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آشکارساز نور فرابنفش خودبایاس برپایه نانوژنراتور تریبوالکتریک

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چکیده – در این مقاله یک آشکارساز نوری خود بایاس بر پایه نانوژنراتور تریبوالکتریک معرفی گردیده است. با بهره گیری از نانوذره های نقره و گرافن اکساید کاهش یافته ، مقاومتی موازی و حساس به نور فرابنفش در ساختار نانوژنراتور تعریف شده است. حضور این مقاومت زمان دشارژ خازن تریبوالکتریک را کاهش می دهد . همچنین در حضور نور فرابنفش زمان دشارژ به میزان بیشتری کاهش می باید. همچنین مقدار ولتاژ خروجی نانوژنراتور از ۱/۲ ولت بدون اتصال موازی، به ۰/۹ ولت در حالت موازی، و سپس در حضور نور فرابنفش به ۰/۶ ولت کاهش می یابد. بدین ترتیب خروجی نانوژنراتور با نور فرابنفش تاثیر می بیند.

کلید واژه- آشکارساز نور فرابنفش، گرافن اکساید کاهش یافته، نانوژنراتور تریبوالکتریک، نانوذرات نقره.

Self-powered UV-Photodetector Based on Triboelectric Nanogenerator

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Abstract- A self-powered photodetector based on triboelectric nanogenerator (TENG) is demonstrated in this work. Two surfaces of the main TENG are polydimethylsiloxane (PDMS) and steel. Surface of PDMS was coated with silver nanoparticles and then further covered with reduced graphene oxide (rGO). By utilizing the photosensitivity of rGO and silver nanoparticles, a shunt variable resistance controlled with the UV light illumination was introduced to the structure. This shunt resistance reduces the triboelectric capacitance's discharge time and the output voltage. It also makes a path for charges in reverse direction which provides opposite polarity output voltage peaks that are related to pressing part of the TENG's mechanism. Peak to peak output voltage of the TENG was 1.2 V without the connection that imports the shunt resistance. After the connection, output voltage decreases to 0.9 V and under UV illumination it further decreases to 0.6 V. Thus output voltage of TENG is affected by UV exposure.

Keywords: Reduced graphene oxide, Silver Nanoparticles, Triboelectric Nanogenerator, UV-photodetector.

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Self-powered Photodetector Based on triboelectric Nanogenerator

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1 Introduction

Developing technologies of self-powered sensors that can utilize the ambient environmental energy to drive the operation themselves is highly desirable and mandatory. In recent years, triboelectric nanogenerators have attracted much attention because of their great potential in self-powered nanosensors and nanosystems. Since the first invention of triboelectric nanogenerator (TENG) in 2012, [1] it has been developed into a new energy technology and has been applied to efficiently convert the mechanical vibration into electricity. TENGs are based on the coupling of two effects: contact electrification and the electrostatic induction. When two different materials are brought into contact, charge transfer occurs. After separation they induce charge in their back electrode and a current flow in the external load.

UV photodetectors have been widely used in communications, biological and chemical analysis, environmental monitoring, remote control, memory storage, and optoelectronic circuits [2-4]. Here we demonstrate a self-powered UV photodetector based on triboelectric nanogenerator which utilizes silver nanoparticles/reduced graphene oxide photosensitivity.

2 Results and Discussion

The fabricated photodetector is shown in Figure 1. Two surfaces of the main TENG are steel and PDMS. ITO is used as transparent back electrode for PDMS. The rGO sheets on silver nanoparticles in addition to the photosensitivity role, protect them from oxidizing. Silver nanoparticles were characterized using UV–visible spectroscopy and SEM as shown in Figure 2. The absorption peak was observed at 400 nm.

