Analysis of the performances of a conventional GaAs solar cell operating at up to 200 °C

Paul Oublon, Frédéric Martinez, Stéphanie Parola, Yvan Cuminal, Rodolphe Vaillon

IES, Univ Montpellier, CNRS, Montpellier, France

The conversion efficiency of most photovoltaic devices declines when their temperature rises [1]. Despite this, there are cases that push solar cells far above the Standard Tests Conditions (STC) temperature of 25 °C. Depending on how the cell dissipates heat and the application (concentrated solar photovoltaics, photovoltaic -thermal [2] or -thermoelectric [3] or -CSP [4] hybrid systems, cells for near-the-sun space missions [5], see Figure 1), the equilibrium temperature may reach 150 °C or more, making the thermal behavior of the cells a critical issue.

To establish a firm basis about the temperature dependence of the main physical parameters affecting the behavior of the cells under thermal stress, the first step of our research project consists in analyzing the performances of a conventional GaAs solar cell designed for the STC but operating under thermal stress (at up to 200 °C). Up-to-date physical parameters of the materials were collected and validated using an in-house optical and electrical simulation code [6] and experimental data from [7] (Figure 2). The code was then used for optimizing the architecture of the conventional GaAs cell to be analyzed under thermal stress in a laboratory setup. In the analysis of the cell performances, a peculiar attention is paid to the temperature sensitivity of contact resistances and optical properties of layers (antireflection coating, window, emitter and absorber). Results of this steps will be the basis for designing and fabricating a prototype GaAs cell operating optimally in the temperature range from 150 to 200 °C.

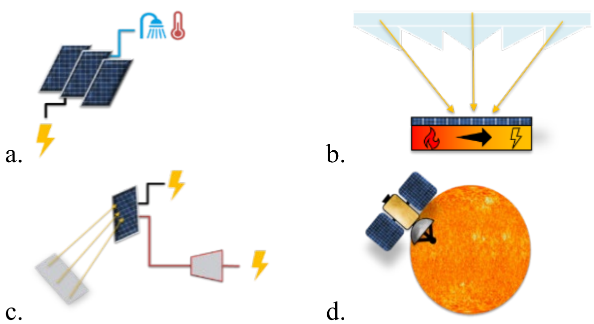

Figure 1. Solar cells operating under thermal stress in: (a) photovoltaic-thermal, (b) photovoltaic-thermoelectric, (c) photovoltaic-CSP terrestrial hybrid systems, and (d) near-the-sun space missions.

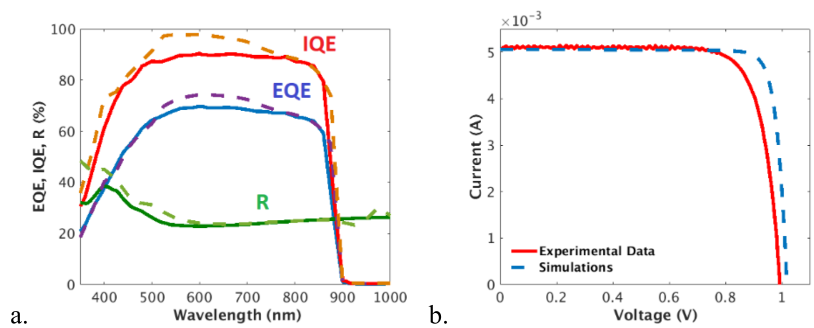

Figure 2. Comparison between simulation results (dash lines) and experimental data [7] (plain lines) for a conventional GaAs solar cell: (a) quantum efficiencies and reflectance; (b) I(V) characteristics.

[1] O. Dupré *et al.*, Thermal behavior of photovoltaic devices. Physics and Engineering. Springer, 2017.
[2] A. Mellor *et al.*, Roadmap for the next-generation of hybrid photovoltaic-thermal solar energy collectors, Solar Energy, 2018.
[3] D. Narducci *et al.*, Hybrid and Fully Thermoelectric Solar Harvesting, Springer, 2018.
[4] J. Zeitouny *et al.*, Assessing high-temperature photovoltaic performance for solar hybrid power plants, Solar Energy Materials and Solar Cells, 2018.
[5] E. López *et al.*, Optimum single-gap solar cells for missions to Mercury, Journal of Spacecraft and Rockets, 2016.
[6] S. Parola *et al.*, Improved efficiency of GaSb solar cells using an $Al_{0.50}Ga_{0.50}As_{0.04}Sb_{0.96}$ window layer, Solar Energy Materials and Solar Cells, 2019.
[7] K. Louarn, Etude et réalisation de jonctions tunnel à base d'hétérostructures à semi-conducteurs III-V pour les cellules solaires multi-jonction à très haut rendement, Ph. Thesis, Univ Toulouse 3, 2018.

Acknowledgements

The work is supported by the program « Investments for the future » managed by the French National Research Agency (ANR) under contract ANR-10-LABX-22-01-SOLSTICE. Fruitful discussions with G. Almuneau, M. Levillayer, and I. Massiot from LAAS–CNRS are acknowledged.