

Study on Application of Thermoelectric Generation Technology

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Abstract: Thermoelectric generation, which can convert thermal energy to electrical directly, is a green, energy saving and environmentally friendly technology. Based on Seebeck effect, a simple thermoelectric generator was designed in this paper by using Bi₂Te₃ thermoelectric material. In order to study the performance of thermoelectric generator, experiments were done in the case of cold end temperature was independent controlled and was not independent controlled in the paper. When the cold end temperature was controlled, the generation efficiency was improved. The test conclusion has important significance in improvement and industry application of the thermoelectric generator.

1 INTRODUCTION

Thermoelectric generation technology is a green, energy conservation and environment protection technology. Thermoelectric generation can convert thermal energy to electric energy directly without consumption and emission (ZHAO Jian-yun, ZHU Dong-sheng, ZHOU Ze-guang et al, 2010). The working principle of this technology is Seebeck effect of thermoelectric materials. When the temperature of two kinds of semiconductors is different, the two semiconductors can produce direct current after being interconnected. Then the thermal energy is converted to electricity without additional electricity energy (CHEN Wei-wei, ZHANG Rui, WANG Jian-zhong, 2013).

As present the green power generation means are mainly solar photovoltaic power generation, hydropower, wind power and so on. But these power generation methods are heavily reliant on environment, and there will be great energy loss during the power generation. Thermoelectric generation technology is not restricted by environment and doesn't need energy conversion process. So, this technology is of much greater value on research and application (WEI Jie-ting etc, 2010) (CHEN Lin-gen, MENG Fan-kai, SUN Feng et al, 2013).

2 THE SEEBECK EFFECT

German scientist Seebeck discovered the Seebeck effect in 1821. Two different metals are joined together at first. When one of the metal is in high temperature T_1 (hot end) and the other is in low temperature T_2 (cold end), there is an open circuit voltage at the cold end. This phenomenon is known as the Seebeck effect (figure 1).

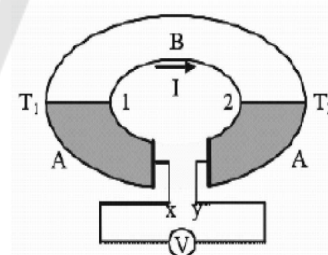


Figure 1: Illustrative diagram of the Seebeck effect.

If the temperature of hot end and cold end is maintained at T_1 and T_2 ($T_1 > T_2$) respectively, there is a potential difference in the open position of the conductor, and the value is:

$$\Delta U_{AB} = \alpha_{AB} (T_1 - T_2) \quad (1)$$

In the type (1), α_{AB} is the relative Seebeck coefficient of two conductors of A and B. $\alpha_{AB} = |\alpha_A - \alpha_B|$. The unit of α_{AB} is $\mu V/K$.

3 DESIGN OF THERMOELECTRIC GENERATOR

Two different types of P and N semiconductor thermoelectric materials are in series by deflector with high electrical conductivity at first. The semiconductor thermoelectric generator can be got after the deflector is fixed on the ceramic plate. When the temperature of thermoelectric generator both ends is different, and the high temperature and low temperature is kept at T_1 and T_2 separately, there will be a voltage. If there is load resistance in the circuit, there will be electric current.

3.1 Design of thermoelectric generator cold end

As shown in Fig. 2, 1 is the aluminium alloy shell. The thermal conductivity of shell is good. Then heat can be transmitted to the hot end much faster, and the cooling of cold end will be accelerated. 2 is storage battery, which can store electricity up for flexible use. 3 is voltage stabilizing module, which can ensure the stability of output voltage. 4 is thermoelectric generator module. Many of the semiconductor thermoelectric generators are joined together by series-parallel connection. Then the thermoelectric generator module is got. The number and the series-parallel connection can be adjusted according to the demand of output current voltage and the shape of thermoelectric generator. 5 is heat-transfer silicone grease, which makes the connection between the semiconductor thermoelectric generator both ends and the shell much better. And the heat conduction efficiency will be high. 6 is the output interface. The standardized output interface is conducive to flexible use of the energy storage (YANG Su-wen, XIAO Heng, OU Qiang, et al, 2012).

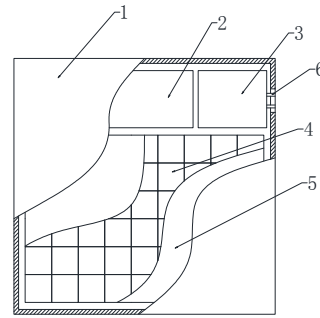


Figure 2: The structure of cold end.

3.2 Design of thermoelectric generator hot end

As shown in Fig. 3, which is structure of the thermoelectric generator hot end. The structure of thermoelectric generator hot end is similar to the structure of thermoelectric generator cold end. The only difference of hot end and cold end structure is 7, which is a layer of insulating material. This material can ensure the normal work of the battery, voltage stability and output module when the heat comes from hot end.

