

## PERFORMANCE OF MICRO-THERMOPHOTOVOLTAIC POWER GENERATORS WITH DIFFERENT EMITTING MATERIALS

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### ABSTRACT

As part of an effort to develop a micro-thermophotovoltaic (micro-TPV) power generator, a series of experiments are carried out to test the performance of a prototype micro-TPV power generator with different emitting materials. Micro combustor is one of the most important components of micro-TPV system. In this work, we present experimental results of two kinds of micro cylindrical combustors made of SiC and Platinum. Owing to the catalytic effect of platinum, the temperature along the wall of the micro platinum combustor is much higher than that of the SiC combustor under the same testing conditions. When the flow rate of hydrogen is 4.2 g/hr, and H<sub>2</sub>/air ratio is 0.9, the maximum output powers of the micro-TPV power generator are 0.81 W and 0.78 W for micro SiC combustor and micro platinum combustor respectively.

### 1. INTRODUCTION

There has recently been renewed interest in Thermophotovoltaic (TPV) generation of electricity [1-4]. This interest has been sparked by recent technological advances in emitter and cell fabrication, as well as the prospect of potential military and commercial applications. The operating principle of TPV is: fuel is combusted in a micro combustor, heat energy released from combustion is then transferred from the emitter to the photovoltaic (PV) cells through radiation, the radiated photons interact with the electrons in the PV cells by imparting their energy to the electron as kinetic energy. This kinetic energy raises the electron from the valence band to the conduction band creating a mobile charge that can be collected across a PN junction to produce a current. Because

it doesn't involve any moving parts, its fabrication and assembly are relatively easier.

The Micro-TPV power generator that we are developing is originated from conventional TPV concept [5-6]. However, compared to conventional TPV system, the output power density of micro-TPV system is greater due to the higher surface-to-volume ratio of micro combustor. An emitter is one of the most important components of micro-TPV power generator. The objective of this paper is to investigate the effect of emitting materials on the performance of micro-TPV power generators.

### 2. DESIGN OF MICRO-TPV POWER GENERATOR

A prototype micro-TPV power generator has been built-up and tested in National University of Singapore. The system mainly consists of (1) a heat source, (2) a micro cylindrical emitter (i.e. micro-combustor), (3) a simple nine layer dielectric filter, and (4) a GaSb photovoltaic cell array, see figure 1, the schematic of the system. The combustor-emitter can be made of blackbody materials or selective emitting materials. In this paper, two kinds of materials i.e., SiC and platinum, are studied. The Platinum is employed to study the effect of catalytic combustion on the performance of micro-TPV power generators. Furthermore, Platinum is also a selective material. The shortcoming of platinum is its emissivity is very low. The SiC is selected as the materials of micro-combustor because of its good emissivity and high temperature reliability. Furthermore, compared with other selective emitters such as micro-machining tungsten, rare-earth oxide, it is easier to be fabricated into a cylindrical shape. The SiC emitter is a typical broadband emitter. The spectrums of broadband emitters operating at

temperatures 1000-1600 K contain significant proportions of sub-band gap photons with energies not sufficient to generate charge carriers in the PV cells. This portion of energy will be absorbed by the PV cells and result in a destructive heat load on the generator components, subsequently lower the conversion efficiency of the system. So a simple nine layer dielectric filter is employed in the micro-TPV system to recycle this portion of energy. The filter is fabricated with alternating layers of silicon and silicon dioxide, and is deposited on glass slide and bonded on the top of GaSb PV cells with silicone. The filter is able to recycle the photons emitted in the 1.8 to 3.5 micron mid-wavelength band [7]. Corresponding with the filter, a GaSb PV cell array is employed. This GaSb cell array responds up to 1.8 microns. The process used to fabricate GaSb PV cells replicates the silicon solar cell fabrication process, using inexpensive diffusion steps with no toxic gases [8], in contrast with epitaxy.

