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Comparison of Mechanical Energy Harvesting using Various Triboelectric Generators

Arun Thomas, Sam Vincent, Ranjana A., Reena Thomas*, Seethal Babu
Department of Computer Science, Sahrdaya College of Engineering, Thrissur, India
Corresponding Author
E-Mail Id: reenathomaskoikara123@gmail.com

ABSTRACT

As the variety of moveable electronic gadgets are increasing, property energy sources for these devices become indispensable. The chance to power these devices by energy harvested exploitation renewable sources ought to be found. Triboelectric generators are the most effective answer to reap energy from low-frequency mechanical motions. A lamb may be a energy harvest home device that converts external energy into electricity by a conjunction of contact electrification and electricity induction and this electricity is employed to power our electronic gadgets wirelessly by exploitation wireless module. These devices open brand new horizons for tactics to provide and store wasted energy from our surroundings and during a close to future to power wireless sensors, electronic gadgets and thereby comparison numerous TEG's for harvest home energy.

Keywords: *Triboelectric generator (TEG), renewable energy (RE), polytetrafluoroethylene (PTFE), polyvinylidene fluoride (PVDF), polydimethylsiloxane (PDMS), broadband and hybrid energy harvester (B-HEH)*

INTRODUCTION

Energy plays a key role in the process of economic growth of a nation. Any country's industrial development is dependent on the development of its power resources. Energy is also seems to be indispensable for agriculture, transport, business and domestic requirements. Electricity has a great range of applications in modern economic development that is in its per capita consumption to a major extent, an index of the material advancement of the country. For the economic growth energy seems to be an essential input. It is used in the form of electrical energy, thermal energy, light, mechanical energy and chemical energy etc.

The cost of energy and its usage affects every one of us in our daily lives. Most of the issues arise from the usage of energy such as greenhouse gas emissions, acid rain,[3] climate change and much more from politically unstable regions of the world. Today, 80 percentage of the world's electrical production comes from fossil and nuclear fuels, and virtually all transportation is fuelled by liquid petroleum.

In today's world, the TEG has developed a capable concept for the use of multiple forms of renewable energy in the ambient environment. The triboelectric generator relies on contact electrification coupled with electrostatic induction between two media for energy conversion. TEGs have been suggested to have higher energy harvesting efficiencies in the low-frequency range. This phenomenon is particularly vital because, for ambient environmental sources, most of the surrounding media oscillates with low to medium frequency motion. Many efforts have been devoted to exploring advanced TEG designs by inducing electron flow from coalescing electrostatic induction

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during contact electrification. These designs have attracted interest for microscale energy harvesting devices.
The adaptive and integrative features of TEGs can provide significant assistance to wind-based energy solutions with multiple hybrid blue energy sources, such as wind–wave, wind–solar, and water–solar. Therefore, the capability to harvest blue energy, especially with large networks under relatively weak water waves and air currents, puts TEGs at the forefront of developing the next generation of sustainable energy sources. To meet the great need for renewable and sustainable power sources, mechanical energy in the environment is widely used for electricity generation.

PROBLEM DEFINITION

Energy is the necessity of all activity. Without energy, nothing can be moved or transformed and thus a sustainable society can only exist based on a sustainable energy system. Though different concentrated forms of energy found in nature allow the free time to make ever more sophisticated tools quickly, their use is not sustainable. In common, the practice of obtaining naturally concentrated energy causes 4 interrelated fundamental problems such as disrupting natural energy flows, depletion, centralization, and resource wars.

Energy is a vital part of all developing programs. Without energy, fashionable life might not exist. We tend to all want energy to take care of physical comfort in a lot of the globe, to overcome and manufacture helpful materials also as artefacts, for transport, for communications, for agriculture and for trade generally. Energy can be created simply offered by dominant and creating use of natural energy flows like moving water, solar radiation, wind, and conjointly by mistreatment fuels like wood, coal, oil, fossil fuel and metallic element. Moreover, the harnessing and utilization of energy is related to worrying issues, namely, depletion and environmental injury.

MOTIVATION

Nowadays, the renewable energy (RE) is changing into a large business in most of nations within the world. There square measure 2 factors have forced this business developed. First, the general public awareness of relative blessings provided by RE. Second, the restructuring of the electricity provide trade thanks to the principles and regulation imposed by the govt.