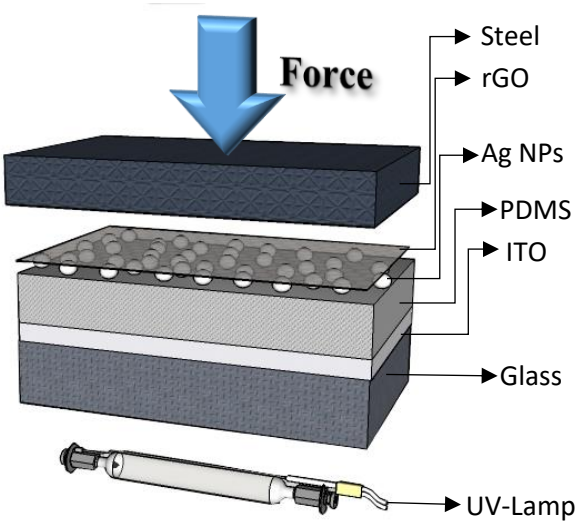


Figure 1 Fabricated photodetector schematic

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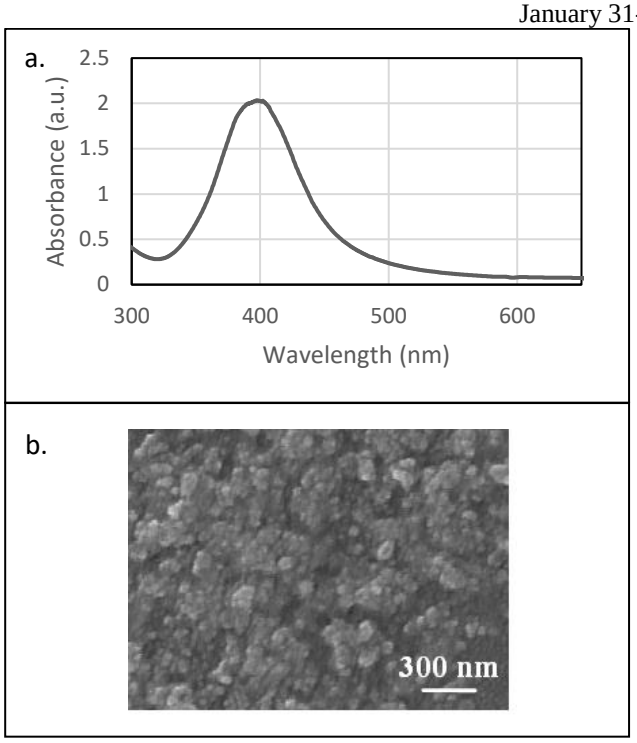


Figure 2. UV-visible spectroscopy (a) and SEM of the Ag NPs (b)

The fundamental mechanism of main TENG is as follows. When an external force is applied, two surfaces come into contact. According to triboelectric series which ranks materials' tendency to lose or gain electrons, electrons will inject from one side to another. [5] In this structure, electrons will flow from steel to PDMS. In this stage charges of the surfaces in contact are in balance. After separation, PDMS will induce charge in its back electrode, thus ITO will possess a higher electric potential than the steel sheet, which makes an electric potential difference. Such a potential difference drives electrons through external load, until no more potential difference remains.

When an external force is applied for the second time, distance between two surfaces will decrease and charges on the surface of PDMS will screen opposite polarity charges on steel and electrons that flew through external circuit now will flow in opposite direction to balance the charges. This process will lead to an ac output current with a periodic force. In this work, a 0.5 Hz force is applied on the steel sheet periodically using a dc motor.

For The photodetector part, rGO sheets are used on top of the PDMS surface which is decorated with silver nanoparticles. Output voltage of the structure is shown in Figure 3.a. It is expected for rGO sheet to play the role of a variable resistance with light illumination. In order to import the effect of this variable resistance on the output of our TENG, rGO sheet is connected through a carbon tape to steel sheet. Output voltage of TENG with this configuration is shown in Figure 3.b . It is observable that output voltage decreases from 1.2 V to 0.9 V with the new configuration. Discharge of the TENG's capacitance is also faster in the new configuration. UV light is produced by a SunKraft UV lamp with the power of 5 mW/Cm^2. Period of UV exposure is illustrated in Figure 3.b.

