Journal of Engineering and Science Research 7 (1): 01-04, 2023
e-ISSN: 2289-7127
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DOI: 10.26666/rmp.jesr.2023.1.1

Design Footstep Power Generator Using Barium Titania

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Received: 01 November 2022; Revised: 05 November 2022; Accepted: 30 December 2022; Published: 10 February 2023

Abstract: Healthy human walks every day yet the energy from walking is not exploited. In order to harvest the energy from walking, piezoelectric material is applied because it possesses the ability in transforming mechanical energy into electrical energy. This work presents the fabrication process of footstep power generator using barium titanate as piezoelectric material. Piezoelectric sensors were first fabricated by pressing the deposited barium titanate on the copper substrate using the pelletizer. Subsequently, a foot step power generator was built by connecting the piezoelectric sensors with a full wave bridge rectifier and a lead acid battery. The output voltages of the fabricated footstep power generator with 1, 3 and 5 barium titanate piezoelectric sensors connected in series are measured and analysed. The experiment results show that the output voltage is directly proportional to human body weights stepping on the device and the energy conversion efficiency increases with the number of sensors. In conclusion, a small voltage was generated by human steps with the footstep power generator fabricated using barium titanate piezoelectric sensors.

Keywords: *Energy Harvester, Barium Titanate, Piezoelectric, Micropower Supply.*

1. Introduction

Walking is one of the natural activities for a healthy human. Gurusamy reported that Malaysians averagely walk 3,963 steps everyday [1]. However, the energies produced by human steps are still untapped. Piezoelectric material is a material that can convert mechanical energy from vibration and pressure into electrical energy. Hence, it has great potential in harvesting the energy from human steps to produce small voltage. This small voltage can be used to power up electronic devices [2]. The objective of this work is to demonstrate the generation of voltage from human steps.

Recently, many piezoelectric materials are studied for the purpose of energy harvesting such as barium titanate, lead-zirconate-titanate (PZT), potassium niobite, polylactic acid, and polyvinylidene fluoride [3]. Among these piezoelectric materials, PZT is the most dominant material in energy harvesting researches due to its strong piezoelectric effect. Ang et al. [4] developed a footstep power generator with the rack and pinion concept. Kamboj et al. [5] designed a footstep power generator to stored two 6V batteries. Jeevan et al. [6] proposed a power harvesting system to charge E-vehicle. Apart from these projects, numerous footstep power generators were demonstrated recently [7-10].

However, there are only limited projects demonstrated the output voltage per step, the effect of human body weights and number of piezoelectric sensors on the output voltages of the footstep power generator. In 2018, Teh and Dahari demonstrated [11] that ~13 V was generated by 6 pieces PZT piezoelectric sensors which connected in series. In the same year, Abadi, Darlis and Suraatmadja [12] reported an average voltage of 63.98 V was generated when 20 pieces parallel connected PZT piezoelectric sensors were pressed by a 60 kg-weight human for 30 seconds. In 2020, Jai

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Ganesh et al. [10] fabricated a footstep power generation system with 12 pieces PZT piezoelectric sensors. The average output voltage generated by a 60kg human footstep was 0.555mV. However, the application of PZT materials has a disadvantage, which is the preparation and disposal of PZT materials will cause toxic lead to be released into the environment [13].

Lead toxicity increases the researchers' interest in environmentally friendlier piezoelectric materials. Barium titanate was discovered in 1947, even earlier than the discovery of PZT [14]. Barium titanate is one of the lead-free piezoelectric materials. It has high piezoelectric coefficient (149 pC/N) and dielectric constant (100-11000) [15]. The applications of barium titanate in fabricating the energy harvesting system usually involve barium titanate nanostructures in piezoelectric composite film [16, 17]. Sahu et al. [16] reported an output voltage of 7.2 V was generated by polyvinylidene fluoride – barium titanate composite films piezoelectric sensor upon finger tapping. In this work, barium titanate piezoelectric sensors are fabricated with a simple method. A footstep power generator is designed using barium titanate piezoelectric sensors to harvest untapped energy from human steps.

