# NANO-GENERATOR

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***Abstract: Nano structured energy harvesting devices, are termed nano-generators. They are a prototype nanometer-scale generator that produces continuous direct-current electricity by harvesting mechanical energy from such environmental sources as ultrasonic waves, mechanical vibration or blood flow. These nanogenerators take advantage of the unique coupled piezoelectric and semiconducting properties of zinc oxide nanostructures. Here we discuss the working and geometrical configurations of a piezoelectric nano generator generates electricity resulting from pressure, as well as the development of triboelectric nano-generator which converts the external mechanical energy into electricity. Batteries and other traditional sources are too large and depend on other sources for power, nano generators provide a good substitute as they are self-powered nanodevices. Also, since zinc oxide is non-toxic and compatible with the body, open many areas of applications such as biomedical and others which weren't exploited before.***
***Keywords: piezoelectric; triboelectric; zinc oxide; vibration; energy***

## I. INTRODUCTION

Ever since Thomas Edison developed the electric light bulb, scientists have looked for better ways to power it. This search has led to major development in two key areas of technology: energy and electronics. The search for ever-better power sources has led to large-scale electric utility services, rechargeable batteries, and devices for harnessing renewable energy from the world around us, such as wind turbines and solar panels. In electronics, developers are continually on the quest for cheaper yet more powerful devices that use less energy than their predecessor technologies. The search for ever-better power sources has led to large-scale electric utility services, rechargeable batteries, and devices for harnessing renewable energy from the world around us, such as wind turbines and solar panels. In electronics, developers are continually on the quest for cheaper yet more powerful devices that use less energy than their predecessor technologies. What if we could produce electricity from the power we generate just by being alive? Imagine if you could keep your iPod charged just by tapping your fingers to the beat of the music or by wearing a hoodie with a tiny embedded circuit board that senses your pulse. Though it might sound like science fiction, nanogenerators are bringing such power sources into reality. The search for ever-better power sources has led to large-scale electric utility services, rechargeable batteries, and devices for harnessing renewable energy from the world around us, such as wind turbines and solar panels. In electronics, developers are continually on the quest for cheaper yet more powerful devices that use less energy than their predecessor technologies.

## II. WHAT IS A NANOGENERATOR?

Nanogenerator is the term researchers use to describe a small electronic chip that can use mechanical movements of the body, such as a gentle finger pinch, to generate electricity. The chip has an integrated circuit etched onto a flexible surface, similar to components on the circuit boards inside your computer. As the "nano-" prefix implies, these generators are a piece of nanotechnology, or technology so small its size is measured by the nanometer (one billionth of a meter). So, even the most complex and powerful nanogenerators in existence today are small enough to be held between two fingers.

## III. WHAT IS THE NEED OF A NANOGENERAOTR?

With the threat of global warming and energy crises, searching for renewable and ''green''-energy resources is one of the most urgent challenges to the sustainable development of human civilization. On the larger scale, besides the wellknown energy resources that power the world today, such as petroleum, coal, hydroelectric, natural gas, and nuclear, active research and development are taking place into exploring alternative energy resources such as solar, geothermal, biomass, nuclear, wind, and hydrogen. At a much smaller scale, energy and technologies are desperately needed for independent, sustainable, maintenance-free, and continuous operation of implantable biosensors, ultrasensitive chemical and biomolecular sensors, nanorobotics, micro-electromechanical systems (MEMS), remote and mobile environmental sensors, security applications, and even portable/wearable personal electronics.

## IV. TYPES OF NANOGENERATOR

Nanogenerators are of three types:

- Piezoelectric Nanogenrators
- Triboelectric Nanogenerators
- Pyroelectric Nnaogenrators

## V. PIEZOELECTRIC NANOGENERATOR

The piezoelectric nanogenerator gets its name from the Piezoelectric Effect which the basis of its working and structure.

