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Nano Generator Intended for Energy Harvesting

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ABSTRACT

In this era, immense energy crisis is a core problem. At those places with frequent power outage, gasoline motor generators are used as a solution. Production of more energy using renewable energy resources such as solar energy, wind energy, or hydropower is preferred, but it has limited use and is dependent on weather and topography. As an alternate resource of energy, Nano Generators can be used. Nano generators convert mechanical/thermal energy produced by small-scale physical change into electricity. Harvesting vibration energy from walking, voices, engine vibration, automobile, train, aircraft, wind and many more can be used for powering mobile electronics. Zinc oxide is a unique material that exhibits semiconducting and piezoelectric properties. Nanowire arrays of ZnO can be grown on flexible plastic substrates to form nano-generator. The nano-generator converts random mechanical energy into electric energy using piezoelectric zinc oxide nano wire arrays. The advantage of using nano wires is that tiny physical motions can trigger them and the excitation frequency can be 1Hz to 1000Hz, which is ideal for harvesting random energy in the environment. The voltage generated from a single Nanowire can be as high as 50mV, which is large enough to power many nano-scale devices.

Keywords: Piezoelectric, Nano-Generator, Energy Harvesting, ZnO and Nano Wires.

1. Introduction

Harvesting renewable energy from our living environment is of critical importance for our long-term energy needs and Sustainable development as it offers a fundamental energy solution for various wearable electronics and wireless sensors without the need for frequent battery replacements. Among these energies, solar, thermal, and mechanical energies are most-common and feasible sources of energy in the ambient environment. Since the self-powering nanotechnology was proposed in 2006, nano scale energy harvesters including piezoelectric and piezoelectric Nano-generators (NGs) have been developed to effectively harvest mechanical and thermal energies in the living environment to power small electronic devices. Usually, for different nano generators, the materials and the design methodologies are different. In order to improve the properties and extend the applications of NGs, is highly desired to develop an integrated device simultaneously harvesting mechanical and thermal energies [2].

Among many functional materials, the poly vinylidene fluoride-co tri-fluoro ethylene (polymer) has both the pyro-electric and piezoelectric properties, which make it ideal material for fabricating hybrid energy cell [5]. Currently, electro spinning process based on electro hydrodynamic deformation have been presented to produce P(VDF-TrFE) fibers, but this involves specialized equipment and high voltages of nearly 10 kV that electrically pole the fibers and the output of the process is again quite low [6]. Development of large-scale P(VDF-TrFE) nano-generator with a low-cost fabrication method has remained a major challenge. In this paper, we demonstrate a high performance flexible P(VDF-TrFE) nano-generator based on P(VDF-TrFE) nanowire array [7]. The piezoelectric and pyro-electric output electric signals of the flexible hybrid nano-generator were measured respectively, and output voltages were successfully integrated together. As a demonstrated application, the output electricity was used to power a large-scale liquid crystal display screen.

2. Proposed System

A tribo electric nano generator is an energy-harvesting device that converts the external mechanical energy into electricity by a conjunction of tribo electric effect and electrostatic induction. This new type of nano generator was firstly demonstrated in Prof. Zhong Lin Wang's group at Georgia Institute of Technology in the year of 2012. In power generation unit, at the inner circuit, a potential is created by the tribo electric effect due to the charge transfer between two thin organic/inorganic films that exhibit opposite tribo-polarity; in the outer circuit, electrons are driven to flow between two electrodes attached on the backsides of the films in order to balance the potential. Since the most useful materials for TENG are organic, it is also named organic nano generator, which is the first of using organic materials for harvesting mechanical energy [1].

The output power density of TENG has increased for five orders of magnitude within 12 months. The power density attains 313 W/m^2, volume density attains 490 kW/m^3, and a conversion efficiency of 60% has been demonstrated. Besides the unprecedented output performance, this new energy technology also has a number of other advantages, such as low cost in manufacturing and fabrication, excellent robustness and reliability, environmental-friendly, and so on. The tribo electric nano generator can be applied to harvest all kind mechanical energy that is available but wasted in our daily life, such as human motion, walking, vibration, mechanical triggering, rotating tire, wind, flowing water and more. The tribo electric nano generator has three basic operation modes: vertical contact-separation mode, in-plane sliding mode, and single-electrode mode. They have different characteristics and are suitable for different applications. The nano generator converts random mechanical energy into electric energy using piezoelectric zinc oxide nanowire arrays. The function of the nano generator depends on the piezoelectric potential generated in the nanowires by an external strain; a dynamic straining of the nanowire portrays in a transient flow of the electrons in the external load due to the driving force of the piezzo potential. The primary advantage of using nanowires is it can be triggered by tiny physical motions and the excitation frequency can be one Hz to thousands of Hz, which is suitable for extracting random energy in the environment.

