Performance Study on Thermoelectric Voltage Generation Using Infrared Light Source

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***Abstract*— Thermoelectric (TE) module is energy harvester that transfer heat to electrical energy. However, it can be complemented with photovoltaic (PV) cell by using sunlight as source and convert into electrical energy. This is due to the fact that the spectrum of sunlight from ultraviolet (UV) to infrared (IR) is not fully utilized, whereby at the IR light spectrum PV cell does not perform at its optimum in conversion into electrical energy. However, IR spectrum produces heat, which is good for TE module. In this paper, the experiment will carry out in the lab. IR light bulb is used to simulate the IR spectrum from sunlight. Besides, a convex lens is used to focus the light beam from IR light. Therefore, the light is focused and can obtain higher temperature. When the temperature is increased, the voltage output of the TE module will also be increased. In the experiment, two different covers are put on the top of TE module which is aluminium sheet and heat sink. The performance study of TE module is focused on open circuit voltage output of the module. The comparison is also made to investigate the voltage output of TE module with cover and without cover and it is found out that a voltage of 0.35V can be achieved at a temperature difference of only 12 °C when using a heat sink to spread the heating source uniformly on the TE module.**

***Index Terms*— Convex Lens; Energy Harvesting; Seebeck Effect; Temperature Gradient; Thermoelectric (TE) Module.**

I. INTRODUCTION

The energy harvester is the generator that converts waste energy into useful electrical energy. The most common harvester that converts heat energy into electrical energy is Thermoelectric (TE) module. Many electronic systems will generate heat while it is operating such as automotive internal combustion engines[1]. Besides of this, some of the research obtain the heat source from heat pipes [2], gamma radiation [3], chimney [4] and so on.

Lauri and Matti[1] reviewed some other paper and discovered a suitable heat source for TE module which is automotive internal combustion engine. Therefore, they also suggest diesel engine as a location to obtain heat energy and the heat produced is enough to harvest energy. From the study, they discovered that the highest temperature gradient of TEG by using diesel engine as a heat source could reach 200°C. In addition, the voltage output of the TE module is 0.0376V/°C. Besides, Toshihiko and Hiroaki[2] suggested using heat pipes as heat source to generate the voltage. TE module is sandwiched by heat pipes and heat sink. The highest temperature gradient is about 50°C. The output voltage of this experimental set-up is about 0.00656V/°C. In addition, Jie Chen[3] suggests gamma radiation as a heat source for the TE module. Additionally, the heat sink is attached to TE module to release the heat from the cold surface. Thus, the higher voltage can be generated from TE module. In the research, the highest temperature gradient is about 120°C, and the output voltage is 0.0508V/°C. On the other hand, Rajeh and Kiran[4] discovered the chimney from the industrial plant can be used as heat source also. From this paper, they realize that the highest temperature by using industrial plant is about 85°C and the output voltage is 0.0198V/°C.

In this paper, the heat source of the TE module is IR light beam. Firstly, TE module is characterized by using heater the voltage output and temperature gradient is recorded and plotted in the graph. Next, the temperature of the IP light with focus and without focus is measured. Then, the output voltage of TE module with cover and without cover are measured. Lastly, the voltage output of TE module by using IR light as a heat source is compared to the voltage output of characterization TE module.

II. THERMOELECTRIC (TE) MODULE

TE module transfers heat energy into electrical energy by using Seebeck effect. Seebeck effect was proposed by T.J Seebeck in 1821; electrical energy is generated between two dissimilar conductors while both conductors connect with different temperature [5].

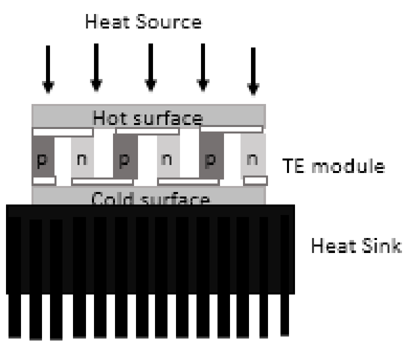

Figure 1: Schematic diagram of TE module

Figure 1 shows the schematic diagram of TE module. TE module consists pairs of p-n junction which are two dissimilar semiconductors so the electron can flow through it. The p-n junctions are connected electrically in series and thermally in parallel. When heat is applied to the hot surface of TE module, and released from the cold surface, TE module will produce electrical energy. The voltage output of the TE module depends on the temperature gradient that applies to TE module. In addition, the ceramic plate is used to cover the combination of thermocouple because the ceramic plate is good heat conduction and high electric resistance material [7].