A. Piezolectric effect and materials

Piezoelectric Effect is the ability of certain materials to generate an electric charge in response to applied mechanical stress. One of the unique characteristics of the piezoelectric effect is that it is reversible, meaning that materials exhibiting the direct piezoelectric effect (the generation of electricity when stress is applied) also exhibit the converse piezoelectric effect (the generation of stress when an electric field is applied). When piezoelectric material is placed under mechanical stress, a shifting of the positive and negative charge centers in the material takes place, which then results in an external electrical field. There are many materials, both natural and man-made, that exhibit a range of piezoelectric effects. Some naturally piezoelectric occurring materials include Berlinite (structurally identical to quartz), cane sugar, quartz, Rochelle salt, topaz, tourmaline, and bone (dry bone exhibits some piezoelectric properties due to the apatite crystals, and the piezoelectric effect is generally thought to act as a biological force sensor). An example of man-made piezoelectric materials includes barium titanate and lead zirconate titanate. The most commonly used piezoelectric ceramic is barium titanate.

### *B. Nanowires*
Nanowires are just like normal electrical wires other than the fact that they are extremely small. Like conventional wires, nanowires can be made from a variety of conducting and semiconducting materials like copper, silver, gold, iron, silicon, zinc oxide and germanium. Na nowires can also be made from carbon nanotubes.Normally an electron can't pass through an insulator. If the insulator is thin enough, though, the electron can pass from one side of the insulator to the other. It's called electron tunneling, but the name doesn't really give you an idea of how weird this process can be. The electron passes from one side of the insulator to the other without actually penetrating the insulator itself or occupying the space inside the insulator. You might say it teleports from one side to the other. You can prevent electron tunneling by using thicker layers of insulator since electrons can only travel across very small distances. Another interesting property is that some nanowires are ballistic conductors. In normal conductors, electrons collide with the atoms in the conductor material. This slows down the electrons as they travel and creates heat as a byproduct. In ballistic conductors, the electrons can travel through the conductor without collisions. Nanowires could conduct electricity efficiently without the byproduct of intense heat.

### *C. Construction and Working*
A nanogenerator consists of an integrated circuit, with components made from silicone and a piezoelectric ceramic, etched onto a flexible surface, called a substrate. The electricity is generated in the piezoelectric material. ZnO is used to develop nanowires. In their nanogenerators, Wang's team attaches an array of nanowires to the substrate and places a silicone electrode at the other end of the wires. The electrode has a zigzag pattern on its surface. When a small physical pressure is applied to the nanogenerator, each nanowire flexes and generates an electrical charge. The electrode captures that charge and carries it through the rest of the nanogenerator circuit. The entire nanogenerator might have several electrodes capturing power from millions of nanowires. Z.L. Whnag and his group have successfully powered a light-emitting diode, alaser diode and a liquid crystal display using nanogenerated power exclusively.

## VI. TRIBOELECTRIC NANOGENERATORS
The triboelectric nanogenerator has three basic operation modes:

- Vertical Contact-Separation Mode
- In-Plane sliding Mode
- Single-Electrode Mode

### *A. Vertical Contact-Separation Mode*
Periodic change of the potential difference induced by the cycled separation and re-contact of the opposite triboelectric charges, on the inner surfaces of the two sheets achieved by mechanical agitation . Once the two surfaces are separated by a small gap by an external force, a potential drop is created. If the two electrodes are electrically connected by a load, free electrons in one electrode would flow to the other electrode to build an opposite potential in order to balance the electrostatic field.The electricity generated in this process will continue until the potentials of the two electrodes get back to even again.
As for the pair of materials getting in contact and generating triboelectric charges, at least one of them need to be an insulator, so that the triboelectric charges cannot be conducted away but will remain on the inner surface of the sheet.

### *B. Lateral Sliding Mode*
A lateral polarization is thus introduced along the sliding direction, which drives the electrons on the top and bottom electrodes to flow in order to fully balance the field created by the triboelectric charges. A periodic sliding apart and closing generates an AC output.