2. Materials and Methods

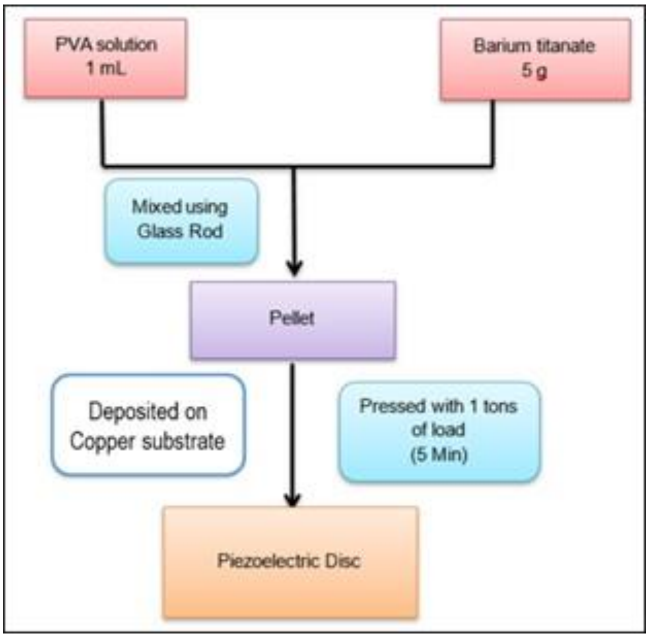

Figure 1. Flowchart of fabricating barium titanate piezoelectric sensors.

Figure 1 shows the flowchart of fabrication process for piezoelectric sensors using barium titanate. Firstly, 5-gram barium titanate was mixed with 1 ml polyvinyl alcohol (PVA) solution by stirring the mixture with a glass rod. PVA worked as a binder in the fabrication process. Subsequently, the mixture was deposited on a copper substrate. It was then pressed with pelletizer at 1 ton of loads for 5 minutes. A piezoelectric sensor in disc form was fabricated.

Figure 2 shows the fabricated piezoelectric sensor by pressing the mixture of barium titanate and PVA on a copper substrate with pelletizer. The dimension of the copper substrate was 35 mm × 50 mm and 0.1 mm thickness.

Figure 2. Fabricated barium titanate piezoelectric sensors with a copper substrate at the dimension of 0.1 mm × 35 mm × 50 mm.

In this work, 1, 3 and 5 fabricated barium titanate piezoelectric sensors were connected in series as shown in Figure 3, 4 and 5 to measure generated output voltages. The full wave bridge rectifier was used in the measurement to rectify the output voltages that generated by piezoelectric sensors because they were random in polarity. The polarized output voltages were used to charge a lead acid battery for energy storage. A voltage sensor which controlled by an Arduino Uno microcontroller board was connected to the lead acid battery for displaying voltage level inside the battery.

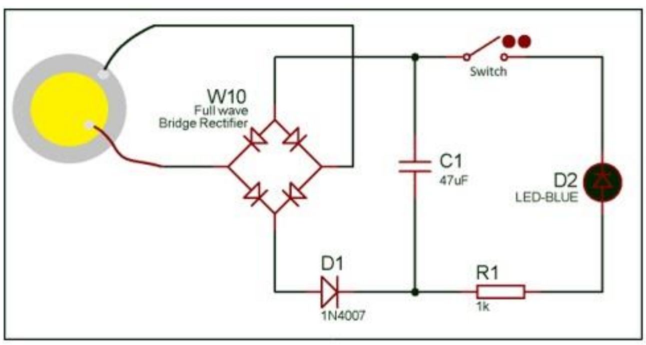

Figure 3. Circuit diagrams of footstep power generator with a piezoelectric sensor [18].

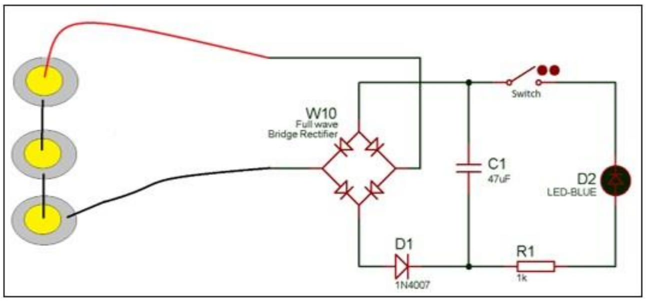

Figure 4. Circuit diagrams of footstep power generator with 3 piezoelectric sensors were connected in series.