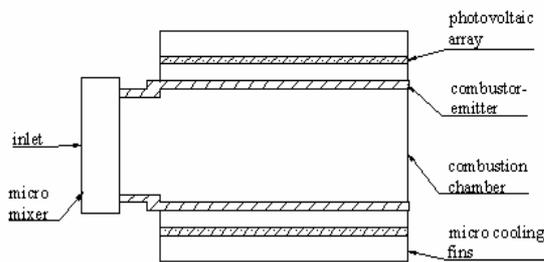
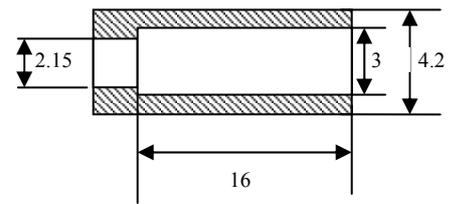


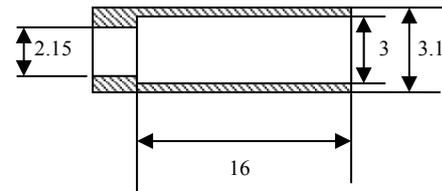
Fig.1. The schematic of micro-TPV power generators

Compared to conventional combustors, a micro combustor is more highly constrained by inadequate residence time for complete combustion and high rates of heat transfer from the combustor. In this work, hydrogen is chosen as the fuel because of its original short reaction time, and high flame speed.

Figure 2 shows the specifications of two kinds of micro combustors made of SiC and Platinum materials respectively. They have the same combustion chamber, but the wall of the SiC combustor is thicker than that of the platinum combustor, because it is very hard to fabricate such a thin wall with SiC material.



(a) SiC combustor



(b) Platinum combustor

Fig.2. Specifications of two kinds of micro combustors (units: mm)

### 3. RESULTS AND DISCUSSION

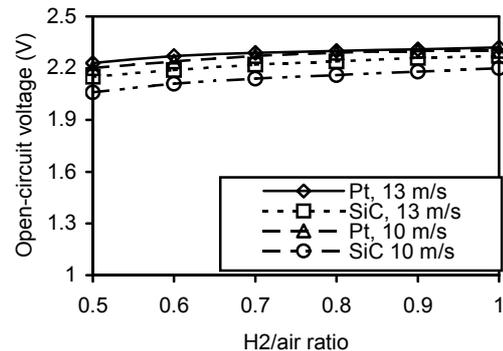


Fig.3. Open-circuit voltage of micro-TPV power generator with different combustors

The performance of the micro-TPV power generator is measured for all kinds of flow rates and H<sub>2</sub>/air ratios. Figure 3 shows the open-circuit voltage of the micro-TPV power generator with different combustors. Under different flow rate and H<sub>2</sub>/air ratio, the open-circuit voltage of the system with a platinum combustor is a little higher than that with a SiC combustor, the biggest difference is about 4%. This is because Platinum can restrain its emissivity at long wavelength, and decrease the waste heat load on the PV cells, while operating temperature is a major factor affecting the open-circuit voltage of PV cells [9].

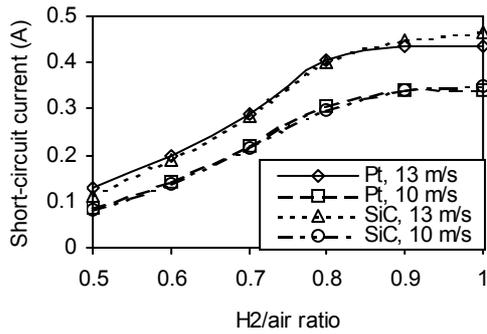


Fig.4. Short-circuit current of micro-TPV power generator with different combustors

