Abstract

[Project Information]

Project Title : Power generation from exhaust heat in medium/small-scale waste incinerator using silicon photovoltaic cells

Project Number : JPMEERF20243RA2

Project Period (FY) : 2024-2024

Principal Investigator : Shimizu Makoto

(PI ORCID) : ORCID0000-0002-6094-8827

Principal Institution : Tohoku University
Sendai City, Miyagi, JAPAN
Tel: +81227956925
E-mail: makoto.shimizu.a3@tohoku.ac.jp

Cooperated by :

Keywords : Thermophotovoltaic, Thermal radiation, Waste incinerator, Photovoltaic cell, Waste heat recovery

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This study proposes and evaluates a novel thermophotovoltaic (TPV) power generation system that utilizes silicon photovoltaic (Si-PV) cells to convert exhaust heat from medium- to small-scale waste incinerators into electricity. Unlike conventional waste-to-energy systems that rely on steam turbines—often unsuitable for compact incinerators due to cost and space limitations—the TPV approach offers a solid-state, maintenance-free solution capable of non-contact heat-to-electricity conversion, making it well-suited to facilities operating at approximately 900–1000 °C.

The core innovation lies in the experimental application of widely available Si-PV cells to TPV systems, overcoming the traditional reliance on expensive III-V compound semiconductor TPV cells. Although Si-PV cells possess a wider bandgap and consequently lower output power density and conversion efficiency at infrared wavelengths, their low cost, scalability, and thermal robustness render them promising candidates for this application.

A series of experimental investigations were conducted to evaluate the optical and thermal performance of several Si-PV cell types under controlled TPV conditions. High infrared reflectivity and reduced thermal loading were achieved with peak power densities exceeding 0.35 kW/m² at 1000 °C. Notably, the temperature coefficient of power output was found to be positive in some types of Si-PV cells, particularly under TPV-specific radiation spectra. This is attributed to bandgap narrowing at elevated cell temperatures, which enhances the absorption of longer-wavelength photons and increases short-circuit current density. As a result, the adverse impact of temperature rise -typically seen in solar applications- was counteracted or even reversed in the TPV context.

This research demonstrates the technical viability of Si-based TPV systems as a cost-effective and practical solution for waste heat recovery in distributed incineration infrastructure. It lays the groundwork for further development and implementation of localized energy networks contributing to Japan's circular economy and carbon neutrality goals.

This study was supported by the Environment Research and Technology Development Fund of the ERCA (JPMEERF20243RA2) funded by the Ministry of the Environment.