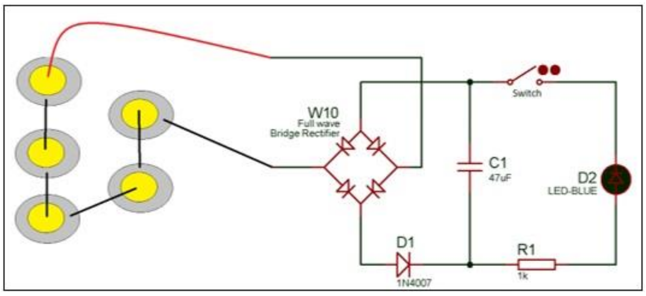

Figure 4. Circuit diagrams of footstep power generator with 5 piezoelectric sensors were connected in series.

The experimental setup of footstep power generator using barium titanate piezoelectric sensors in this work is exhibited in Figure 6. The barium titanate piezoelectric sensors were placed underneath an acrylic plate. Output voltages were generated by the barium titanate piezoelectric sensors when people were stepping on the acrylic plate as shown in Figure 6. To investigate the performance of this setup, the output voltages generated by this footstep power generator were measured for different human body weights.

Figure 6. Output voltage measurement setup for footstep power generator.

3. Results and Discussion

Table 1 shows the average output voltage of piezoelectric sensors when different human body weights are stepped on the footstep power generator. It is apparent that the average output voltage is linearly proportional to the human body weights for footstep in the investigated range, as plotted in Figure 7. Teh and Dahari reported that a higher electrical energy was generated when a larger human body weight was applied on their energy harvesting system [11].

Table 1. Average output voltage of footstep power generator versus human body weight at different number of piezoelectric sensors.

Weight	**1 sensor**	**3 sensors**	**5 sensors**
65 kg	6.6 mV		
78 kg		21.6 mV	30.4 mV
85 kg	8.6 mV		
92 kg		23.6 mV	47.8 mV
115 kg		33.4 mV	55.0 mV
130 kg	12.3 mV		

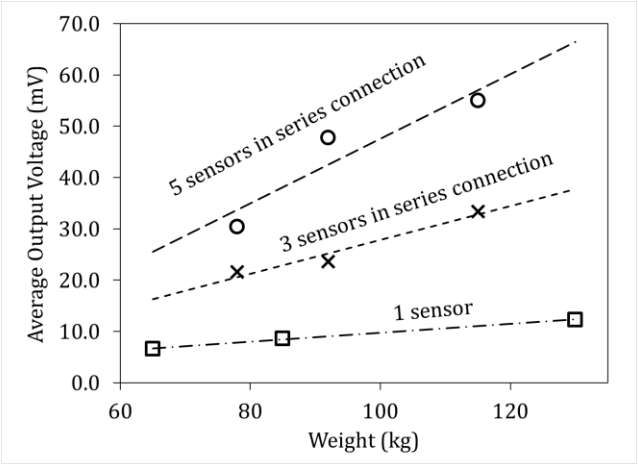

Figure 7. The graph of average output voltages of footstep power generator versus human body weight at different number of piezoelectric sensors.

From Figure 7, the gradient of plots for 1, 3 and 5 sensors are 0.0868, 0.3295 and 0.6301, respectively. This result shows that more piezoelectric sensors can generate higher average output voltage when a heavier human is stepping on the footstep power generator. As a result, the efficiency of footstep power generator in harvesting energy can be increased with number of piezoelectric sensors.

From Table 1, 30.4 mV was generated by the footstep power generator when a 78 kg human stepped on the generator. To increase 1 V charge in battery, 33 steps are needed. Hence, a 12 V battery can be charged if a 78 kg human walks 396 steps on the footstep power generator. If the human walks at the pace of 2 steps per second, 3 minutes and 18 seconds is needed. Compare to Jai Ganesh et al. [10] and Sahu et al. [17], this work generates lower average output voltage. However, this footstep power generator implements a lead-free material as piezoelectric sensors with a simple fabrication method.

4. Conclusion

In this work, a footstep power generator has been fabricated successfully using barium titanate, the lead-free piezoelectric material. It is demonstrated that the average output voltages generated by the footstep power generator is directly proportional to human body weight that stepping on it. In addition, the number of piezoelectric sensors can increase the efficiency of footstep power generator in harvesting energy. The future direction for this work is to increase the efficiency of the device by optimizing the number of piezoelectric sensors.

5. Acknowledgements

The author would like to thank Multimedia University for providing the facilities and supports in completing this work.

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