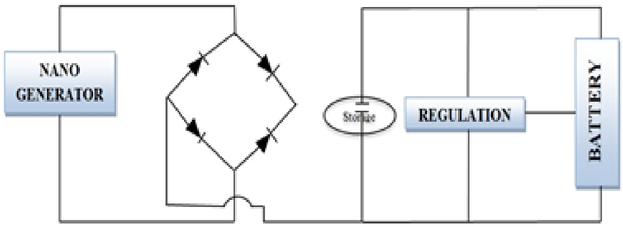

Fig. 1. Block diagram

Fig 1 shows the block diagram, the capacitors vary and capacitance values range from about 1 pF (10-12 F) to about 1 mF (10-3 F) [3]. The larger the surface area of the conductors greater the capacitance. ZnO nanowires had been the most widely used material for nano-energy harvesting. ZNO has wide application in nano coating [8]. ZnO is highly tensile and can have massive mechanical deformations for a long period. The piezoelectric properties are not temperature-dependent and so can be operated in higher temperature environments.

3. Simulation Results

The figure shows the overall geometry of our model of nano generator. The geometry describes the whole over structures of the ZnO nano generator. ZnO is piezoelectric and it has largest piezoelectric coefficient among tetrahedral crystals, open-handed to give very great electro-mechanical coupling.

Table 1

Geometric entity level	Domain
Selection	Domains 3–4, 6–7

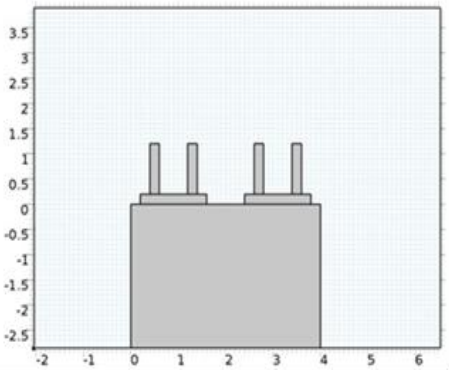

Fig 2. Overall geometry of the system

Piezoelectric single crystal materials (ZnO) [3]-[4] have a high piezoelectric coefficient and electromechanical coupling. ZnO is highly tensile and canthus undergoes huge mechanical deformations for a long period. The piezoelectric properties are not depending on temperature and so can be operated in higher Temperature environments.

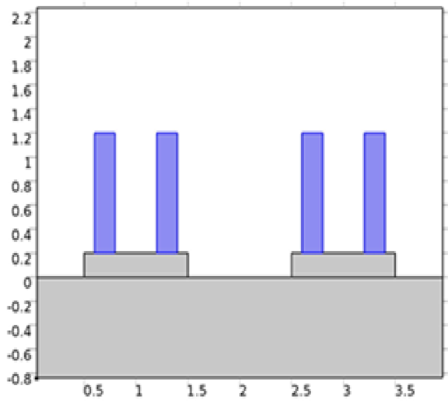

Fig. 3. Geometry of ZnO

Following results are getting from the simulation done by using the material Zinc Oxide as Nano generator. The top part of the ZnO is kept fixed, thus the centre part of ZnO will displaced and generate a potential.

