Energy Tapping from Ones Footwear While Walking

[1] Vaitheeswari.S [2] Praveena.B [3] Mrs.S. Radhika. Assistant Professor, ECE

1. svaishu94@gmail.com 2.praveenabanu93@gmail.com

ABSTRACT

In the last few years, there has been an increasing demand for low-power and portable-energy sources due to the development and mass consumption of portable electronic devices. Furthermore, the portable-energy sources must be associated with environmental issues and imposed regulations. These demands support research in the areas of portable-energy generation methods. In this scope, piezoelectric materials become a strong candidate for energy generation and storage in future applications. This paper describes the use of piezoelectric polymers in order to harvest energy from people walking and the fabrication of a shoe capable of generating and accumulating the energy. In this scope, electroactive β-polyvinylidene fluoride used as energy harvesting element was introduced into a bicolor sole prepared by injection, together with the electronics needed to increase energy transfer and storage efficiency. An electrostatic generator was also included in order to increase energy harvesting.

I. INTRODUCTION

As low-power and wearable electronic devices are more and more present in our everyday life, there is a growing need for the delivery of power to different points of the human body. Table I shows the approximate energy consumption for 1 h of operation of some portable devices that can be considered as possible applications of the energy generated by our system.

TABLE I Approximated energy consumption for 1 h of operation of some portable devices

Device	Energy
Heart rate meter	3 J
Respiratory rate meter	3 J
MP3 Player	350 J
Mobile phone (conversation)	2800 J
Mobile phone (standby)	150 J

TABLE II Comparison between portable-energy and power sources

Power Source	Power (μW/cm³)	Energy (J/cm³)	Power/yr (μW/cm³/yr)	Need of secondary Storage	Need of Voltage regulation	Commercially available
Primary battery	N/A	2880	90	No	No	Yes
Secondary battery	N/A	1080	34	N/A	No	Yes
Micro fuel cell	N/A	3500	110	Maybe	Maybe	No
Ultracapacitor	N/A	50-100	1.6-3.2	No	Yes	Yes
Heat engine	10^6	3346	106	Yes	Yes	No
Radioactive (^{63}Ni)	0.52	1,640	0.52	Yes	Yes	No
Solar (outside)	15000[1]	N/A	N/A	Usually	Maybe	Yes
Solar (inside)	10[1]	N/A	N/A	Usually	Maybe	Yes
Temperature	40[1,2]	N/A	N/A	Usually	Maybe	Soon
Human power	330	N/A	N/A	Yes	Yes	No
Air flow	380[3]	N/A	N/A	Yes	Yes	No
Pressure variation	17[4]	N/A	N/A	Yes	Yes	No
Vibrations	375	N/A	N/A	Yes	Yes	No

[1] Measured in power per square centimeter, rather than power per cubic centimeter.

[2] Demonstrated from a 5°C temperature differential.

[3] Assumes an air velocity of 5 m/s and 5 percent conversion efficiency.

[4] Based on 1 cm³ closed volume of helium undergoing a 10°C change once a day.

The objective of this paper is to harvest energy from piezoelectric materials. The piezoelectric material fabricated inside the shoe which is capable of generating and accumulating energy when people walk.

This project provides solution for converting human mechanical energy into electrical energy. We believe that our approach has the potential to solve these problems for a class of wearable devices by placing both the generator and powered electronics in a location where considerable energy is easily available, namely the shoe.

II. MOTIVATION

Vibration based generators are of three types. They are

A. Electromagnetic generators

B. Electrostatic generators

C. Piezoelectric generator

Vibration based generators works on the principle of converting mechanical energy to the electrical energy. To achieve the required movement, the generators are coupled with the seismic mass. The suspension and the damping are connected to the seismic mass to give the mechanical support from the outside world.

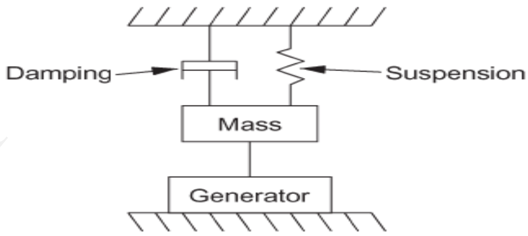

Fig. 1 Schematic diagram of a vibration scavenger

Fig.1 gives the schematic diagram of the vibration based generator device.