III. EXPERIMENTAL SET-UP

Firstly, the TE module is characterized by using the heater. The open circuit voltage output and temperature gradient of TE module were measured and plotted in the graph.

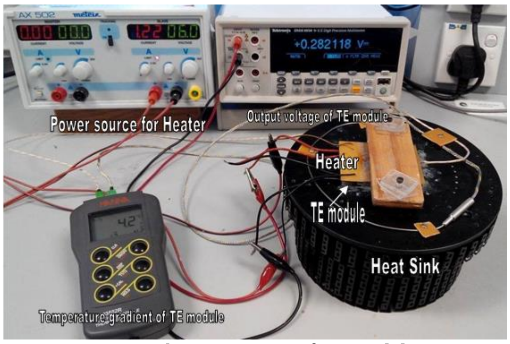

Figure 2: Characterization of TE module

Figure 2 shows the set-up for characterization of TE module. The heater was used as heat source for TE module, and heat sink on the bottom was used to release heat from TE module. After that, the result was recorded and plotted in the graph.

Then next measuring is the temperature of IR light bulb with focused and without focus. In this part, two thermocouples were used to measure this two different temperature. Thus, one of the thermocouples is place on the bottom of the lens. The other thermocouple was placed in outside focused area.

Figure 3 and Figure 4 show the experimental set-up to measure the temperature. The length between convex lens and device under test is focus length which is 5cm, and the distance between IR light bulb and a convex lens is between 10cm until 55cm. The variance reading was taken by every 5cm different. Then, the results were plotted in the graph and discuss.

Next, the device under test is changed to TE module. The TE module used in this experiment is Laird Technology UltraTEC series. The dimension of the TE module is 52mm in length and width, 3mm in thickness. Then, open circuit voltage output of TE module was measured using a multimeter and plotted in the graph

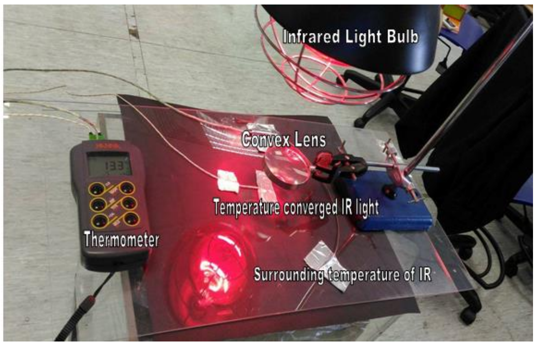

Figure 3: Measuring IR temperature

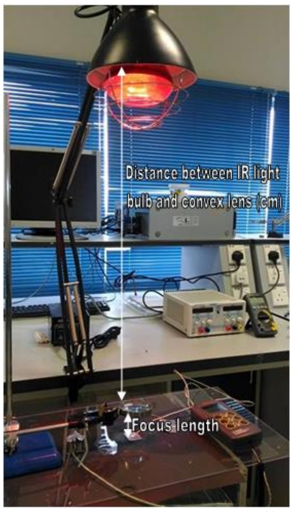

Figure 4: IR temperature reading taking with different distance (cm)