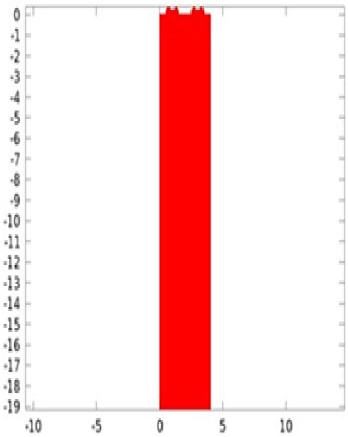

Fig. 4. Structure of nano generator using ZnO

Table 2

Geometric entity level	Point
Selection	No points
Name	Value
Data set	Solution 1
Name	Value
Expression	V

Table 3

X	Y	Value
0.70238	1.4711	4.63566e-4
3.23044	-4.67402	4.36357e-5
1.28826	0.59011	0.05958

From this table we can realize that the ZnO nano strand will produce a potential of 3.98V at frequency of 8.40373Hz. The two figures given below represent the displacement and potential developed in the ZnO nano strand.

Table 4

Eigen frequency	Electric potential (V), Point: 8	Electric potential (V), Point: 8
7.60314e8	0.45971	-0.01778
7.62594e8	0.07681	0.65798
8.40373e8	3.98216	2.57803
8.64088e8	0.05448	0.03215
8.74557e8	-3.18999	-0.7327
9.05063e8	-0.97703	0.32613
9.06983e8	-1.17152	-0.30064
9.29338e8	0.68153	-0.5708
9.41552e8	1.00621	0.40241
9.45995e8	1.58971	-0.01257
9.64537e8	0.14605	0.98739 - 2.8634e-7i
9.91082e8	-0.99429 + 6.91411e-8i	0.20855 - 4.70954e-9i

The displacement is around 70 micrometer and the potential developed is 8V from a strand. This nano strand will produce a 4V at Eigen frequency of 8.40373Hz.

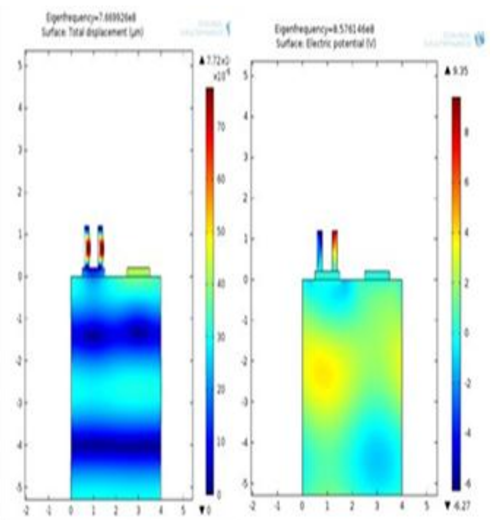

Fig. 5. Displacement and potential developed in the ZnO nano strand

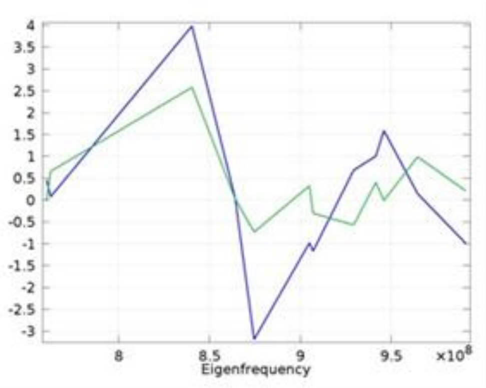

Fig. 6. 1D plot

Piezoelectricity can be defined as the property of certain materials to produce electrical potential when subjected to mechanical stress. Some natural piezoelectric materials include DNA, enamel, silk, dentin, etc. Single crystals, like quartz, ZnO and synthetic crystalline materials, and ceramics like barium titanate, lead titanate, lead zirconate titanate, sodium potassium niobate, bismuth titanate, etc., and polymers like poly vinylidene fluoride, are found to exhibit this property.

Table 5

Geometric entity level	Point
Selection	No points
Name	Value
Data set	Solution 1
Name	Value
Expression	V