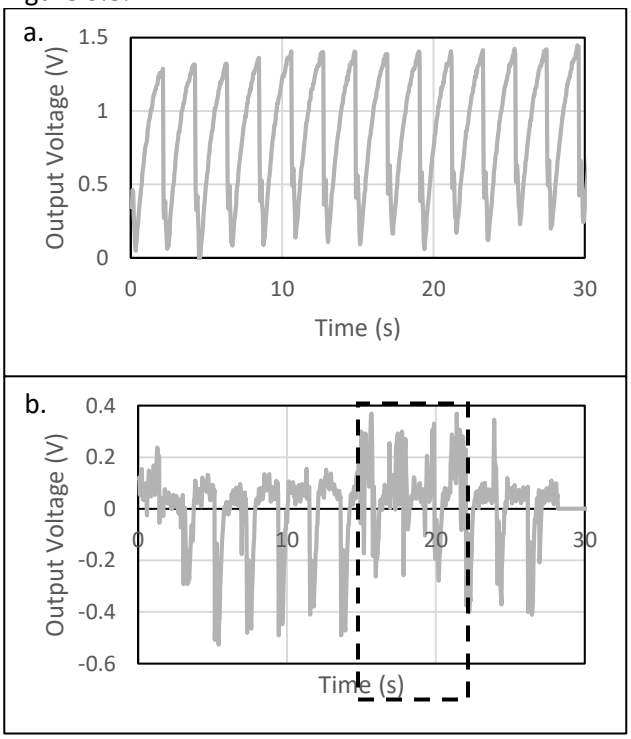


Figure 3. Output voltage of rGo/Ag NPs decorated TENG. (a)without Steel-rGO sheet connection, (b) with steel-rGO sheet connection. Dashed square shows the output under UV exposure

There are three important information about the outputs:

First, the UV-exposed part of the TENG's output peak to peak voltage is smaller. It is reduced from 0.9V to 0.6V. This is because of the decrease in the resistance of rGO layer in presence of UV illumination, which decreases the ability of the surface to store and maintain tribo charges for a period of time. The main factor responsible for the observed effect is the surface Plasmon-assisted desorption of oxygen from the graphene in according to reference [6].

Second, the attachment of rGO layer to the steel layer makes an additional path for charges to pass. This makes discharging time of TENG's capacitance lower. UV- exposure can decrease this time further because of a lower rGO sheet 's resistance.

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Third, in the dark period, the output voltage has just one peak for releasing two surfaces and the peak for pressing surfaces toward each other is not observed. But under the UV illumination these peaks are provided. This also comes from the fact that UV-illumination reduces resistance of rGO. Tribo charges can now screen charges of opposite polarity on the other surface throughout the time that distance between surfaces is decreasing and this leads to two peaks for each press and release process.

4 Experimental Section

4.1 PDMS preparation.

Sylgard 184 was purchased from Dow Corning. Silicone elastomer base and curing agent were mixed at the ratio 10:1. Mixing was continued for ten minutes. After removing all the bubbles that have been created thorough mixing, it was spin coated carefully on the ITO glass. The spinning speed used was 1000rpm. Sample was cured at 100°C for 35 minutes.

4.2 Silver nanoparticles synthesis.

Ag NPs are synthesized by solution method [7], in which silver nitrate (AgNO3) is the precursor and sodium borohydride (NaBH4) is used as the reducing agent and stabilizer [8].

4.3 GO sheets synthesis.

Graphene oxide (GO) sheets are synthesized by chemical exfoliation of graphite, using modified Hummers' method [9].

4.4 Sample preparation and plasma treatment

First PDMS was spin coated on a cleaned ITO-glass substrate and cured. Because of the hydrophobicity of the PDMS surface, a plasma treatment is needed for further use of the sample as a substrate for aqua solution of colloidal silver nanoparticles. PDMS was treated with oxygen plasma for 1minute. Power of the plasma was 50watt and the flow was set at 100sccm. After the treatment, silver nanoparticles solution was drop casted on the surface of the PDMS and left it in oven at 60°C to let it dry. GO sheets were coated on the prepared sample by dip coating. Finally, a carbon tape was attached to one side of the rGO for further use in connecting rGO to steel paper.

5 Conclusion

A self-powered UV photodetector was introduced utilizing photosensitivity of rGO / silver nanoparticles coated surface as a shunt resistance in the TENG's structure. Peak to peak output voltage was reduced from 1.2V to 0.9V with the configuration of introducing shunt resistance. It further decreased to 0.6V under UV exposure. Discharge time of the TENG's capacitance also decreased under the same circumstances. Thus output of the TENG was modified under illumination of ultraviolet light.

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