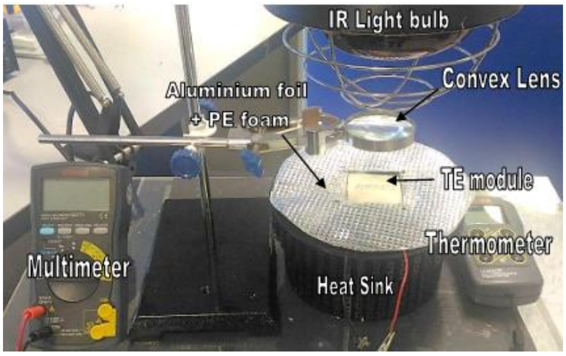

Figure 5: Focused IR light on TE module

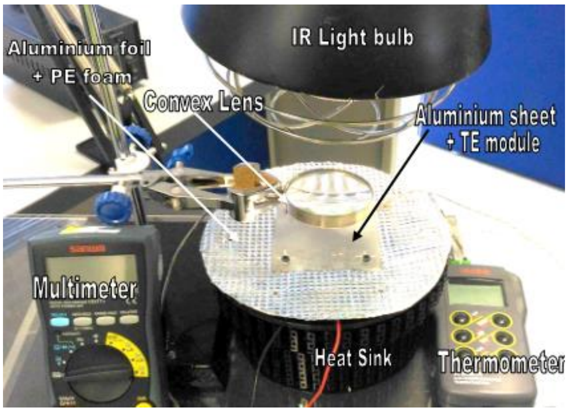

Figure 6: Focused IR light on aluminium sheet

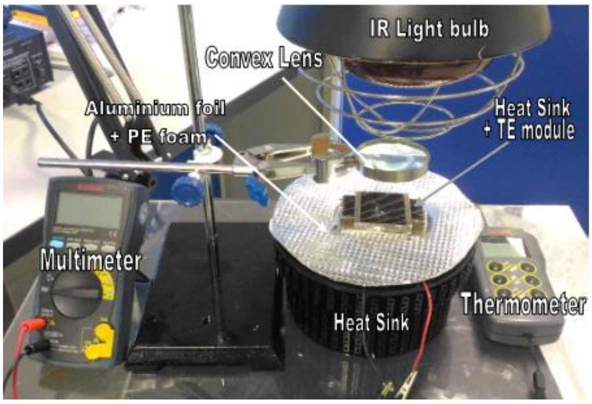

Figure 7: Focused IR light on heat sink

Figure 5, Figure 6 and Figure 7 show the experimental set-up to obtain the voltage output of TE module. Figure 5 shows the focused IR light direct focus on TE module; Figure 6 shows the aluminium was put on top of TE module, and Figure 7 shows the heat sink was placed on top of TE module. Aluminum sheet and heat sink can dissipate heat formally in TE module. Besides, aluminium foil used to reflect the heat and PE foam was used to insulate the heat from the heat sink. In addition, the heat sink used is in 19cm diameter and 9cm height. To avoid the air flow between heater, TE module and heat sink, thermos paste was used to reduce the air gap between. Therefore, it can increase the heat conduction of TE module. In addition, the thermometer was used to measure the temperature gradient of TE module. Lastly, the voltage output of TE module by using heater and IR light bulb as a heat source is plotted in the same graph and compared.

IV. Result and Discussion

The figure below shows the open circuit voltage output of TE module; the voltage output was measured every 5˚C increased on the temperature gradient of TE module.

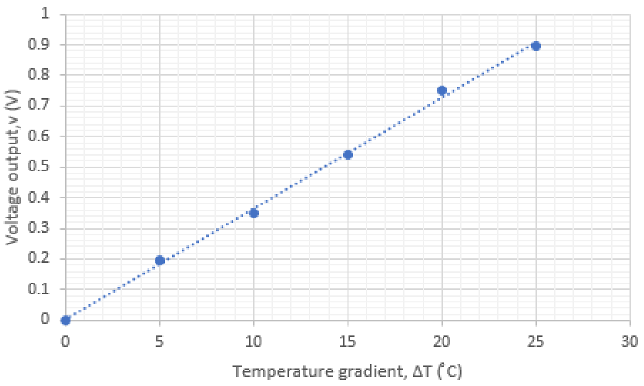

Figure 8: Temperature gradient (°C) versus voltage output of TE module

Figure 8 shows that, the voltage output of TE module is increasing while the temperature gradient of TE module is increased. Therefore, voltage output and temperature gradient of TE module is directly proportional. The voltage output per degree Celsius of TE module is 0.035v/ ˚C. After that, the voltage output will compare with the voltage output of TE module by using IR light bulb as ha eat source.

