Designing and Fabricating a Prototype of the Elastic Thermoelectric Generator

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Abstract. The elastic thermoelectric generator (ETEG) was fabricated by using 27 couples of n-Bi$_2$Te$_3$ and p-Sb$_2$Te$_3$ bulk thermoelectric materials in size of 3 $\times$ 3 $\times$ 5 mm$^3$ on silicone substrate and using copper plate for electrodes. It was found that the open circuit voltage shows maximum value of 46.74 mV at temperature difference 13.85 K. External load resistences were apply in the measurement and varies for obtaining the maximum output power. The matched load resistance is 0.22 $\Omega$ obtaining maximum power about 3.46 mW at temperature difference of 13.85 K. The output power, voltage and current were increased with temperature difference increasing and show maximum values about 35.19 mW, 27.82 mV and 126.36 mA at temperature difference 12.75 K.

1. Introduction

Thermoelectric generator (TEG) is device to convert heat energy into electrical energy and vis versa by Seebeck effect: $S = \Delta V / \Delta T$ where $\Delta V$ is electromotive force (V) and $\Delta T$ is temperature difference (K). These devices is easily to fabrication and low cost due to many thermoelectric materials for example alloy materials, semiconductor compounds and oxide materials. Moreover, TEG is applied to microgenerator [1], microelectronics, no moving parts, no noise and friendly environment [2–3]. The general substrate of TEG devices is strongly from alumina or ceramics can’t bend or flexible with human body skills.. S.E. Jo et al. shows the simple fabrication process of flexible TEG using polydimethylsiloxane (PDMS). The fabricated thermoelectric generator was attached to the human body for generating electrical energy. When the temperature difference between the human body and ambient air was 19 K, the output power of the thermoelectric generator was 2.10 mW [4]. Sung-JinJung et al. were reported a flexible thermoelectric generator made of porous PDMS fillers and Bi$_2$Te$_3$-based thermoelectric legs and found that Eight flexible thermoelectric module connected in series successfully operated 32 LEDs for more than 30 minutes [5]. Taemin Kim et al. were experimental evaluation of a flexible thermoelectric generator and found that the most influential parameters were the contact pressure, which could affect the generation by 10 – 20 mW (increased by up to 83.30%), and the choice of thermal interface material (increased by up to 51.90%) [6]. This work has proposed model and fabricated ETEG by using silicone substrates to generate electricity from heat on human body skin.
2. Materials and Methods

The fabrication of ETEG was started by making a mask for sticking Cu electrode on the silicone as shown in Fig. 1 (a). The 6 TE pellets were connected in parallel on 1 Cu plate for 1 leg. The module was used totally 5 legs of P-type and 5 legs of N-type connecting by series junction as shown in Fig. 1 (b). The p and n legs were connected by Cu plate as shown in Fig. 1 (c). Finally, leading wires were connected on the first p and last of n leg as shown in Fig. 1 (d).

To evaluate the performance of the fabricated TEG, the TEG was placed on the measurement setup, which consisted of a heating unit and cooling unit. The electrical characteristics of the TEG were measured using an oscilloscope, a microammeter, and an LRC meter. The temperatures of the heating unit and cooling unit were measured using a thermocouple temperature sensor.

![Fig. 1 shows the fabricated ETEG](image)

3. Results and Discussion

The open circuit voltage was measured in hot side and cool side temperature ranges of 301 – 330 K and 301 – 317 K, respectively obtaining temperature difference of 0 – 13.85 K as shown in Fig. 2. The open circuit voltage show increase with temperature difference and exhibit maximum value about 46.74 mV at temperature difference 13.85 K as shown in Fig. 2.
Fig. 2 The open circuit voltage depends on temperature difference

The matched external load resistance was obtained by various value from 0.06 – 0.88 Ω and fix temperature difference at 13.85 K. The voltages were increased with increasing load resistance while output power also increasing until 0.22 Ω after that decrease. The maximum output power was obtained about 3.45 mW at external load resistance 0.22 Ω namely that is matched external load resistance as shown in Fig.3.
The output power and voltage depending on temperature difference ranges of 0 – 13.85 K were measured by using matched external load resistance of 0.22 Ω. Both of values show increase with temperature difference increasing and obtain the maximum value of 3.51 mW and 27.82 mV at temperature difference 13.85 K, respectively.

Fig. 3 The relationship between voltage, current and power
Fig. 4 The voltage and power depends on temperature difference

4. Conclusion
The ETEG is proposed. The proposed ETEG comprises thermoelectric materials that are inserted into a thick polydimethylsiloxane film. The ETEG was easily fabricated using dispenser printing. The fabricated ETEG was flexible, and hence, it could be attached to the human body and successfully generate electrical energy. When the ambient temperature was 301 K, the ETEG generated an output power of 2.1 mW at the human body.

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