Thermal energy conversion using thermophotovoltaic devices

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Context and motivations:

According to recent studies [1], 90% of the world's energy consumption involves the production or manipulation of heat over a wide temperature range. As a result, thermal energy and heat management is a central point in our energy production/consumption. Thermal energy can also be converted into other forms of energy such as electricity. It can be done by thermoelectric conversion, for example, but this requires maintaining a temperature difference between the two faces of a solid component. A promising alternative is thermophotovoltaic conversion (TPV) [2–6], which converts the radiative heat flux emitted by a hot body into electricity using a photovoltaic cell that operates in the infrared spectral range (Figure 1). Multiple sources of heat (thermal engines, industrial heat waste, solar heat, etc.) could be used.

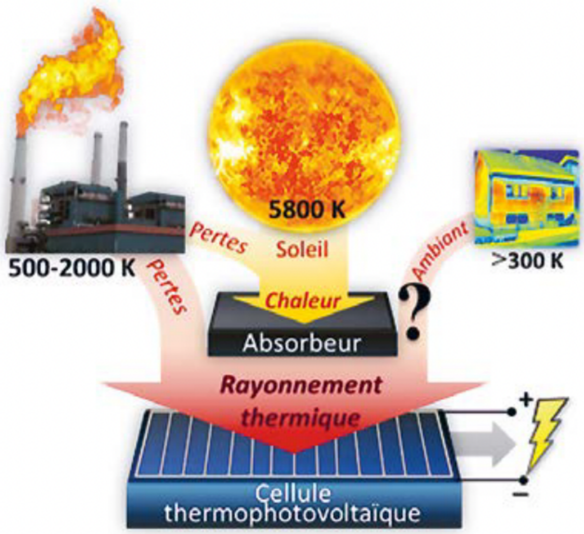

Figure 1 : Principle of thermophotovoltaic conversion [5].

In the case of solar photovoltaics (PV), the radiation spectrum is given and cannot be controlled. It is the main source of efficiency limitations in PV. Contrarily, in TPV, it is possible to control, at least partially, the radiative (optical) properties of the radiation source to match the TPV requirement and improve the system overall efficiency. Spectral radiation control is one of the key strategies to reach high efficiency TPV systems. As shown in Figure 2-a, only a part of the emitted radiation (total black body radiation, in orange), with wavelengths shorter than the gap wavelength λ_g, can be converted by a given PV or TPV cell. An optimal system therefore requires the concentration of the emitted radiation in the so-called "emission window" ($\lambda < \lambda_g$) which can be achieved using different IR photonics techniques for radiation spectral control.

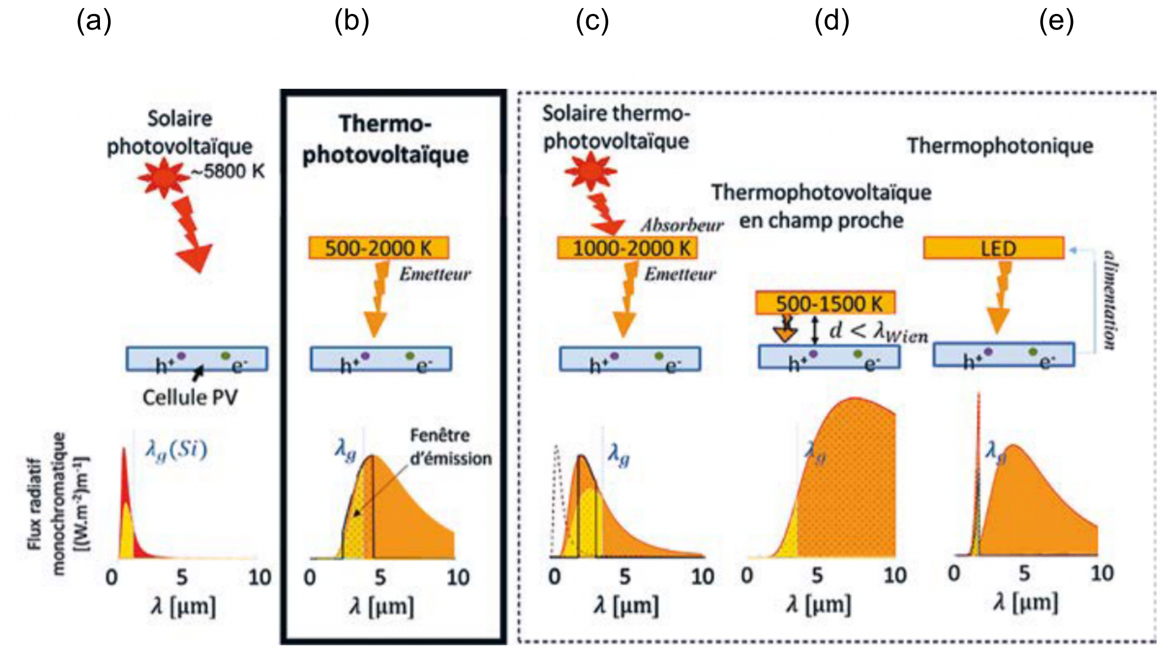

Figure 2 : The family of thermophotovoltaic concepts [6].

Objectives:

This project aims to understand the IR properties of a new Silicon based metamaterials, called Black Silicon (BSi), and its possible use in TPV devices. We have recently shown that BSi can be used for solar photothermal conversion [7] and has very good antireflection properties in both the visible and infrared [8,9]. In order to use it for TPV as a IR radiation emitter, it is mandatory to characterize its emissive properties at elevated temperatures. This involves using and improving an experimental setup for direct emissivity measurement already available at ESYCOM Lab. The development of an experimental setup for TPV conversion is then required to implement BSi in a TPV system combining BSi metamaterial as an emitter and commercial TPV cells. Numerical simulations can also be considered to estimate the performance of a BSi based TPV system.

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