Modeling and Simulation of GaSb/GaAs Quantum Dot Solar Cells in SILVACO TCAD

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Abstract

GaSb/GaUtilizing type-II band alignment to increase sub -bandgap absorption and possibly exceed the Shockley–Queisser efficiency limit, quantum dot solar cells (QDSCs) offer an attractive solution for third -generation photovoltaics. In this work, a GaSb QD-embedded GaAs p-i-n solar cell structure is mathematically modeled using the SILVACO TCAD Atlas simulator. An effective medium approximation is used to describe the quantum dot area, and modified Shockley–Read–Hall recombination parameters are used to model intermediate band states. Under AM1.5G illumination, the effects of QD layer count, dot density, and doping concentration on J_SC, V_OC, fill factor, and total power conversion efficiency are carefully examined. Delta-doping and surface passivation have been suggested as mitigation techniques, and results confirm increased infrared photocurrent collection together with a V_OC deficit ascribed to interface recombination. Standard empirical models are used to incorporate temperature-dependent material properties to guarantee physical accuracy under all operating situations. For the experimental design of high-efficiency GaSb/GaAs QDSCs, the simulation framework provides a solid basis.

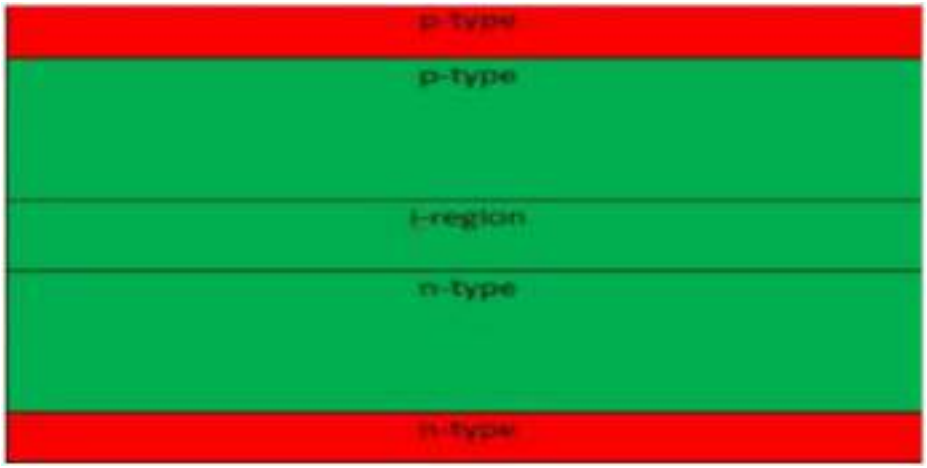

Fig 1: standard structure of p-i-n solar cell.

Keywords: GaSb/GaAs, quantum dot solar cell, SILVACO TCA D, efficiency.

Acknowledgements:
The work is partially funded by national funds through FCT – Fundação para a Ciência e Tecnologia, I.P., in the framework of the UID/06107/2025 – Centro de Investigação em Ciência e Tecnologia para o Sistema Terra e Energia (CREATE), DOI https://doi.org/10.54499/UID/06107/2025.

References:

[1] Luque, A. and Martí, A., Increasing the efficiency of ideal solar cells by photon-induced transitions at intermediate levels, Physical Review Letters, 78(26), 1997, pp. 5014–5017.
[2] Nozik, A.J., Quantum dot solar cells, Physica E, 14(1–2), 2002, pp. 115–120.
[3] Tomic, S., Intermediate-band solar cells: Influence of band formation on dynamical processes in InAs/GaAs quantum dot arrays, Physical Review B, 82(19), 2010, pp. 195321.
[4] Wagener, M.C., Botha, J.R. and Venter, A., GaSb/GaAs quantum dot solar cells: Type-II band alignment and photovoltaic performance, Journal of Applied Physics, 109(9), 2011, pp. 094321.
[5] Silvaco International, Atlas User's Manual: Device Simulation Software, Silvaco Inc., Santa Clara, CA, 2023.