Development of Piezoelectric Nano- generator with Super-Capacitor

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Abstract— *Harvesting mechanical energy from human motion is an attractive approach for obtaining clean and sustainable electric energy to power wearable sensors, which are widely used for health monitoring, activity recognition, gait analysis and so on. This paper studies a piezoelectric energy based device which conserve mechanical energy in shoes originated from human motion. The device is based on a on a pressure based energy generation. Besides, consideration is given to both high performance durability and build with repect to keeping the comfort in mind . The device provides an average output power of 1 mW during a walk at a frequency of roughly 1 Hz., a direct current (DC) power supply is built through integrating the device with a power management circuit.*
Keywords— super capacitor, piezoelectric, sensors.

I. INTRODUCTION

Wearable sensors are becoming smaller and increasingly widely used, resulting in an increasing need for independent and compact power supplies. Electrochemical batteries, the most common power supplies for wearable sensors, cannot meet the need because of their limited energy storage capacity and potential environmental and health risks, emerging as a critical bottleneck for wearable sensors. This has driven the development of wearable energy devices, which harvest the mechanical energy dissipated in human motion to provide renewable and clean energy .Several concepts of wearable energy harvesters based on different mechanisms have been studied, such as electromagnetic ,electrostatic. Piezoelectric energy harvesters and nano-triboelectric generators can convert mechanical energy into electric energy directly, thus their structures are more compact and simpler in comparison to those of other types. Other devices require a transducers or inductors for the same. The materials for nano-triboelectric generators are generally not accessible in the market, hence this work focuses on piezoelectric energy devices. The mechanical energy dissipated in shoes(through pressure by human motion) can even power a mobile if fully charged, serving as an attractive energy source for wearable devices. This paper develops a shoe-embedded piezoelectric energy harvester, which can be integrated in a shoe readily for energy harvesting from human locomotion with little discomfort for the wearers. The device is based on a specially designed sandwich structure, resulting in a thin geometrical form, a high performance and an excellent durability. Some of the device prototypes are made and tested. The first one is made up of a multilayer PVDF film and a structure of engineering plastics, which is placed under the heel. The second one is designed as an insole shape and used as a normal insole, consisting of a structure of flexible silicone rubber and two multilayer PVDF films.More power can be generated by the former prototype, while the other one has an advantage of remarkable comfort. In order to store the harvested energy and provide a constant DC output voltage, a power management circuit is designed. A series of experiments are performed to characterize the device prototypes, proving that the device can serve as a wearable power supply for low power wearable sensors and potentially provide a valuable alternative to the use of batteries.

II. NEED OF THE DEVICE

As the world is growing rapidly so it consumes a high amount of energy. Energy coming into the picture, it can be broadly classified as Direct and Indirect sources. While speaking of Direct sources :Sun, Wind ,Water and Indirect Sources are fossil fuels, reactors etc. They both have their limitation and effects for one whose Implementation cost is higher while Cost has its adverse effect on the environment respectively. This project is developed so as to generate a clean Energy at much lower Cost for its Implementation and without any harmful effect on both the Environment as well as the human body and Also promotes Health and Fitness.

Harvester Design:

The main structure of the harvester is a sandwich structure, where a multilayer PVDF film is sandwiched between two wavy surfaces of a movable upper plate and a lower plate, as shown in Figure 1a. The multilayer PVDF film (Figure 1b) is fixed on the lower plate, and composed of several PVDF layers which are wired in parallel for a high output current. When the upper plate is subject to a compressive force produced by foot, the upper plate moves down and the PVDF film is stretched along 1-axis simultaneously, as presented in Figure 1c. This leads to a piezoelectric field created inside every PVDF layer, driving the free electrons in the external circuit to accumulate on the upper and lower 3-axis surfaces (electrodes) of every PVDF layer to screen the piezo-potential. When the force is lifted, the upper plate moves up and the PVDF film is relaxed, therefore the piezo-potential diminishes, resulting in releasing the accumulated electrons. A dynamic force *Ffoot* applied by foot on the upper plate drives the electrons in the external circuit to flow back and forth with an alternating current (AC) output. The sandwich structure is characterized by the inner wavy surfaces, where arc-shaped grooves and arc-shaped ribs exist. The specially designed surfaces enable the PVDF film to generate a large longitudinal deformation and reduce the device thickness, which enhances the harvesting performance and makes it possible to integrate the harvester into a shoe whose inner space is limited. The Ac current generated is then passed to the Super capacitor(SC) where it is to be stored ,the benefit of use of super capacitor instead of a rechargeable battery is that the SC gets charged Quickly and can store amount of energy.