### *C. Single-Electrode Mode*
The object that is part of the TENG cannot be electrically connected to the load because it is a mobile object, in which the electrode on the bottom part of the TENG is grounded. In the original position, the surfaces of skin and PDMS fully contact with each other, resulting in charge transfer between them. According to the triboelectric series, electrons were injected from the skin to the PDMS since the PDMS is more triboelectrically negative than skin.The negative charges on the surface of the PDMS can induce positive charges on the ITO electrode, driving free electrons to flow from the ITO electrode to ground. This electrostatic induction process can give an output voltage/current signal if the distance separating between the touching skin and the bottom PDMS is appreciably comparable to the size of the PDMS film. by increasing the separation distance between the PDMS and skin, no output signals can be observed when the skin was reverted to approach the PDMS, the induced positive charges on the ITO electrode decrease and the electrons will flow from ground to the ITO electrode until the skin and PDMS fully contact with each other again, resulting in a reversed output voltage/current signal

  

## VII. PYROELECTRIC NANOGENERATOR

Pyroelectricity is the ability of certain materials to generate a temporary voltage when they are heated or cooled. The change in temperature modifies the positions of the atoms slightly within the crystal structure, such that the polarization of the material changes. Spontaneous polarization is temperature dependent, so a good perturbation probe is a change in temperature which induces a flow of charge to and from the surfaces. The mechanism is based on the thermally induced random wobbling of the electric dipole around its equilibrium axis, the magnitude of which increases with increasing temperature. Due to thermal fluctuations under room temperature, the electric dipoles will randomly oscillate within a degree from their respective aligning axes.

*Ferroelctric Materials(spontaneous electric polarization)*

Under a fixed temperature, the total average strength of the spontaneous polarization form the electric dipoles is constant. The increase in temperature will result in that the electric dipoles oscillate within a larger degree of spread around their respective aligning axes. The quantity of induced charges in the electrodes are thus reduced, resulting in a flow of electrons. If the nanogenerator is cooled instead of heated, the spontaneous polarization will be enhanced since the electric dipoles oscillate within a smaller degree of spread angles due to the lower thermal activity. The total magnitude of the polarization is increased and the amount of induced charges in the electrodes are increased. The electrons will then flow in an opposite direction. Here, the obtained pyroelectric response is explained by the secondary pyroelectric effect, which describes the charge produced by the strain induced by thermal expansion. Example: CdS, ZnO. The thermal deformation can induce a piezoelectric potential difference across the material, which can drive the electrons to flow in the external circuit. The output of the nanogenerator is associated with the piezoelectric coefficient and the thermal deformation of the materials.

## VIII. ADVANTAGES

*A. Self-powered nano/micro devices*

One of the feasible applications of nanogenerator is an independent or a supplementary energy source to Nano/micro devices consuming relatively low amount of energy in a condition where the kinetic energy is supplied continuously.
One of example has been introduced by Professor Zhong Lin Wang's group in 2010 by the self-powered pH or UV sensor integrated VING with an output voltage of 20~40 mV onto the sensor. Still, the converted electrical energy is relatively small for operating Nano/micro devices; therefore the range of its application is still bounded as a supplementary energy source to the battery. Mr. Zhong Lin Wang, a pioneer in the field of nanogenerators, and his team at Georgia Institute of Technology introduced a smart, self-powered, self-cleaning keyboard. They designed the keyboard in a way that would attract electrons when the user pushes down on a key, inducing current.

*B. Smart Wearable Systems*

The outfit integrated or made of the textiles with the piezoelectric fiber is one of the feasible applications of the nanogenerator. The kinetic energy from the human body is converted to the electrical energy through the piezoelectric fibers. The nanogenerator such as VING can be also easily integrated in the shoe employing the walking motion of human body.