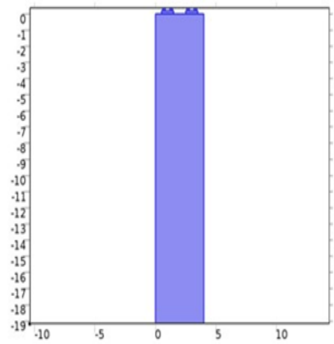

Fig. 7. Geometry of piezoelectric devices

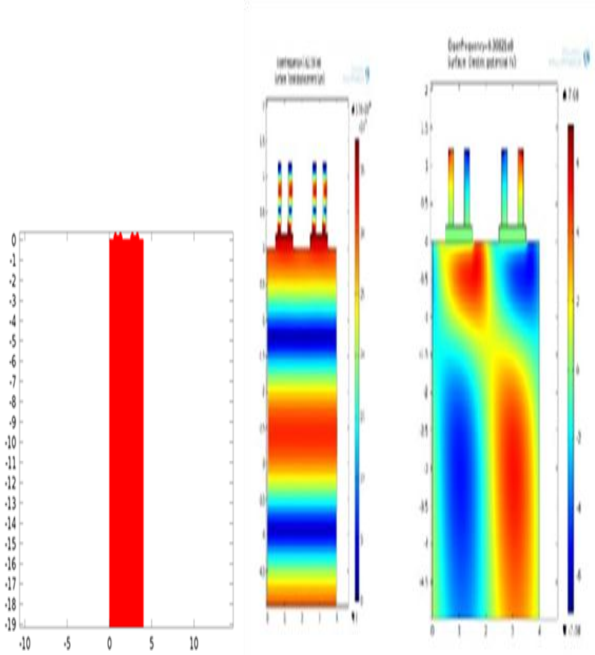

Fig. 8. Nano generator using PZD and Displacement produced by the PZT

By this figure 7, we can understand that the displacement produced by the PZT is approximately equal to 35 micrometer and potential developed is 6V. In addition, the displacement and potential is very low compared to the ZnO nanowire. Thus, we can finalize that ZnO nanowire is more suitable for harvesting the small vibration to electrical energy.

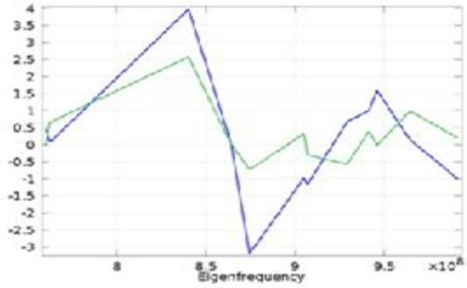

Fig. 10. Variation of potential with respect to the Eigen frequency

4. CONCLUSION

Conventional power sources and batteries cannot be integrated with micro or nano systems and need periodic replacement or recharging. In addition, they can be very bulky in size and weight as compared to the parent device. In order to avoid such power problems, we looked into piezoelectric energy harvesters, which promise to be a solution. Ideally, wireless devices should be self-powered rather than using a battery. The human body provides numerous potential energy sources – mechanical energy, like body movements, muscle stretching and blood pressure, etc., and hydraulic energy, like blood flow and blood vessel contraction, etc. Nature is also abundant with vibration energy in the form of acoustics, ultrasonic and hydraulic energy, like dynamic fluids, etc. In this work, we looked into the details of the technology of piezoelectric nanostructures used for the generation of piezo potential in order to convert it into electrical energy for use in developing self-powered nano systems. The most efficient conversion of this energy into electric energy at the macro-scale is a challenge. Objective research in this direction is gradually leading us towards such power sources, and we look to a future of integrated nano systems of greatly reduced size for optoelectronics, biosensors, resonators and medical electronics, etc. Self-powered devices for the in situ implantation for bio sensing, biomedical monitoring, diagnostics and therapy, are also being investigated and successfully demonstrated. Certain polymers have been used for piezo-energy harvesting. We had explored the various micro- and nano-scales. PZT is the most widely used ceramic material. Ceramic materials like PZT have high piezo electric sensitivity and coupling coefficients. They are available commercially at low cost and in a variety of designs. Stability is an issue for them, as they suffer from the loss of polarization with continued use. The piezoelectric properties are also strongly dependent on the operating temperatures. Electrical charge separation can occur not just from mechanical deformation but with temperature changes as well. These are brittle substances; hence, they cannot withstand mechanical deformation for long. Piezoelectric single crystal materials (ZnO) have a high piezoelectric coefficient and electromechanical coupling. We found that, throughout the reported research work done up until now and referenced above for nano-energy harvesting, ZnO holds the advantages over other materials that it is a metal oxide semiconductor material with piezoelectricity properties.

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