Examination of thermophotovoltaic GaSb cell technology in low and medium temperatures waste heat

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Abstract. In this study, waste heat was evaluated and examined by means of thermo-photovoltaic systems with the application of energy production potential GaSb cells. The aim of our study is to examine GaSb cell technology at low and medium temperature waste heat. The evaluation of the waste heat to be used in the system is designed to be used in the electricity, industry and iron and steel industry. Our work is research. Graphic analysis is done with Matlab program. The low and medium temperature waste heat graphs applied on the GaSb cell are in the results section. Our study aims to provide a source for future studies.
Keywords: Thermophotovoltaic, Electricity generation, GaSb cell, Waste Heat

1.Introduction

Waste heat is the low-energy heat generated by the work done in the system. Systems such as machines, ovens and stoves emit heat for the duration of their work [1]. Waste heat can be produced by evaluating in thermophotovoltaic systems. The working temperature of thermophotovoltaic systems is in the range of 1000-1500 ° C. The waste heat at this temperature value is converted to electricity energy by passing through the system components heat source, selective emitter, filter and photovoltaic (PV) cell. The discovery of TPV dates back to about 1956. Most literature references, MIT in 1956, also made the concept suggests a series of conferences during the Aigra TPV. [2, 3]. Nelso Un, TPV system and by Kolmar 'Solar cells power supply,' 'about a post that has been given [4, 5]. Until the mid-1970s, research conducted in the US, uses fossil fuels as a heat source independent military focused on the low-noise electrical generator. During this period three main heat source (solar, nuclear and combustion) and spectral control options (eluent radiator, filter, PV cell front and back surface reflector) is defined [4, 6]. Industrial waste heat recovery using TPV conversion was proposed by Coutts at the end of 1990s [7-9]. These studies show that TPV applications are increasingly increasing, contributing greatly to energy conversion and productivity. The applications of TPV are residential, automotive, and industrial and so on. It is seen that it has entered the sectors and brought an alternative to electricity generation.

In this study, firstly waste heat is classified. In the second stage, electricity production by thermophotovoltaic methods is investigated by using GaSb cell from low and medium temperatures waste heat.

2.Classification of Waste Heat

Waste heat; Waste heat from low-temperature heat sources, waste heat from medium-temperature heat sources, and waste heat from high-temperature heat sources. Low temperature waste heat can be useful as a complementary way to low vapour pressure needs and preheating purpose [1]. Waste gas temperature values in the medium temperature range of industrial process equipment are shown in Table 1. Most of these mid-temperature values are obtained from combustion processes [1,14]. Waste gas temperature values at high temperature ranges of industrial process equipment are also shown in Table 1. All these results are obtained directly from the combustion processes [1].

Table 1. Waste heat values obtained from different sources at low, medium and high temperatures [1].

Low Temperature		**Medium Temperature**		**High Temperature**	
Heat Source	**Temperature (°C)**	**Heat Source**	**Temperature (°C)**	**Heat Source**	**Temperature (^{0}C)**
Steam Condensation Processes	55-88	Steam Exhaust Exhausts	230-480	Nickel Refine Ovens	1370-1650
Cooling Water	-	Gas Turbine Exhausts	370-540	Aluminium Refined Ovens	650-760
Welding Machines	32-88	Piston Engine Exhausts	315-600	Zinc Refined Ovens	760-1100
Injection Machines	32-88	Piston Engine Exhausts (Turbo Charged)	230-370	Copper Refined Ovens	760-815
Annealing Furnaces	66-230	Heat Treatment Furnaces	425-650	Steel Heating Furnaces	925-1050
Internal Combustion Engines	66-120	Drying and Cooking Ovens	230-600	Copper Reverber Oven	900-1100
Mold Forming	27-88	Catalytic Crackers	425-650	Open hearth furnaces	650-700