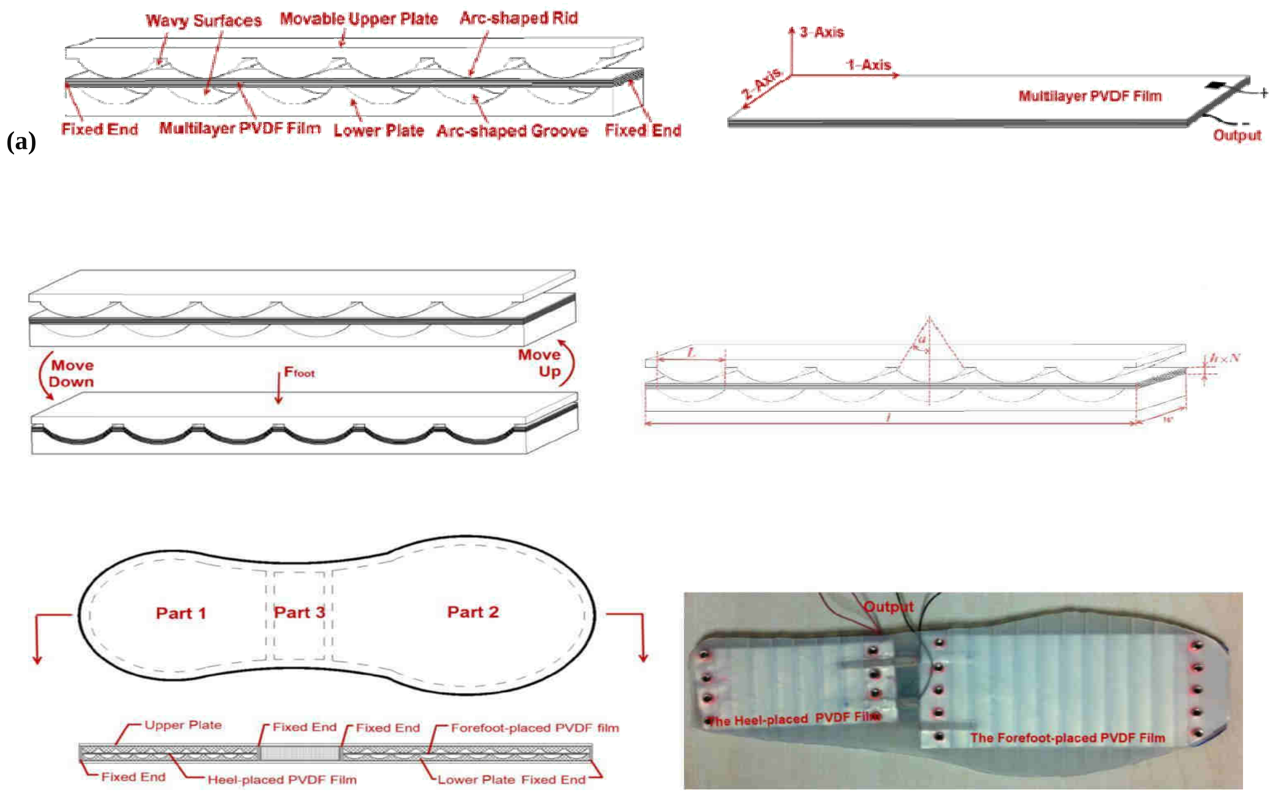

Fig.1: *(**a**) The sandwich structure of thedevice; (**b**) The multilayer PVDF film; (**c**) The force applied by foot drive the upper plate to move up and down circularly; (**d**) The design parameters.*

Super capacitors:

Super capacitors (SC's) are energy storages having similarities with both batteries and conventional capacitors. Unlike batteries, SC's store electrical energy, not chemical energy. Unlike capacitors SC's contain moving ions. Super capacitors have many names: electrochemical capacitor (EC Capacitor), Electric double-layer capacitor (EDLC), ultra capacitor , ... All meaning the same thing. Super capacitors can be fully charged and discharged in seconds, even in several degrees below zero; Almost linear voltage curves enables very accurate state of charge (SoC) estimations; SC's can be charged and discharged even up to a million times.

In discharged state all the ions are distributed randomly within the cell. In charged state all the positive ions travel to the negative terminal and vice versa. The higher the carbon electrode surface area is, the higher the cell capacitance is.

Table: Comparison Super Capacitor and Li-ion

Function	Supercapacitor	Lithium-ion (general)
Charge time	1–10 seconds	10–60 minutes
Cycle life	1 million or 30,000h	500 and higher
Cell voltage	2.3 to 2.75V	3.6 to 3.7V
Specific energy (Wh/kg)	5 (typical)	100–200
Specific power (W/kg)	Up to 10,000	1,000 to 3,000
Cost per Wh	$20(typical)	$2 (typical)
Service life (in vehicle)	10 to 15 years	5 to 10 years
Charge temperature	–40 to 65°C (–40 to 149°F)	0 to 45°C (32° to 113°F)
Discharge temperature	–40 to 65°C (–40 to 149°F)	–20 to 60°C (–4 to 140°F)

III. DISCUSSION

Compared with other reported shoe-embedded PVDF energy harvesters, the harvester proposed here has advantages of a thin geometrical form, high performance and an excellent durability, benefitting from its specially designed sandwich structure. The deformation of the multilayer PVDF film is kept elastic and the maximum deformation is close to PVDF elastic limit, thus there is a tradeoffs between performance and durability. The average power of the harvester is up to 1 mW (at 1 Hz), which approximates the power of 1.1 mW (at 1 Hz) of the PVDF insole in reference .While more comfort and durability can be provided by our design. By combining the merits of different prototype , a better harvester can be developed with addon functionality in the future work. The arc-shaped grooves and ribs on the wavy surfaces will be made of some harder material, polyurethane for example, to improve the PVDF film deformation for more energy produced, and the other parts of the plates are made of flexible material to keep users comfortable. In addition, increasing the number of PVDF layers serves as another approach to improving generating performance.

IV. CONCLUSIONS

A shoe-embedded piezoelectric energy device is developed in this paper, and it can be integrated in a shoe readily for energy harvesting from human locomotion. prototypes with different characteristics are to be fabricated and tested with Super Capacitors.

The DC power supply system, including the device and a power management circuit, is added to collect the mechanical energy produce while pressure applied by human body and is stored in SC and power some low-power wearable sensors, such as activity trackers,Heart rate monitors ipods. Even though the device is unlikely to replace completely the batteries in all wearable sensors, it is a significant role in reducing the problems related to the use of batteries. The work presents a successful attempt in harnessing the kinetic energy expended during person's everyday actions to produce power for wearable device.

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