The table II specifies the comparison between the vibration based devices and the portable energy devices.

A. Electromagnetic generators

In electromagnetic generator works on the principle that an electromotive force (emf) is induced across a coil if the magnetic flux coupled to the inductor changes as a function of time. The relationship between this emf and the displacement of the mass depends on the design of the system. An expression that relates the emf with the displacement (z) can be written as,

Emf =k (dz/dt) where k is a constant.

k depends upon the number of turns of the coil, their length, area, and shape, and the magnetic field intensity. A similar relationship exists between the mechanical force on the coil and the current through it

F=Ki where K is a constant.

B. Electrostatic generators

An electrostatic generator consists of a capacitor whose value changes as a function of the displacement.

I= [Vo (dc (z)/dt)) +(C (z) (dV/dt))]

Where, V represents the voltage across the charged capacitor, Vo represents the initial value. Vo(dc(z)/dt) represents the value of electromechanical coupling. C (z) (dV/dt) represents the value of the capacitor with respect to the change in voltage and the time.

The electromechanical coupling attains its value when the capacitor is given the voltage of Vo. The capacitor can be charged either by preloading the capacitor or by using the piezo electric materials which is one of the innovative ideas of our paper.

C. Piezo electric generators

The material is said to be piezoelectric when it can perform the conversion of mechanical energy to the electrical energy and vice versa.

The piezoelectric signals are of two types.They are

a. Direct piezoelectric effect.

b. Converse effect.

III. SYSTEM DESCRIPTION

The idea to use footwear to produce energy has been followed for a long time. In the following sections, the basics in piezoelectric polymers will be discussed, and their suitability for harvesting energy will be demonstrated through the construction and test of a sole prototype. This paper shows an integrated way to include the piezoelectric material into a sole, its geometry and harvesting of the energy. In the next sections, the different steps: development and preparation of the electro active material, positioning of the material into the sole of the shoe, readout electronics design, and preliminary test results of the system will be presented.

A. Polymer preparation

The piezoelectric films can be used for the energy generation. These films are constructed by a polymeric material coated in both sides by conducting material which forms the electrode. The polymeric material is based on the polyvinylidene fluoride (PVDF) polymer in its electroactive (β) phase. It can be processed in the form of a film by extrusion and injection, usually in the non- electroactive α phase. To obtain electroactive β phase, films must be subjected with mechanical stretching at temperature below 100 °C and with stretching ratio 4 to 7. (i.e., ratio between final and initial lengths of the sample) This β phase must be activated by polling. This can be done by subjecting the film to an electric field with amplitude larger than 60 MV/m along the thickness direction. We are going for polymeric films instead of piezo ceramics or single crystals because polymer films are more flexible and can be fabricated in the desired shapes through simple processing process. Also these polymer films are cheap compared to piezoceramics. The electro mechanical properties of film can be improved by treatment that consists of pressing, stretching and polling at very high temperatures. The final thickness of the film is in the range of ~ 20 to 60 µm.

B. Positioning of the Piezoelectric Material

As piezoelectricity is a dynamic process, the material should be positioned in places were larger and more variable pressure is exerted during walking. Those places are shown in Fig. 2, together with the first prototype. In this prototype, single layers of electroactive material were placed on the top of the sole.

Fig. 2 First prototype of the energy generator. Two piezoelectric polymer films above the sole.

C. Performance Tests

The material reacts to pressure variations as it is a dynamic process. The generated voltage changes when the pressure on the material increases or decreases. Fig. 4 shows the experimental setup developed for testing the material performance. A shaker applies force to the piezoelectric material at different frequencies and forces. The voltage is recorded on the digital oscilloscope, and the energy is stored in a battery.

Fig. 3. Experimental setup for material testing.