With the fast development of transportable physical science and sensing element networks, researchers have dedicated intensive efforts to sorting out property mobile energy supply with the output level from µW to mW. Currently, the foremost usually utilized approach is to power them by energy storage units like batteries or capacitors. However, there square measure 2 major shortcomings. The primary one is that the restricted lifetime, in order that they can't sustainably drive the physical science. The second is that the difficulty of disposal, that may cause serious environmental drawback if not dealt with properly.

LITERATURE SURVEY

Broadband Energy Harvester Using Non-linear Polymer Spring and Electromagnetic / Triboelectric Hybrid Mechanism[1]

The self-powered sensors, piezoelectric energy harvesting mechanisms have been comprehensively explored because of the direct piezoelectric effect, charge output caused by strain or deformation on PZT, ZnO and AlN ceramics and poly (vinylidene fluoride) (PVDF) polymer films. A piezoelectric PZT micro cantilever[2] has been studied as air flow sensors and wind-driven energy harvesters with flow sensing sensitivity of

0.9mV/(m/s) and electrical output power of 3.3 nW at load resistance of 100K ohm and flow velocity of 15.6 m/s.

The flexible triboelectric nanogenerator (TENG) consists of two polymer films, which have different electron-attracting abilities, with metal films deposited on their back sides. As the two films contact and separate, the alternative potential will drive electrons in the external load to flow back and forth. The polytetrafluoroethylene (PTFE) and polydimethylsiloxane (PDMS) are widely used polymer films of electronegativity in the TENG. Due to the nature of insulator-to-insulator or insulator-to-metal contact interface, the internal impedance of TENG is generally high. In order to enhance the output power, integration of piezoelectric PVDF thin film with other triboelectric functional layers to form a hybrid energy harvester.[4,5,7]

Electromagnetic energy harvesters with low internal impedance gather the energy and generate current from coils owing to the variation of magnetic flux induced from the movement of a permanent magnet. Piezoelectric energy harvesters outperform electromagnetic energy harvesters at low frequency, and the electromagnetic mechanism is favourable in the high-frequency range. Piezoelectric energy harvesters usually generate high voltages and lower current, electromagnetic energy harvesters tend to produce relatively low AC voltage, and the voltage output is decreased when the size scales down.

A multi-frequency electromagnetic energy harvester consisting of three permanent magnets and corresponding to the resonant frequencies of 369Hz, 938Hz and 1184Hz83. However, the bulkiness and complexity of the device overshadows its advantage in broadband behaviour. One main challenge is non-engagement of stoppers and therefore negligible output from triboelectric energy harvester due to non-contact of triboelectric layers at low accelerations. It also leads to non-triggering of bandwidth broadening property. Another main challenge is to avoid mechanical energy loss incurred due to impact between moving mass and stoppers at high accelerations. Alternatively, in multimodal energy harvesting, the multiple modes of vibration can effectively widen the frequency bandwidth by merging multiple resonant peaks into one over a wide frequency range.

A broadband and hybrid energy harvester (B-HEH) which overwhelms the stated challenges with its characteristic design. At first a soft polymer spring exhibiting closely located mode frequencies (1st and 2nd resonant mode) to widen the operating bandwidth at low acceleration. In this acceleration range (<0.5Gg) the electromagnetic mechanism can harvest reasonable output even if oscillation amplitude is very small at higher modes. Thus, at a higher mode, combined output from triboelectric and electromagnetic mechanisms increases the overall B-HEH performance. Secondly, the mechanical energy loss during impact of a movable magnet, i.e., inertial mass, to top/bottom electrodes at high acceleration is reduced because part of this lost energy is scavenged and transformed into triboelectric output by integrating triboelectric electrodes as the top/bottom layer of the B-HEH. With adequate acceleration for the inertial mass to come in contact with top/bottom layer, the engagement with such stopper layer introduces non-linear stiffening. Due to contact-electrification on triboelectric layers, equal and opposite charge is generated and then collected by two electrodes utilizing freestanding mode of triboelectric mechanism91. The fabricated device can harvest over wide range of

HBRP PUBLICATION
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Volume 2 Issue 1
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frequency from 50 to 130Hz over widespread range of accelerations (0.1 g–2.0 g). The polymer spring fabricated using PDMS has been used to obtain nearby multimode frequencies. Compared with other reported HEHs74–81, the proposed B-HEH can operate under wide range of frequencies with its unique design, while it generates complementary output from electromagnetic and triboelectric mechanisms. Furthermore, this B-HEH design addresses two major objectives: firstly, the soft polymer spring with non-linear stiffness benefits in operation bandwidth widening, and secondly, hybrid mechanism increases the device performance over the attained frequency range.