3. Termophotovoltaic System and Structure

Thermophotovoltaic systems are systems that generate heat energy and electric energy from high temperature waste heat and solar radiation [7-9]. Thermophotovoltaic system includes selective emitter, heat source, filter and a photovoltaic cell. The heat source is the source of photons. Heat sources with operating temperatures between 1000° C and 1500°C can be used in TPV systems [1, 10-15]. The heat energy from the heat source passes through the selective emitter, filter and cells by radiation. The heat source comes from photovoltaic cells and allows photons to be obtained. Selective spreader is used to increase system efficiency. The selective emitter translates the emission spectrum from the heat source to the emission spectrum by providing the appropriate receiver cell sensitivity before transferring the filters. Because the receiving cells can only use an energy absorber above the band spacing. This leads to less electricity generation [8-11]. The photons from the selective emitter reach the filter before they reach the cells. The filters have the same characteristics as the selective emitter. Reflects non-energized radiation and sends the selective emitter back. Photovoltaic cells; Absorb photons from the emitter and convert them into thermal energy electrical energy. The necessity of absorbing as many photons as possible obligates the use of materials with low band gap [1,8-11].

4. Analyses

Analyses TPV low and medium temperature waste heat values were obtained using GaSb cells. The analyses were done in MatLab program. The graphs obtained according to this analysis result are in our study. In the analysis made, TPV low and medium temperature graphs were obtained using GaSb cell. The parameters used are; the temperature of the cell is the source temperature and the radiation temperature. With these graphs, energy efficiency, filling factor, effect of open circuit voltage and short circuit current values are determined. In Figure 1. the energy efficiency was examined by varying the cell temperature at different source temperatures of 450-950 K. For example, when the cell temperature is 300 K at a 650 K source temperature, the energy efficiency is 11% while the cell

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temperature is 350 K, resulting in an energy efficiency of 3%. In this case, as cell temperature increases, energy efficiency decreases.

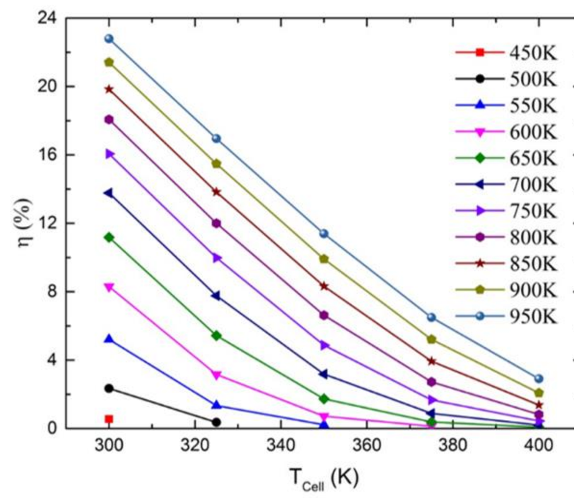

Figure 1. Effect of change in cell temperature on energy efficiency

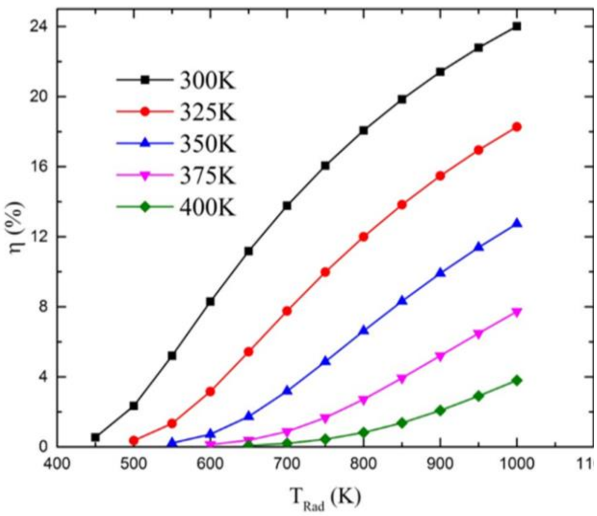

Figure 2. Effect of radiation temperature change on energy efficiency

In Figure 2. the energy efficiency was investigated by changing the radiation temperature at different sources temperatures of 300-400 K. For example, at a radiation temperature of 325 K at a radiation temperature of 800 K, the energy efficiency increased to 16% while the energy efficiency was around 12% and the radiation temperature was 1000 K. In this case, the higher the radiation temperature, the higher the energy efficiency.

