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Fabrication and Characterization of a Flexible Nanogenerator Using Reverse Electrowetting Concept

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ABSTRACT: Many researchers are interested in powering sensors and electrical circuits in wireless networks through energy harvesting from environmental waste energies. In this study, a flexible nanogenerator is designed and fabricated based on the reverse electrowetting concept. The performance of the nanogenerator has been investigated in different conditions including various bias voltage, different excitation frequency, and several external loads. The nanogenerator comprises of water droplets, as a strong dipole fluid, and two dielectric layers; polymethylsiloxane polymer. The latter has good hydrophobicity and flexibility. These two dielectric layers are formed on the surface of copper electrodes by using a spin coater. It is shown that increasing the excitation frequency augments the generated power to some extent that the capacitor is not fully discharged. The nanogenerator power output increases with the external load up to equality between the external load and the nanogenerator's internal resistance. The results show that the fabricated nanogenerator can generate a power density equal to 1.08 W/m2 using 1 yl water droplet, 7V bias voltage, and an excitation frequency of 1 Hz.

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1. Introduction

Direct conversion of wasted mechanical energy into electrical energy has been interesting either from the environmental viewpoint or in terms of various applications such as self-powering sensors and electrical circuits in wireless networks. Among the devices for such a direct conversion, a power generator based on the reverse electrowetting concept has been recently presented and studied by researchers [1-2].

Hsu et al. [3] presented a new method for mechanical energy harvesting using a combination of reverse electrowetting methods with the fast self-oscillating process of bubble growth and collapse. They obtained 10W as power output with power cell arrays. Yang et al. [4] show that using the atomic layer deposition method for preparing Al2O3 thin film of a reverse electrowetting-on-dielectric energy harvester (REMOD), significantly augments the performance of the device. Yang et al. [5] showed that minimizing the current leakage can maximize power output. They used TiO_2 (a high-k dielectric material) with Al_2O_3 (as a leakage barrier layer) as a lamination. They demonstrated that using the laminated structure decreases the current leakage and augments the capacitance compare to the monolayer of TiO_2 or Al_2O_3. They demonstrated that an enhanced power density of 15.36 mW cm^2 at a low bias voltage using laminated REWOD energy harvesting device.

In this work, a flexible nanogenerator is designed and fabricated based on the reverse electrowetting concept. The nanogenerator includes water droplets, as a strong dipole fluid, and two flexible dielectric layers; Polymethylsiloxane (PDMS) polymer.

2. Fabrication of REWOD

To fabricate the REWOD nanogenerator, polymethylsiloxane polymer is used as a dielectric layer and a water droplet is selected as a conductive liquid. PDMS is flexible and also is a hydrophobic polymer. These two characteristics of the PDMS polymer are very important in the nanogenerator performance. The physical properties of the materials are shown in Table 1.

A thin layer of PDMS is coated on a copper substrate using a spin coater as a top layer. It is heated for two hours in the oven at 80 oC. Then four spherical cavities were formed on a polymeric frame as the bottom part (see Fig. 1). A water droplet was added to each cavity and then was covered with the top layer. Then the device was put in the oven at 80 oC for four hours. The schematic of the experimental setup is shown in Fig. 2. It includes a digital multimeter (GDM-8261A, GW INSTEK), a power supply (MP-3003D, GW INSTEK), and external resistance. The external forces are created using a homemade mechanism for generating

3. Results and Discussion

The effects of different bias voltages (5,7, and 9V), external loads (1 and 51 kΩ), and frequency of exerted forces (4, 6.5 and 9 Hz) on the nanogenerator performance

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Table 1. Physical properties

Properties	Material	
	Water	PDMS
Dielectric constant	80	2.2–2.8
Density (kg/m^3)	998	0.97
Tensile strength (MPa)	–	2.23
Electrical conductivity (μS/cm)	0.055	–

