Investigations on a very low bandgap InAs/InAsSb thermophotovoltaic cell: TCAD simulations, band engineering and clean room processing

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Similar to solar photovoltaics (PV) on the principle but different regarding its applications, thermophotovoltaics (TPV) is recently regaining interests [1][2], especially thanks to low cost energy storage perspectives (thermal battery [3]). In this kind of system, the TPV cell harvests infrared photons radiated by a hot emitter (usually ≈500-2500 °C) in order to produce electrical power. The infrared spectrum being shifted toward lower energy, the cell bandgap needs to be lower than what is typically used for solar PV. In this aspect, most of the literature on TPV focuses on gallium-containing cells with bandgaps ranging between 0.5 to 0.8 eV (cf. figure 1), however this is still far from the optimum gaps (around 0.3 eV) predicted by the detailed balance limit for emitter temperatures lower than 1300°C.

Thus, we propose in our work to design and investigate the performances of a very-low bandgap (0.25 eV) TPV cell made of an InAs/InAsSb superlattice absorber. This choice was motivated by the possibility to increase the part of the emitter spectrum used for conversion, while decreasing the cooling power flux (usually more than a few W/cm^2) needed to prevent a rise in cell temperature. The counterpart of this low-bandap choice is the low (cryogenic) temperature requirement for the cell. Overcoming this limitation is somewhat similar to what researches in the infrared photodetectors community are trying to address [4]. Thus, we decided to apply the same strategy proposed in this closely related field and use a barrier structure (cf. figure 2) for suppressing the generation-recombination current and increasing the operational temperature.

TCAD simulations were performed to optimize the structure and better adapt to TPV figures of merits. Front contact substitution to GaSb has been decided to improve spectral and electrical performances, and the metallic contacts were modified to better match the high currents of TPV. These theoretical studies were followed by molecular beam epitaxy growth of the samples on GaSb substrate and clean room processing. A strong anisotropic (wet) etching in the latter was noticed, leading to adjustments in the process. The different aspects of these steps will be presented and discussed more thoroughly in this poster.

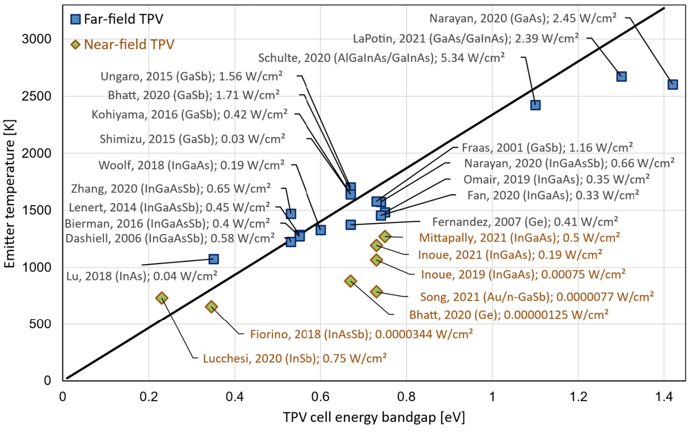

Figure 1: Overview of experimental TPV cell results taken from the literature. Graphic adapted from [5].

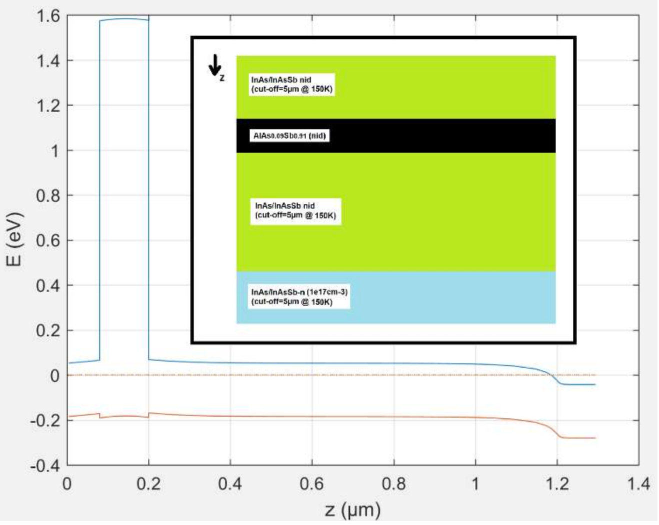

Figure 2: 1D TCAD simulation of the device band structure (no bias voltage). In-house code [6].

[1] LaPotin, Alina, et al. "Thermophotovoltaic efficiency of 40%." *Nature* 604.7905 (2022): 287-291.
[2] Fan, Dejiu, et al. "Near-perfect photon utilization in an air-bridge thermophotovoltaic cell." *Nature* 586.7828 (2020): 237-241.
[3] Datas, Alejandro, et al. "Latent heat thermophotovoltaic batteries." *Joule* 6.2 (2022): 418-443.
[4] Klipstein, Philip C. "Perspective on III–V barrier detectors." *Applied Physics Letters* 120.6 (2022).
[5] C. Lucchesi, "Design and development of a near-field thermophotovoltaic conversion device". PhD thesis, Université de Lyon, INSA, (2020).
[6] Parola, Stéphanie, et al. "Improved efficiency of GaSb solar cells using an Al0. 50Ga0. 50As0. 04Sb0. 96 window layer." *Solar Energy Materials and Solar Cells* 200 (2019): 110042.

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