*C. Transparent and Flexible Devices*

Some of the piezoelectric nanostructure can be formed in various kinds of substrates, such as flexible and transparent organic substrate. The research groups in SKKU (Professor Sang-Woo Kim's group) and SAIT (Dr. Jae-Young Choi's group) have developed the transparent and flexible nanogenerator which can be possibly used for self-powered tactile sensor and anticipated that the development may be extended to the energy-efficient touch screen devices.

*D. Harvesting vibration energy*

Vibration is one of the most popular phenomena in our daily life, from walking, voices, engine vibration, automobile, train, aircraft, wind and many more. It exists almost everywhere and at all the time. Harvesting vibration energy is of great value especially for powering mobile electronics.

*E. Change in Temperature*

Pyroelectric nanogenerator is expected to be applied for various applications where the time-dependent temperature fluctuation exists. One of the feasible applications of the pyroelectric nanogenerator is used as an active sensor, which can work without a battery. Professor Zhong Lin Wang's group in 2012 by using a pyroelectric nanogenerator as the self-powered temperature sensor for detecting a change in temperature. In general, the pyroelectric nanogenerator gives a high output voltage, but the output current is small. It not only can be used as a potential power source, but also as an active sensor for measuring temperature variation.

## IX. LIMITATIONS

- The cell would always be charged (you can’t place a switch to cut off the charge path).
- It’s still too uneconomical to manufacture them.
- The technology for mass production of the materials is still unavailable.
- The overall power density delivered is insufficient for most mobile devices.

## X. FUTURE SCOPES

The discovery can provide a new way to power mobile devices such as sensors and smartphones by capturing the otherwise wasted mechanical energy from such sources as walking, the wind blowing, vibration, ocean waves or even cars driving. While listening to music and tapping on the phone or tapping your feet at the beat of the music and you are charging your phone.

  

## REFERENCES

[1] Special Issue on Sustainability and Energy, Science 2007, 315, 721.
[2] Special Issue on Harnessing Materials for Energy, MRS Bull. 2008, 33, No. 4.
[3] Z. L. Wang, Sci. Am. 2008, January, 82.
[4] For a review see J. A. Paradiso, T. Starner, IEEE Pervasive Comput. 2005, 4, 18.
[5] For a review see E. S. Leland, J. Baker, E. Carleton, E. Reilly, E. Lai, B. Otis, J. M. Rabaey, P. K. Wright, V. Sundararajan, IEEE Pervasive Comput. 2005, 14, 28.
[6] Zheng, T. J. Kempa, Y. Fang, N. Yu, G. Yu, J. Huang, C. M. Lieber, Nature 2007, 449, 885.
[7] Z. L. Wang, J. H. Song, Science 2006, 312, 242.
[8] X. D. Wang, J. H. Song, J. Liu, Z. L. Wang, Science 2007, 316, 102.
[9] Y. Qin, X. D. Wang, Z. L. Wang, Nature 2008, 451, 809.
[10] Z. L. Wang, MRS Bull. 2007, 32, 109.
[11] Z. L. Wang, X. Y. Kong, Y. Ding, P. X. Gao, W. L. Hughes, R. S. Yang, Y. Zhang, Adv. Funct. Mater. 2004, 14, 944.
[12] J. Liu, P. Fei, J. Zhou, R. Tummala, Z. L. Wang, Appl. Phys. Lett. 2008, 92, 173 105.
[13] X. Y. Kong, Z. L. Wang, Nano Lett. 2003, 3, 1625.
[14] X. Y. Kong, Y. Ding, R. S. Yang, Z. L. Wang, Science 2004, 303, 1348.
[15] P. X. Gao, Y. Ding, W. J. Mai, W. L. Hughes, C. S. Lao, Z. L. Wang, Science 2005, 309, 1700.
[16] M. H. Zhao, Z. L. Wang, S. X. X. Mao, Nano Lett. 2004, 4, 587.

  