WORKING PRINCIPLE

The voltage generation of B-HEH is tested with two modes of mechanical input as sinusoidal vibration and tapping. The EMEH works on Faraday's law of electromagnetic induction,[6] which develops the electromagnetic force with change of rate of flux passing through the coil. The working modes of B-HEH can be divided in to two modes as shock/tapping and resonant mode. The electromagnetic output is extracted directly from the coil while the TEH output is collected using freestanding electrodes. Initially the proof mass remains in the middle position at an equal distance from the upper and lower triboelectric layer. As, mechanical vibration is given to the device in z-axis, the proof mass moves to contact with the upper layer or tend to contact depending upon applied acceleration.

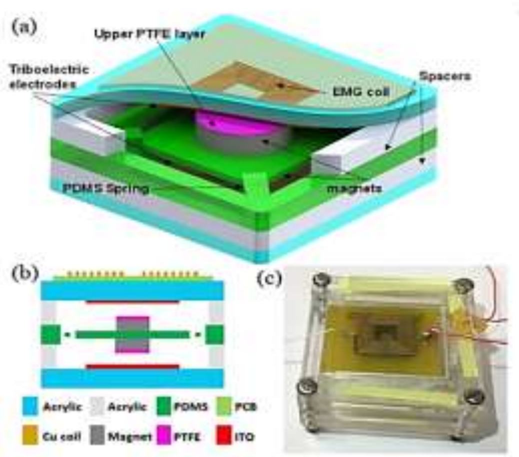

Fig. 1: *(a) Schematic Drawing of Broadband and Hybrid Energy Harvester (B-HEH). (b) Cross Sectional View of the Device. (c) Prototype Image of Fabricated Device.*

RESULTS

The B-HEH consists of an electromagnetic coil, a pair of NdFeB magnets, a polymer spring structure, triboelectric materials and electrodes. The TEH consists of two PTFE layers and two Indium tin oxide (ITO) electrodes. The EMEH consists of fixed coil and moving magnet as proof mass for the resonant system suspended through PDMS spring structure. The proposed design generates simultaneous electrical output from the electromagnetic coil and triboelectric energy harvester over broad range of frequencies. The mechanical spring structure used for the device is fabricated using PDMS polymer. The spring is fabricated using casting by a metal mould. For TEH, the freestanding mode of triboelectric mechanism is realized by having PTFE dielectric layers

Journal of Optoelectronics and Communication
Volume 2 Issue 1
DOI: [To be assigned]

of dimension 20mm×20mm×250μm attached on magnets moving between two electrodes. The dielectric PTFE layer is negatively charged upon contact with metal electrode. The metal layers serve as positive triboelectric charged layers and electrodes for collecting the generated charge. The ITO coated PET sheet of dimension 20mm × 20mm × 200μm are attached on top and bottom acrylic substrates as electrodes. The size of whole device is 5cm × 5cm × 2.5cm.

Study of a Hybrid Generator Based on Triboelectric and Electromagnetic Mechanisms

