

Basic Study of an Onboard Thermoelectric Power Generation System Utilizing Solar Heat and Driving Wind

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To utilize ambient energy around vehicles, this study focuses on onboard thermoelectric generation (TEG) using solar heat and driving wind (Fig. 1). Recent advances in low-cost materials and flexible modules enable large-area integration onto vehicle exteriors. Here, we evaluate a fundamental TEG unit to clarify the thermal roles of its components and establish an optimal thermal management structure combining thermal insulation, light concentration, and heat dissipation.

A custom test system simulated dynamic thermal environments with $1,000 \text{ W/m}^2$ irradiance and 50 km/h wind. From 12 test configurations combining absorber sizes (50 and 100 mm), covers (none, PMMA, Fresnel lens), and heat sinks (HS), four representative cases (100mm Base, 50mm Base, 100mm PMMA+HS, and 50mm Lens+HS) were evaluated in detail (Figs. 2 and 3). Open-circuit voltage was measured across a 3,600-s driving scenario: [1] stationary heating (1,200 s) → [2] solar driving (1,200 s) → [3] shaded driving (1,200 s).

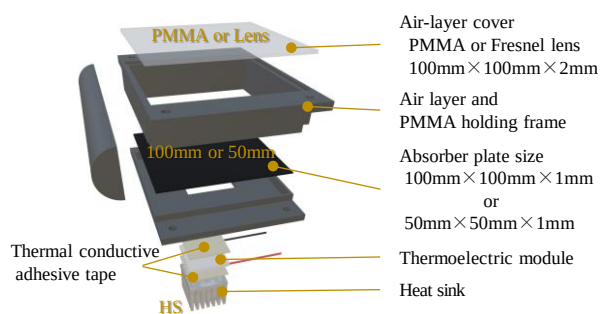


Fig. 2 Exploded view of the test specimen configuration

The 50mm Lens+HS configuration exhibited superior performance (Fig. 4). At the end of [1] (1,140–1,200 s), it achieved 0.32 V versus 0.10 V for the baseline (50mm Base), demonstrating that air-layer insulation effectively suppresses convective heat loss. Initiating wind at [2] (1,200 s) induced a sharp peak of 0.86 V via rapid cold-side cooling, maintaining a high output of 0.36 V under steady driving (vs. 0.28 V for 100mm PMMA+HS). During shaded driving in [3], the air layer retained residual heat, ensuring continuous power output.

In conclusion, combining an internal air layer, Fresnel lens, and heat sink effectively boosts TEG output and sustains power generation during temporary shading, demonstrating high practical potential for automotive applications.

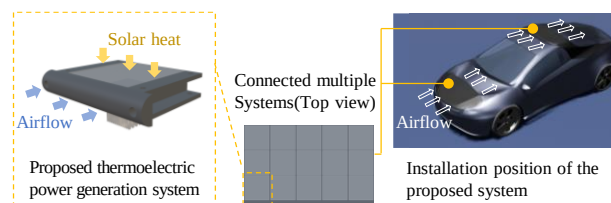


Fig. 1 Concept of the proposed TEG system for vehicle application

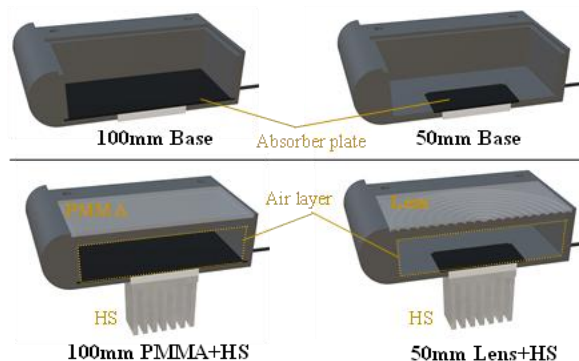


Fig. 3 Cross-sectional views of the four evaluated test cases

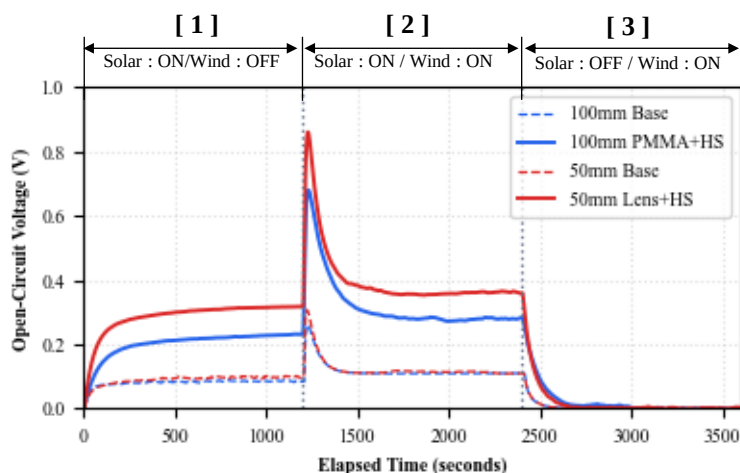


Fig. 4 Time-series voltage data under four representative conditions