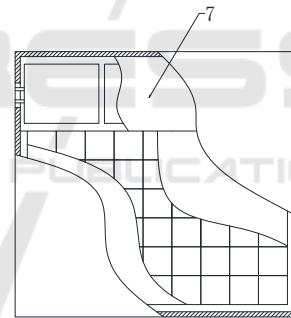


Figure 3: The structure of hot end.

3.3 The simple thermoelectric generator

The Seebeck coefficient of various materials are measured through tests, as shown in table 1:

Table 1: The Seebeck coefficient of common thermoelectric materials

Material	Seebeck coefficient ($\mu V/K$)	Impurity type
Bi ₂ Te ₂	260	P
	-270	N
Sb ₂ Te ₃	133	P
Bi ₂ Se ₃	-77	N
PbTe	380	P

	-320	N
Si _{0.8} Ge _{0.2}	540	P
B ₄ C	250	P

The high cost performance Bi₂Te₂ is chosen as thermoelectric materials of the thermoelectric generator through experiments. The simple thermoelectric generator is got by making series between two semiconductor thermoelectric generator pills. The output voltage is 3.01 V and the current is 0.07 A of the semiconductor thermoelectric generator when the hot end temperature is 115°C and the cold end temperature is 51.9°C.

4 PERFORMANCE TESTS

There are two tests to study the performance of semiconductor thermoelectric generator (LI Ying-lin, HUANG Hu, 2011). The two tests are the cold end temperature be not independent controlled test and the cold end temperature be independent controlled test (XIAO Zhe-peng, WU Wen-ge, FENG Xia, 2014) (WANG Chang-hong, LI Na, LIN Tao, et al, 2016) (WANG Chang-hong, LIN Tao, ZENG Zhi-huan, 2014).

4.1 Voltage admeasurement test of the cold end temperature be not independent controlled

The output voltage of different temperature difference is showed in Fig. 4, which is obtained by heating the hot end directly while the cold end temperature is not fixed. The temperature difference between cold end and hot end is measured by electronic thermoscope.

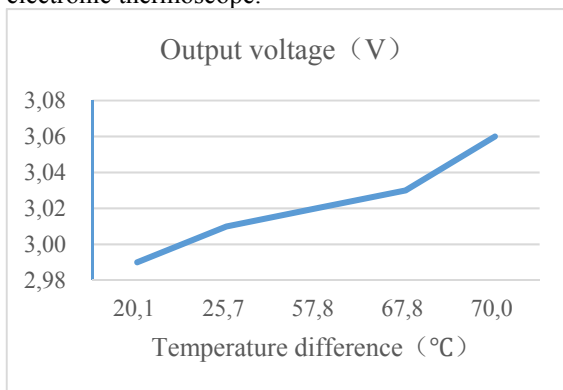


Figure 4: The output voltage with different temperature differences

From Fig. 4, the output voltage increases as the temperature difference increases. When the temperature difference reaches the maximum, the output voltage will reach the maximum value. The larger the temperature difference is, the more obviously the voltage will increase with the increasing of temperature difference.

Therefore, the power generation efficiency can be improved by increasing the temperature difference between the hot end and the cold end.

4.2 Voltage admeasurement test of the cold end temperature be independent controlled

The output voltage is showed in Fig.5, which is obtained by changing the cold end temperature while the hot end temperature is fixed.

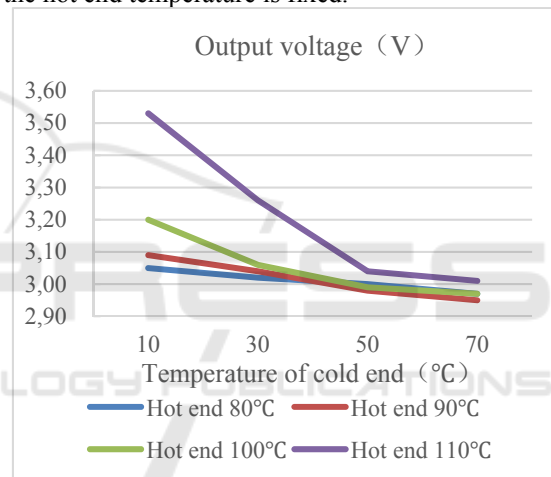


Figure 5: the voltage output with different temperature of the cold end

As shown in Fig.5, with the same temperature of hot end, the voltage reduces when the temperature of cold end rises. In the case of the same temperature difference, the higher voltage can be obtained when the temperature of cold end is lower. The reason for the phenomenon is that the resistance of the semiconductor thermoelectric generator film increases when the temperature of cold end rises.

So, the higher temperature difference power generation efficiency can be obtained by reducing the temperature of cold end during the application.

5 CONCLUSIONS

In this paper, a simple and easy thermoelectric generator device is made by using the high cost

performance Bi_2Te_2 as thermoelectric materials. When the temperature of cold end is independent controlled, the efficiency of power generation will be improved. There is great research value for the improvement and industrial low-grade waste heat utilization of the power generation device.

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