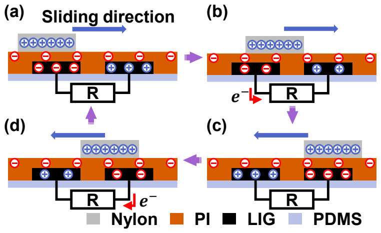

Fig. 4 Principle of the WS-TENG.

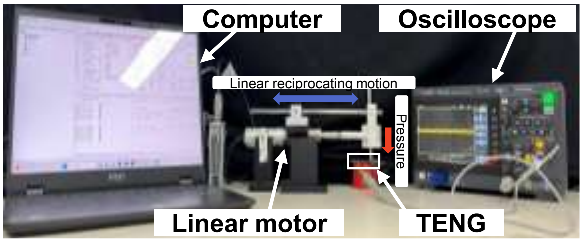

Fig. 5 Measurement setup.

RESULTS & DISCUSSION

According to Table 1, higher laser power results in lower sheet resistance and a concomitant reduction in its standard deviation.

Table 1 Sheet resistance values of the LIG electrode ablated at different laser powers.

Laser power(W)	1.25	1.5	1.75
Sheet resistance(Ω/square)	141±27	106±12	66±8

The electrical output at a scanning speed of 60 mm/s under different laser powers, as presented in Figure 6, shows that the voltage reaches 18.3 V at 1.75 W, 5 V at 1.5 W, and 3.9 V at 1.25 W, indicating that higher laser power generates larger electrical output.

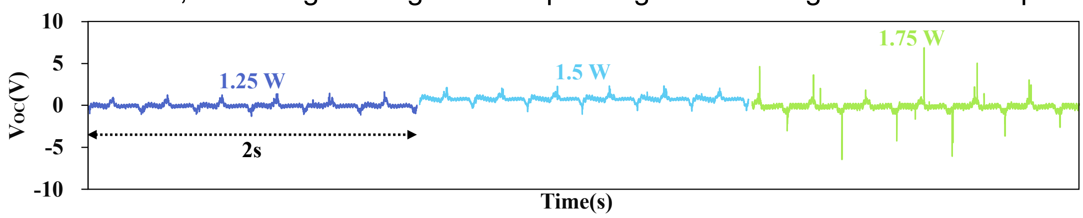

Fig. 6 Output voltages for different LIG electrodes fabricated by different laser powers

CONCLUSIONS

At the same pattern and speed, higher laser power lowers sheet resistance and variation, suggesting improved LIG uniformity due to increased porosity and contact area.

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