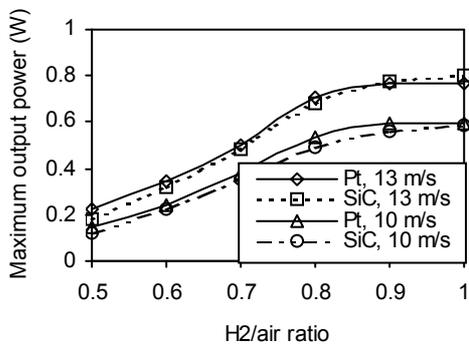


Fig.5. Maximum output power of micro-TPV power generator with different combustors (W)

Figure 4-5 shows short-circuit current and maximum output power of the micro-TPV power generator with above two kinds of combustors. When  $H_2/air$  ratio is low, both the short-circuit current and the maximum output power of the micro-TPV power generator with a Pt combustor is higher than that with a SiC combustor. At 13m/s,  $H_2/air$  ratio of 0.5, the differences are 18% and 22% for the short-circuit current and the maximum output power respectively. With the increase of  $H_2/air$  ratio, both the short-circuit current and the maximum output power of the micro-TPV power generator with a SiC combustor close and even surpass that with a Pt combustor. At 13 m/s,  $H_2/air$  ratio of 1.0, the differences are 6.5% and 4.5% respectively. This is because, compared to micro SiC combustor, the relevant increase in temperature along the wall of micro Platinum combustor at low  $H_2/air$  ratio is higher than that at high  $H_2/air$  ratio. For example, the mean wall temperature of platinum combustor increases 29.4% at  $H_2/air$  ratio

of 0.5 (325 K), while the increase at  $H_2/air$  ratio of 1.0 is only 22.5% (302 K). Figure 6 shows the mean wall temperature of two kinds of combustors under different  $H_2/air$  ratio, the flow rate at the inlet is 13 m/s. The results indicate that catalytic combustion can increase the temperature along the wall of micro combustor drastically. Compared to SiC combustor, the mean wall temperature of the micro platinum combustor is about 230 K higher, even we take the different wall thickness into consideration.

As flow rate of hydrogen is 4.2g/h,  $H_2/air$  ratio is 0.9, the maximum electrical output power are 0.78 W and 0.81 W for micro platinum combustor and micro SiC combustor respectively. However, due to the low emissivity of platinum material and low mean wall temperature of SiC combustor, the output power density of the system is still not high enough. If a thin film of platinum can be deposited on the inner surface of micro SiC combustor as catalyst, a higher electrical power output can be expected from the micro-TPV power generator.

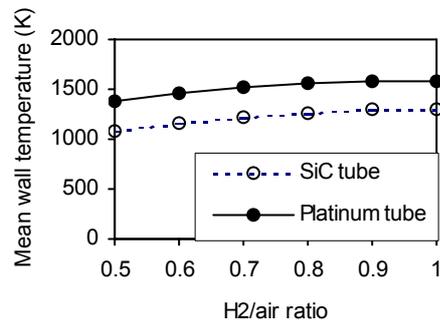


Fig.6. Mean wall temperature at flow rate of 13 m/s

#### 4. CONCLUSION

Micro combustor is one of the most important components of micro-TPV system. For micro-TPV system application, the micro combustor requires a high and uniform temperature distribution along the wall. In this work, we present experimental results of two kinds of micro cylindrical combustors made of SiC and Platinum. Owing to the catalytic effect of platinum, both the temperatures along the wall and on the exit plane of the micro platinum combustor are much higher than that of the SiC combustor under the same testing conditions. The performance of the

prototype micro-TPV power generator with a combustor made of SiC is also tested and compared with the generator whose combustor is made of Platinum. Although the emissivity of platinum is much lower than that of SiC, their electrical power outputs are close. When the flow rate of hydrogen is 4.2 g/hr, and H<sub>2</sub>/air ratio is 0.9, the maximum output powers of the micro-TPV power generator are 0.81 W and 0.78 W respectively. The results indicate that the performance of the micro-TPV power generator will be improved drastically if a thin film of platinum be deposited on the inner surface of SiC emitter or selective emitter.

#### ACKNOWLEDGEMENT

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