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Modeling Thermophotovoltaic Rare Earth-Based Selective Emitters

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ABSTRACT

Thermophotovoltaic (TPV) devices convert heat to electricity using thermal radiation to illuminate a photovoltaic (PV) diode. Typically, this radiation is generated by a blackbody-like emitter. Such an emission spectrum includes a broad range of wavelengths, but only higher energy photons can be converted by the PV diode, which severely limits efficiencies. Thus, introducing a selective emitter and filter to recycle unwanted photons could potentially greatly enhance performance.
In this work, we consider a rare earth-doped selective emitter structure to increase the number of photons emitted above the bandgap of the photovoltaic (PV) cell, while minimizing the total power emitted below the bandgap. A chirped dielectric stack is introduced on top to limit emitted wavelengths, while a broadband dielectric mirror on the bottom ensures unidirectional emission. We developed a GUI-based tool to precisely calculate the emittance spectrum and efficiency for this design as various parameters, such as the number of dielectric bilayers and PV cell bandgap. The tool is hosted and run through nanoHUB.org - an open-access science gateway for cloud-based simulation tools and resources in nanoscale science and technology. Through simulations of chirped dielectric stack structures and coatings on a rare-earth ceramic substrate, it is found that an efficiency of 33.89% is achievable, for a filter bandgap of 0.37 eV and PV bandgap of 0.75 eV. The research thus demonstrates the potential for unprecedented efficiencies of TPV cells. These predictions will be used to experimentally fabricate and characterize these structures.

KEYWORDS

Thermophotovoltaic, Selective emitters, Chirped Dielectric Mirror, Dielectric bilayers, Themophotovoltaic cell efficiency

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