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Communication

A highly-efficient, concentrating-photovoltaic/thermoelectric hybrid generator

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ABSTRACT

A concentrating photovoltaic (CPV) cell exhibits the highest conversion efficiency among any solar cells. However, the further enhancement of the CPV efficiency is strongly limited by the heat generation at high solar concentrations. Here, we demonstrate a concentrating photovoltaic/thermoelectric hybrid generator using a single-junction, GaAs-based solar cell and a conventional thermoelectric module as a model system. Our hybrid generator gives rise to the conversion efficiency larger than the single CPV cell by ~3% at the solar concentration of 50 suns. Controlling thermal flow in the hybrid generator and the Peltier cooling effect is the key to achieving high efficiency. Our result provides a framework for designing a highly-efficient hybrid generator using both photo-electric and photo-thermal effects for the clean-energy production.

1. Introduction

Concentrating photovoltaic (CPV) system has attracted a great attention as it possesses the highest efficiency of all PV technologies [1,2]. Sunlight is focused by mirrors or lenses onto the small array of CPV cells. This can not only enhance the conversion efficiency from solar to electric energy, but also reduce the balance of system costs due to the small size [3–7].

However, concentrating sunlight inevitably causes heat generation, so it significantly increases the temperature of CPV cells. The high temperature is very detrimental to the performance of solar cells. Band gap reduction and higher recombination rate at a high temperature substantially decrease the open-circuit voltage (V_{oc}) of a solar cell, leading to the degradation of solar cell performance [8–10]. Usually, CPV system includes a heat sink to effectively dissipate heat [11–13]. There is, however, a limitation of the heat sink installation: for example, active cooling below the ambient temperature is not desirable because of the extra energy consumption for cooling.

One way to further enhance the CPV cell is to actively utilize the dissipated heat energy as a source for an extra generation of electricity using thermoelectric generator (TEG) [14–16], where the temperature difference (ΔT) between two sides drives electrons and holes to move along the temperature gradient, leading to an electric current. Such an innovative photovoltaic/thermoelectric (PV/TE) hybrid generator is investigated with various types of PV cells [17–22]. Especially, the integration of CPV to TEG has attracted great attention [23–27]. However, it is rare to experimentally demonstrate the viability of CPV/TEG hybrid generator, and to provide a strategy to further improve the performance of the hybrid generator. All these hybrid generators have a common structure, PV cell is placed on top (hot side) of the TEG while the bottom side of the TEG is contacted to a heat sink. The heat generation at PV cell leads to the temperature gradient across the TEG,

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