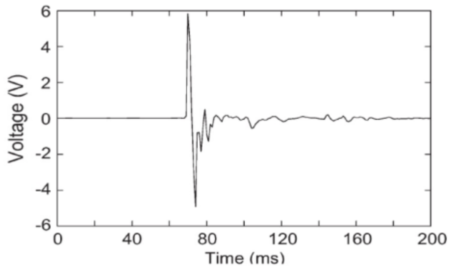

Fig. 4. Voltage change for a single impact applied to the sample.

After the placement of the piezoelectric films into the soles, preliminary tests are performed by simple jumps. Fig. 4 shows the voltage change when a single jump is applied to a 28-µmthick PVDF sample.

D. Electronic Circuit

In order to maximize the energy transfer to battery, a rectifying circuit is necessary in order to obtain a single polarity voltage. This circuit consists of a rectifier bridge with four schottky barriers diodes. (These diodes have a forward bias voltage drop near 0.33V.)

The circuit board of the full wave rectifier is then connected to the piezoelectric element placed in the sole and implemented into a shoe (Fig. 5) and further tests are performed in real walking situations (Fig. 6) for test purpose. This circuit can be further more minimized in order to fully integrate it in the shoe.

Fig. 7 shows a photograph of the final circuit. As can be seen, its dimensions are less than a 1-cent Euro coin.

E. Addition of an Electrostatic Generator

In order to increase the power generation, an electrostatic generator was also coupled to the sole. It consist two metallic plates separated by a flexible dielectric material (foam). When a pressure is applied it changes its thickness, i.e., when the person puts his/her foot on the floor. The steady-state capacitance of this electrostatic generator is 20 pF. When the person steps with a foot on the floor, the capacitance increases about two times, this means that the voltage decreases to one-half. At this time, the piezoelectric voltage is higher than the one at the electrostatic generator terminals; therefore, its capacitance will be charged.

When the person presses the shoe, the capacitance of the electrostatic generator decreases and the voltage increases. In this case, the load is an energy storage device (battery of 3 V); therefore, when the voltage of the electrostatic generator exceeds that of the battery, the charge of the first is transferred to the second. Fig. 8 shows the schematic diagram of the electrical connections between the piezoelectric element, the electrostatic generator, and the load.

Fig. 5. Sole and electronic circuit placed in the shoe.

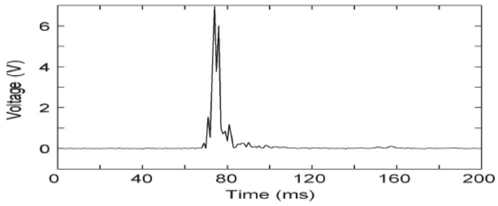

Fig. 6. Voltage versus time after rectification for a single impact applied to the generator.

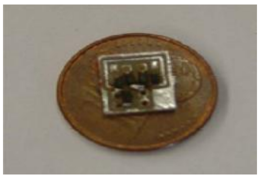

Fig. 7. Circuit implemented in the final prototype shown on a 1-cent Euro coin.

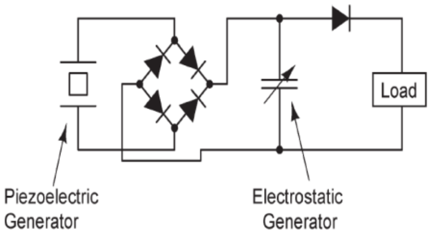

Fig. 8. Schematic diagram of the connections between the piezoelectric film and the electrostatic generators.

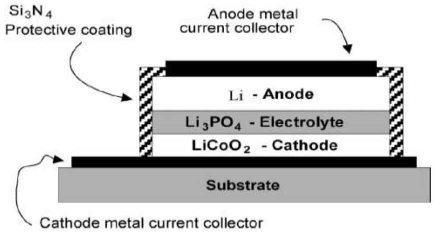

Fig. 9. Cross section of a thin-film lithium battery.

F. Energy Storage

A thin-film rechargeable lithium battery (Fig. 9) can be used to store the energy generated. All-solid-state lithium batteries, fabricated entirely of thin-film components, achieve capacities over 35 µA · h/cm2, with current densities above 200 µA/cm2, in less than 10 µm of thickness.