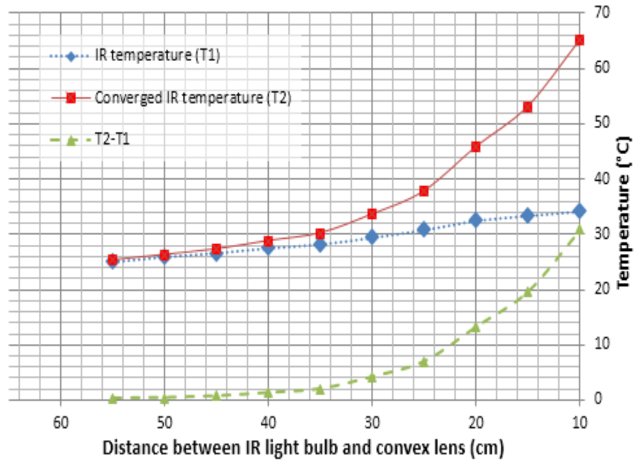

Figure 9: Temperature (°C) versus distance between IR light bulb and a convex lens

Figure 9 shows the reading from the thermometer, which is temperature IR light, focused IR light, and the different both of the temperatures. The reading was taken when the distance between IR light bulb and convex lens between 55cm until 10cm. From Figure 9, it shows temperature different (T2-T1) has not much difference when the distance is between 55cm and 35cm. However, the temperature difference has dramatically changed when the distance less than 35cm. Moreover, the temperature difference is 30.9°C when the distance is 10cm. Therefore, it proves the convex lens can optimize the temperature difference from the IR light.

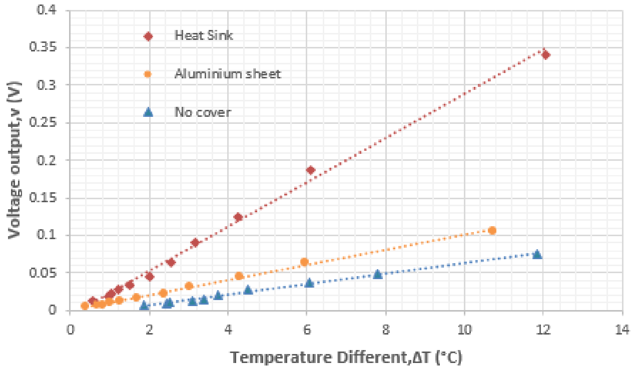

Figure 10: TE module voltage output (v) versus temperature gradient (°C)

Figure 10 shows open circuit voltage output by using IR light bulb as a heat source. Figure shows the open circuit voltage output of TE module is directly proportional to the temperature gradient. From the graph, it shows the highest voltage output generated from TE module with heat sink cover. Then, it is followed by the voltage output of TE module with aluminium sheet cover. Lastly, the lowest voltage output is TE module with no cover.

Besides, the voltage output of TE module without cover, TE module with aluminium sheet as a cover, and TE module with heat sink cover are 0.00496 v/°C ,0.00978 v/°C and 0.0286v/°C. It shows the voltage output of TE module without cover obtain lowest voltage output which is 0.00496 v/°C. Besides, the voltage output of TE module with heat sink cover is three times higher than voltage output of TE module with aluminium sheet cover. Therefore, the heat sink is the better material to gather the heat compared to the aluminium sheet.

By comparing the result to the Figure 8, the voltage output of TE module with heat sink cover is nearer than another cover. The difference between is only 0.0064V/ ˚C. Therefore, the voltage output of TE module is optimized by using heat sink as cover.

V. Conclusion

The result above shows the temperature focused IR light is higher than IR light. Thus, a convex lens is used to focus the heat and gain higher temperature. On the other hand, the performance of TE module is carried out in term of open circuit voltage output of it. TE module with a cover gain higher open circuit voltage then TE module without cover. Because the cover can gather the heat from IR light and dissipate the heat on TE module uniformly. Besides, the heat sink cover is a better material to gather the heat compared to aluminium. From the open circuit voltage output, it shown the TE module with heat sink cover can obtain better performance of voltage harvested. In conclusion, this paper proved that the TE module can used to harvest energy from IR light spectrum. Therefore, it showed the potential of optimizing sunlight in generating electrical energy.

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