As the development in physics the usage of moveable device additionally increase due to restricted battery capability devices have to be compelled to be charged frequently. Li-ion battery isn't an improved answer for powering these devices thanks to problems with short period and environmental pollution. Energy harvested from property sources like as star, vibration, thermal, nuclear that obtainable masses in nature is ideal answer for the charging. The researches on vibration energy harvest focuses on the approaches electricity magnetic attraction and electret. Here a hybrid generator named TMHG with the triboelectric and magnetic attraction components will generate power outputs from given force or environmental vibration is given. Vibration management and testing system want to measure the output performance of the TMHG at totally different excitation accelerations and frequencies. Moreover by changing the gap distance between friction materials we can adjust the operating bandwidth. TMHG is designed with cylindrical tube with diameter 48 mm and height 14.8 mm build on circular base board and a metal coil is tightly wound surrounding the tube. A copper plate is covered on top of the tube and a spring structure is patterned on the copper plate. For the triboelectric part aluminum (Al) film attached on the bottom surface of the magnet, fluorinated ethylene propylene (FEP) layer and copper layer served as the bottom electrode and a spacer between the FEP-Cu layers. When TMHG is excited by external excitation spring structure make vibration in permanent magnet. Based on Faraday's law of induction the change of the magnetic flux across the winding coil will be induced and thereby electric voltage across the coil is generated. As a result ac current output can be obtained due to triboelectrification effect and electrostatic induction. The output performance of the TMHG is strongly dependent on the exciting acceleration and the initial gap distance between contact materials. The output performance of TMHG in frequency domain is because of the increase in rate of change of flux lead to increase in excitation acceleration level and the allowable vibration distance leads to higher induced electromotive force. The working principle of entire TMHG is described in terms of electromagnetic part and triboelectric part. When magnet vibrates according to Faraday's law we get induced voltage across the coil. Triboelectric part of the TMHG uses contact-separation model. When the magnet moves gap between Al layer and FEP layer changes. Due to the difference in capability of the two layers in attract and retain electrons a pressure force is used to make Al and FEP layers contact. As a result positive and negative charges get deposited on the contact surfaces of both layers because of triboelectrification effect. Due to opposite sign charges occur simultaneously on same plane we cannot see electric potential difference between the two contacts. Because of the connection between top and bottom electrodes EPD direct the flow of electrons from Cu to Al .Due to this in the Al layer positive triboelectric charges get neutralized till gap distance reach maximum. So at triboelectric part of the generator in the release process the current is generated. Due to periodic vibration the gap starts to decrease.

Journal of Optoelectronics and Communication
Volume 2 Issue 1
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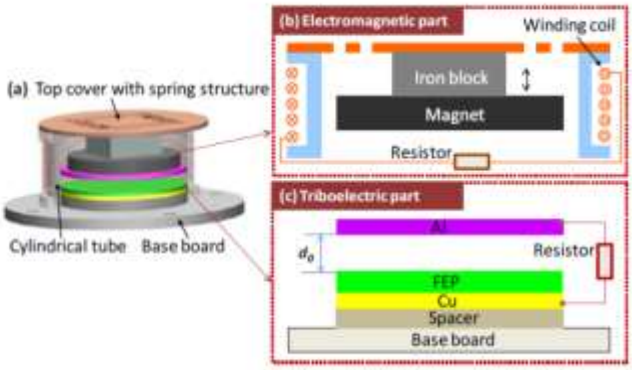

Fig. 2: *(a) Schematic Diagram of the TMHG, (b) Cross Section Views of the Electromagnetic Part, (c) Triboelectric Part.*

When Al layer nearer to FEP layer the electrons flow back from Al to Cu due to electrostatic induction and then the positive charges on the Al increases again. At last when two contact materials comes to contact again the charge distribution return to its initial state. As a result ac current is produced at the time of periodical contact and separation between contact layers of Al and FEP. Output performance in terms of time and frequency is identified at initial gap distances and excitation accelerations. By reducing the initial gap and increasing the excitation acceleration we can expand the bandwidth. At d_0 5 mm and a 1g, the output powers are 0.28 mW and 1.09 mW in triboelectric and electromagnetic parts. The resonant frequency of the TMHG is 23.5 Hz. TMHG with high power density suitable for vibration energy harvesting applications at low frequencies is proposed. In addition, we can adjust bandwidth by changing the gap distance.

A Novel Arch-Shaped Hybrid Composite Triboelectric Generator Using Carbon Fiber Reinforced Polymers

In today's world the number of electronic gadgets is increasing day by day in application domains ranging from healthcare, transport, agriculture and cities. Connected sensors will also use battery as a source of energy. The total number of electronic devices in the upcoming years is expected to be more than 80 billion. So it is very essential that we need a better charging system for the proper working of these gadgets. There are some solutions for this problem. But better, efficient, affordable and less price solutions are not there.

In this project they are satisfying the conditions above mentioned. Therefor triboelectric generators are invented for harvesting the mechanical energy from small vibrations. Triboelectricity is created when there is a contact separation between two dissimilar materials. These triboelectric generators will reduce the use of batteries and its disposal. This will convert the mechanical energy into electrical energy. The produced electrical energy can be stored into a capacitor for later use.