IV. EXPERIMENTAL RESULT

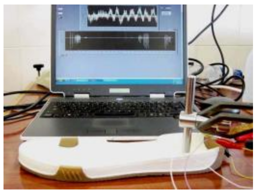

Fig. 10 Performance test. A handspike system was used in order to apply constant pressure impulses to the sole.

Fig. 10 shows the system introduced in a bicolor sole of a shoe prepared by injection molding. It is important to notice that, during this process, temperatures higher than 160 ◦C are reached at certain points of the sole. The power generated by the PVDF foil within the shoes ranges from tens to hundreds of mill watts, depending on the area, the placement, the geometry, and the numbers of foils. It is particularly important that the system allows stretching and not just pressing of the foil, as the longitudinal electromechanical coupling of PVDF (k31) is more efficient that the k33 mode. In this way, the PVDF foils are more efficient in the electromechanical conversion when they are introduced within the sole in the form of a bimorph. A bimorph converts the foot pressure toward the bottom into a combination of pressing and stretching of the PVDF films, making use, in this way, of the k33 and k31 electromechanical conversion. Important for the generation of energy is also the number of polymer layers in each piezoelectric element.

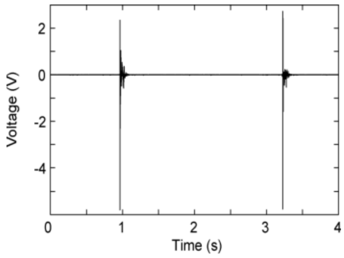

Fig. 11 Voltage generated by a person walking.

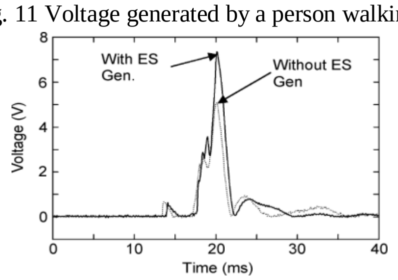

Fig. 12 Voltage generated by a person walking with and without the electrostatic generator.

The fig. 11 shows the voltage generated by a person walking. The voltage generated in a system with two superimposed layers of piezoelectric material was also tested. The generated voltage was approximately double that of the one generated by the single-layer system. The Fig. 12 shows the whole (piezoelectric + electrostatic) performance. It is possible to see that the output peek voltage value is greater in the case that uses the electrostatic generator. Moreover, its time response is slower, which means that the associated piezoelectric-electrostatic generator supplies energy to the load during a long time interval.

We have introduced an idea that the energy generation could be improved by increasing the thickness of the piezoelectric polymer film or by placing four or six generators in each sole or by using films with increased properties with respect to piezoelectricity and elasticity.

V. Conclusion

From the several methods available to integrate energy generating elements harvesting human energy, piezoelectric materials associated with electrostatic generators seem to be one of the most promising elements. In particular, electroactive polymers are particularly used due to their low cost, flexibility, and easy integration into shoes. In this paper, electroactive polymers based on β-PVDF have been used in order to fabricate an energy-harvesting system fully integrated into the sole of a shoe. Through the simple configuration and electronics, energy harvesting is possible.

References

[1] J. G. Rocha, L. M. Gonçalves, P. F. Rocha, M. P. Silva, and S. Lanceros-Méndez, Energy Harvesting From Piezoelectric Materials Fully Integrated in Footwear. Ieee transactions on industrial electronics, vol. 57, no. 3, March 2010

[2] S. Roundy, P. K. Wright, and J. Rabaey, Energy Scavenging for Wireless Sensor Networks With Special Focus on Vibrations. Norwell, MA: Kluwer, 2003.

[3] Nathan S. Shenck, A Demonstration of Useful Electric Energy Generation from Piezoceramics in a Shoe. Submitted to the Department of Electrical Engineering and Computer Science on May 21st, 1999.

[4] Loreto Mateu and Francesc Moll, Review of Energy Harvesting Techniques and Applications for Microelectronics.