Fig. 1. Image of the bottom part with water droplet in the cavities

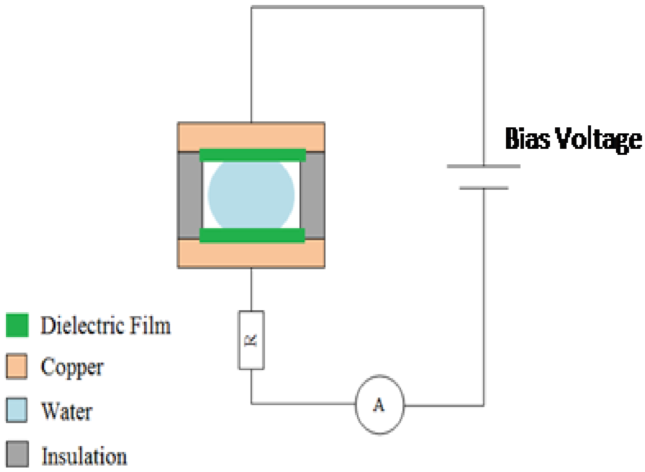

Fig. 2. Schematic of the experimental setup

are presented and discussed. For instance, the effect of the frequency of exerted forces and external loads on the output power are presented in Figs. 3 and 4.

As seen in Fig. 3 for a given configuration (27 μl droplet volume, and 22 kΩ external load) there is an optimum frequency for which the power output is maximized. Polarized droplet deforms with the external mechanical forces and thus the interfacial area with the layer is changed. The latter changes the device's capacitance. Increasing the exerted frequency increases the power output up to 6.5Hz. Further increase in frequency the capacitance discharge current does not match with the droplet polarization time and consequently, the power output decreases. Fig. 4 shows the variation of the power output with the external load. For a given bias voltage, increasing the external load augments the power output. However, this augmentation on the power output with external load is limited with the internal resistance of the nanogenerator; equality between the internal resistance and external load.

4. Conclusions

A flexible nanogenerator based on the reverse electrowetting phenomena is designed and fabricated. It is shown that for a given configuration there is an optimum frequency for which the power output is maximized. Increasing the frequency of exerted forces augments the power output until the capacitor is not fully discharged. The nanogenerator power output augments with the external load. It is limited by the internal resistance of the nanogenerator. A power density equal to 1.08 W/m2 using one μl water droplet, 7V bias voltage, and an excitation frequency of one Hz is generated with the REWOD nanogenerator.

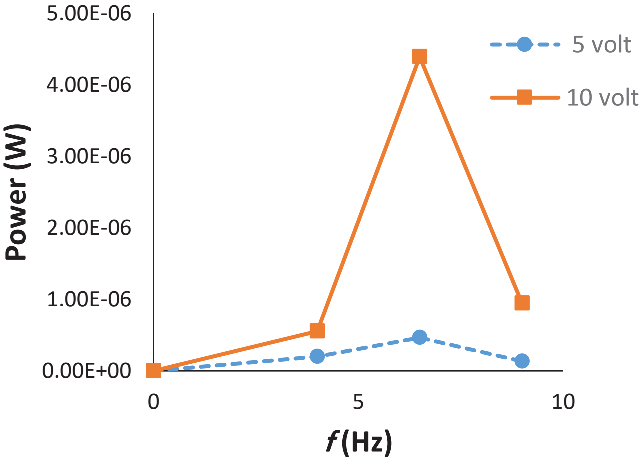

Fig. 3. The effects of frequency of exerted force on the power output for different bias voltages (27µl droplet volume, and 22k Ω external resistance)

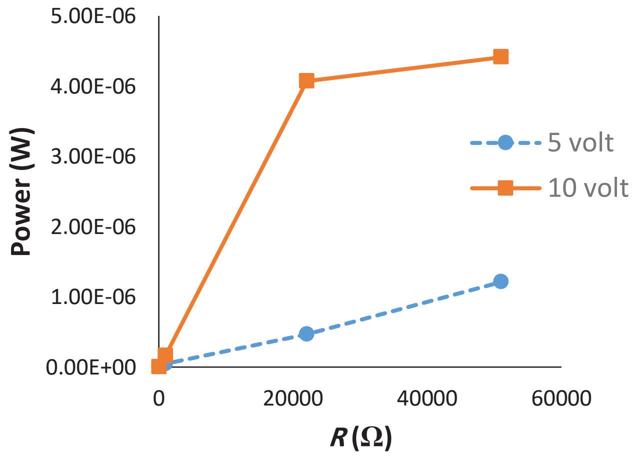

Fig. 4. The effects of external resistance on the power output (27µl, 6.5Hz)

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