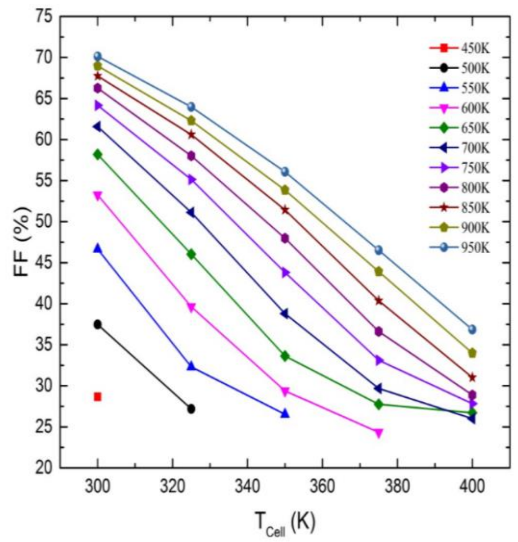

Figure 3. Effect of cell temperature change on filling factor

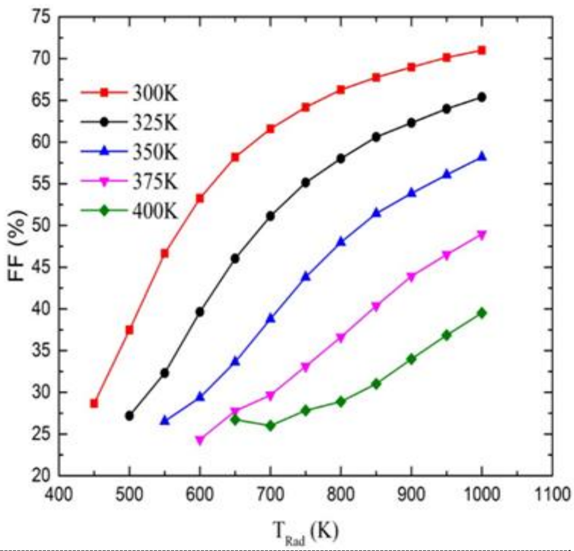

Figure 4. Influence of radiation temperature change on filling factor

In Figure 3. shows the variation of cell temperature and filling factor at different source temperatures of 450-950 K. For example, when the cell temperature is 300 K at 750 K source temperature, the filling factor is 65% while the cell temperature is 380 K, the filling factor has decreased to about 33%. In this case, as the cell temperature increases, the filling factor appears to decrease. In Figure 4, the fill factor was investigated by varying the radiation temperature at different source temperatures of 300-

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400 K. For example, when the radiation temperature is 600 K at 300 K sources temperature, the filling factor has increased to about 67% when the filling factor is about 53% and the radiation temperature is 900 K. In this case, as the radiation temperature increases, the filling factor seems to increase.