First, we examined the behaviour of the triboelectric materials that were selected for integration into CFRP. This involved examination and characterization of polyimide and copper using the vertical contact-separation mode. We created simple flat samples to test the effect, to compare with the materials after integration with the CFRP structure. Acrylic plates were used as mechanical substrates and covered by the two materials elected. This included a copper (thickness of 100 micrometre) and a polyimide (thickness of 50 micrometre). Copper is more positively charged than the polyimide (Kapton). As a copper layer is naturally conductive, it did not require any electrode. Commercially available Kapton sheets were already composed of a thin layer of aluminum (30 nm), which acted as an electrode. As direct current is needed for charging, a full wave rectifier was used to convert the alternating current generated by the triboelectric device to the direct current. The system is able to charge a capacitor of 0.1 microfarad up to 15 V in 30 s.

As the copper triboelectric has a larger coefficient of thermal expansion (CTE) than CFRP in the fibre direction (the 1-direction), it tends to shrink more than the carbon fibre. This behaviour corresponds to what we observe in our arch-shaped device. As the Cu-CFRP is an arch-shape, the polyimide-CFRP section should be flat. Knowing the thickness of the polyimide sheet (50 micrometre), one layer of CFRP would have been too thin to ensure the device's strength. To create a flat CFRP polyimide sample, we created a balanced composite layup with three layers of fibres at $0^{\circ}/90^{\circ}/0^{\circ}$ to achieve a flat CFRP-polyimide sample with sufficient CFRP thickness to achieve structural strength. We estimated the deflection to be only 0.04 mm, which agrees well with the manufactured sample that remained flat once removed from the autoclave. Initial testing of the arch-shaped CFRP-Cu and flat CFRP-polyimide indicated poor triboelectric harvesting when the copper and polyimide surfaces experienced contact separation. This was thought to be due to the fact that conduction carbon fibres in the CFRP could be in direct contact with the copper and the polyimide, which would affect the results by creating a short circuit. Therefore, an insulating "peel-ply" (PP) layer is inserted between the CFRP and both the triboelectric copper or polyimide layers.

They have been able to manually produce a voltage up to 300 mV, which can charge a capacitor of 0.1 microfarad to 250 mV. Further improvements were conducted on a second device, similar to the first one, in which glass layers were added on the edge of copper to avoid mechanical friction between the materials. The ability to combine triboelectric and CFRP materials provided a new approach to integrate energy harvesting into engineering structures and manufacture robust devices.

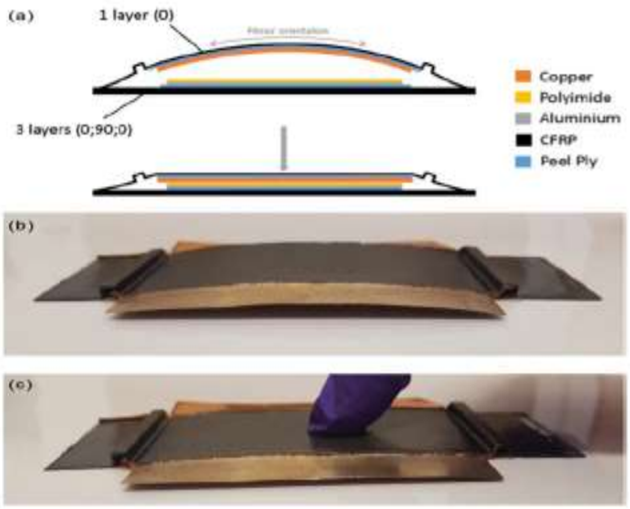

Fig. 3: *(a) Schematic of the One-Piece Triboelectric Device, (b) Opened Position, (c) Closed Position.*

Journal of Optoelectronics and Communication
Volume 2 Issue 1
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CONCLUSION

TENGs open up a lot of potential applications in mechanical structures and even robotics. Last, to require advantage of the self-powered sensing technologies and integrate them with computing. Recently, TENGs are introduced to the realm of present computation that shows the potential of victimisation TENGs to create up associate degree actual device network for any applications. In conclusion, through this analysis, the rising TENG technology has shown nice potential in numerous fields globally and keeps increasing speedily. It can be expected that the upward trend of the TENG development may probably lead to a lot of sensible applications within the future. The projected system with success generated energy from mechanical motions by victimisation triboelectric nanogenerator. This energy is used for charging electronic gadgets in addition because it has several applications which may be worn out future.

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