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Advances in thermophotovoltaics: materials, devices, and systems

Special Issue Editorial

Thermophotovoltaics (TPV) refers to solid-state thermal-to-electrical energy conversion based on the photovoltaic (PV) effect. There are many sources of thermal energy relevant to TPV, such as waste or stored heat, solar energy converted into heat, heat from combustion of fuels, and even electrical energy stored as heat. Up to now, the temperature of the material emitting thermal radiation towards the photovoltaic converter has mostly been above 1000 °C. The photovoltaic cell therefore has to absorb and convert infrared photons. Spectral selectivity, realized by controlling emission of the thermal radiation source and/or reflection by the PV converter, is one peculiarity of TPV compared to solar photovoltaics. Hence thermophotovoltaics is at the crossroads of materials, electrical, optical, and mechanical engineering sciences.

Since the advent of TPV around the middle of the 20th century, research has had its ups and downs, and has not been able to reach the point of widespread and growing deployment. But it seems that the wind has recently begun to turn and rise. In order to support the revitalization of the field, it made sense for us to re-establish actions that would allow researchers to share their results and new ideas in a coordinated manner. One such action is the organization of a Symposium at the 2021 Spring meeting of the European Materials Research Society (online, June 1-3, during 2 and a half days), also being the 12th World Conference on Thermophotovoltaic Generation of Electricity (TPV-12). The other parallel action is the present special issue, published in Solar Energy Materials and Solar Cells, under the same title as the symposium: *Advances in thermophotovoltaics: materials, devices and systems*.

The symposium resulted in more than 50 contributions. Of the 28 full-articles submitted, half are finally included in the special issue. These numbers illustrate the new vitality of the field. As expected, articles in the special issue highlight the mix of scientific areas involved in recent advances in thermophotovoltaics. With respect to the thermal radiation emitter, different strategies for achieving spectral selectivity at high temperature - while ensuring stability of the emitter -, are analyzed in a review article. New findings on emitters are presented in two papers: one- or two-dimensional photonic structures, both with a refractory metal and involving hafnium oxide, are used to progress towards the desired performance. For the PV cell, it is known that

electrical power density should be improved in order to be comparable or even surpass that of the best thermoelectric converters, while maintaining high efficiency. A paper examines near-term options for moving in these directions for single-junction InGaAs airbridge cells, considering thermal management. Narrow bandgap (< 0.5 eV) cells are another option for achieving high electrical power density: the state of the art, factors limiting performance, and new avenues based on interband cascade PV devices are discussed in detail in a review article. Under high omnidirectional illumination, minimizing the space between adjacent cells is key to reduce optical spillage. To that end, an article describes steps towards the fabrication of interdigitated back contact Ge cells that minimize the cell-to-module interconnection losses. But back contacts need to perform several functions simultaneously: a paper explores different processes for fabricating patterned dielectric back contacts to improve sub-bandgap reflectance, which is a very critical parameter for conversion efficiency, especially for wide bandgap cells like GaAs (1.4 eV). The so-called advanced concepts also aim at increasing electrical power density. A review article describes the achievements and remaining challenges for devices that take advantage of the additional contribution of evanescent waves when the distance between the emitter and the cell is reduced to submicron values. Such near-field TPV (NF-TPV) converters almost exclusively considered single-junction cells so far: an article deals with simulations showing expected performances with a dual-junction cell. Maximizing the PV cell sub-bandgap reflectance is also a concern in NF-TPV devices: a paper reports on simulations quantifying the benefits of inserting a vacuum gap between the semiconductor and the metallic back contact. Thermophotonic (TPX) energy converters, where the TPV cell is paired with an electroluminescent emitter, are analyzed with and without near-field effects. Provided that specific conditions relating to material properties are met, promising performance is found for operation with low-grade heat sources (~ 500 K). Combining thermionic and TPV conversion is another option for improving electrical power density: an article reports on advances in the design, fabrication and operation of such a hybrid device composed of an InGaAs TPV anode. Finally, many of the above constraints on emitters and cells needed for performance must be met in real-world converters. An article deals with the constraints of spectral selectivity, thermal stability, and cavity efficiency in the case of a solar TPV system. These 14 articles provide a meaningful view of some recent advances in TPVs. However, this is of course a fragmented view, as many other research avenues are currently being pursued.

In the context of a resurgence in TPV research, the recent coordinated actions respond in part to renewed aspirations of the TPV community, namely: enhance the visibility of TPV research and technology; build consensus on various aspects of TPV science and technology; identify gaps in knowledge, technology, and supporting tools. Other actions are thus ahead of us, including the next conference in the series (TPV-13) to be held in conjunction with the 18th International

Conference on Concentrated Photovoltaic Systems (online and in Miyazaki, Japan, April 25-27, 2022). May this new momentum be the beginning of a fruitful new long chapter in TPV research!

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