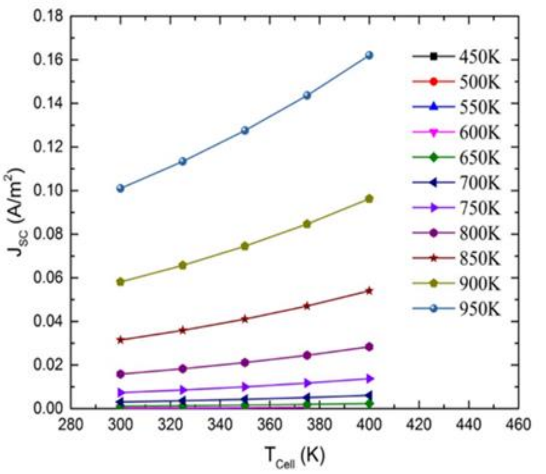

Figure 5. Effect of cell temperature change on short circuit current

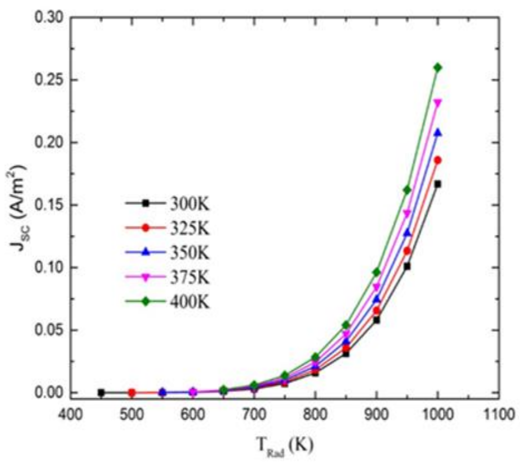

Figure 6. Effect of radiation temperature change on short circuit current

In Figure 5. short-circuit currents were investigated by varying the cell temperature at different source temperatures of 450-950 K. For example, when the cell temperature is 350 K at 800 K source temperature, the short circuit current is about 0.02 A / m² while when the cell temperature is 400 K, the short circuit current is about 0.03 A / m². In this case, short circuit current seems to increase as cell temperature increases.Figure.6. shows the variation of radiation temperature and the short circuit current at different source temperatures of 300-400 K. For example, when the radiation temperature at 350 K is 950 K, the short circuit current is around 0.13 A / m², and when the radiation temperature is 1000 K, the short circuit current is increased by about 0.20 A / m².

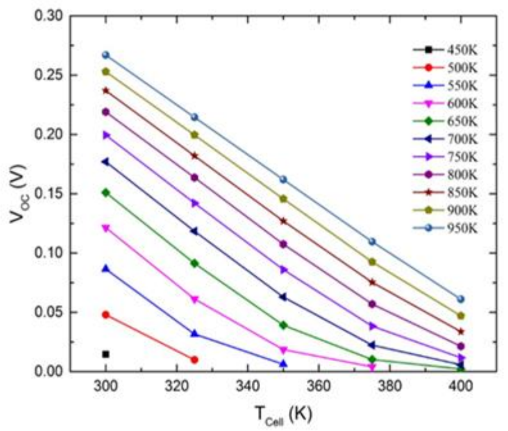

Figure 7. Effect of cell temperature change on open circuit voltage

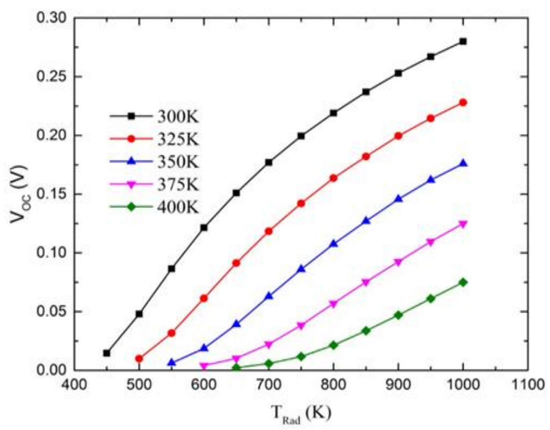

Figure 8. Effect of radiation temperature change on open circuit voltage

Figure 7. examines the open circuit voltage by varying the cell temperature at different source temperatures of 450-950 K. For example, when the cell temperature is 320 K at 700 K source temperature, the open circuit voltage is around 0.14 V, while when the cell temperature is 380 K, the open circuit voltage is reduced to 0.03 V. In this case, as the cell temperature increases, the open

circuit voltage decreases. In Figure 8, the open circuit voltage was investigated by varying the radiation temperature at different source temperatures of 300-400 K. For example, at a radiation temperature of 325 K at a radiation temperature of 800 K, when the open circuit voltage is around 0.17 V and the radiation temperature is 1000 K, the open circuit voltage has increased to about 0.23 V. In this case, as the radiation temperature increases, the open circuit voltage increases.

5. Conclusion

The main conclusions drawn from present study may summarize as follows;

- Cell temperature at different sources temperatures that the effect of the change in energy efficiency decreases when the cell temperature increases energy efficiency examined.
- The effects of radiation temperature changes in the energy efficiency of different sources that the temperature increases of the investigation when the radiation temperature increases energy efficiency.

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