Low Cost Thermophotovoltaic System

Senior Design Team 33

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Abstract—**This paper describes the process of creating a low cost and efficient thermophotovoltaic system. The system is capable of producing up to 5V of electricity using an infrared heat source. The system is also built to be compact so the user can transport it with ease.**

Keywords-Photovoltaic, Emitter

I. INTRODUCTION

Energy production is one of the most important parts of modern life. Without the availability of electricity, today's society would not be able to exist. Throughout time there have been numerous ways of generating power. From giant factories, to wind turbines, and even hydroelectric dams, humans have invented processes to harness vast amounts of energy, however, each system has its set of drawbacks.

For starters, most power generators take up a large amount of space. It may vary from a generator the size of a room, to a powerplant that takes up acres of land. These traditional means of power generation tend to be inefficient, and most times harmful to the surrounding environment.

One promising solution to these concerns is the method of thermophotovoltaics, due to their low cost, high efficiency, and ease of use. Thermophotovoltaic systems operate similarly to a solar panel, however, instead of relying on sunlight to generate electricity, thermophotovoltaics only require a source of heat.

In this paper, we will be demonstrating how our photovoltaic system create clean and efficient energy, and explaining why this new method should be considered, due to its cost, reliability, and ease of operation.

II. MATERIALS

The photovoltaic material chosen for this device was Indium Gallium Arsenide Antimonide (InGaAs). This material was chosen due to its ability to capture infrared radiation and low optimal wavelength dependence [1]. The photodiode chosen was the Model: LSIPD-L2, shown in Figure 1. This model was chosen due to its operating temperature and high forward voltage.

Figure 1: Photodiode

For the emitter, carbon graphite was used as a material capable of radiating at near black body infrared heat at low temperatures. The heat shield and mounting location of the photodiode cells used 304 stainless steel (SS) for its ability to withstand 2000ºF for extended periods of time without deformation and fatigue failure. Further insulation was added to the exterior for added safety using Fyre Wrap that that corresponds to ASTM E2336 standards.

III. POWER PRODUCTION

A. Combustion Chamber

The combustion chamber was a purchase component of the thermophotovoltaic (TPV) system. The selection was done by fuel source as well as temperature output; for these reasons the Bernzomatic TS8000, which can be seen in Figure 2, was chosen for its versatility and control mechanisms.

Figure 2: Bernzomatic TS8000

The TS8000 has an average temperature output of approximately 1750ºF using propane as the fuel source, with an option of MAPP gas if preferred by the user. The temperature of the combustor can be controlled with a variable valve on the combustor itself. The other capability that the combustor has to offer is the ability to lock it in the on position for hand free operation. The tip of the combustor incorporates a turbulent promoter for maximum efficiency, this tip is press fit into the emitter portion of the TPV system.

B. Emitter

The Emitter portion of the TPV is made of a carbon graphite rod. The emitter is the core of the TPV system. The emitter radiates near black body infrared heat which is used by the photovoltaic cell to generate the electricity [2]. The emitter needs to achieve the near black body infrared radiation at a low temperature without risking deformation. The carbon graphite was selected based on its success rates with carbon being used in small infrared space heaters for personal use.

The carbon graphite emitter did have challenges involved in the machining process due to the dangerous nature of machining any brittle carbon based materials proper ventilation and machines are required, and in this case electrical discharge machining (EDM) was selected as the safest practice for manufacturing the emitter portion. The stock carbon graphite is a rod 1.75" in diameter with two concentric inside diameters (IDs) the smaller portion that the combustor tip is press fit into is 1" long and 0.629" in diameter. The heat chamber is 1.5" in diameter and 4" long creating a thin wall of 0.25" for the emitter to achieve operating temperature in a timely manner.

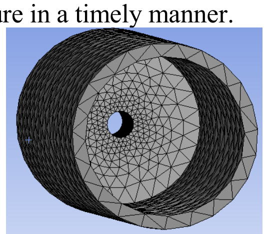

Figure 3: Carbon Graphite Emitter

The 4" heat chamber allows for maximum surface area to be heated to the temperature required for the infrared radiation contributing to the power capable of being produced by the photovoltaic cell.

C. *Photovoltaic Cell*

The photovoltaic cell is where the electricity will be generated in the system. The electrical circuit is comprised of three photodiodes, all oriented to capture the most amount of infared radiation produced by the emitter. Once the photons are captured, the photodiodes covert those photons into electricity which is sent out of the device and into the receiving system. The photodiodes have a maximum operating temperature of 80°C, so it is crucial that they stay within that range.

IV. Results

Unfortunately, due to the COVID-19 pandemic, testing was put on hold and the result was a virtual device that was used for multiple simulations to determine the results. The test simulation according to ANSYS the outer surface of the emitter will average between 1600 and 1700ºF at the outer surface to radiate the infrared heat required for the photodiode cells to reach maximum functionality. The photodiodes that were ordered for this system were never received due to the virus, therefore a similar type of photodiode was used in order to obtain a benchmark. The replacement was a QED 123 IR LED, which behaved similarly to the desired photodiode, but generated less power. A lab test resulted in a voltage of 2.6V which can be seen in Table 1. The test resulted in only half of the expected voltage of the InGaAs photodiode. With the desired photodiode, an estimated 5V would have been able to be achieved due to its higher forward voltage.

Table 1

Light Source Distance (In)	Voltage (V)
0	2.6
1	2.3
2	1.4
3	0.84
4	0.42
5	0.32
12	0.26

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