Three-Terminal Tandems for Space Photovoltaics: Combining End-of-Life Efficiency and Monolithic Integration

Federica Cappelluti[1], Gemma Giliberti[2], Antonio Fronteddu[1], Fabio Matteocci[2], Aldo Di Carlo[2,3]

[1] Department of Electronics and Telecommunications, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino.
[2] CHOSE – Centre for Hybrid and OrganicSolar Energy, Department of Electronic Engineering, Tor Vergata University of Rome, via del Politecnico 1, 00133, Rome.
[3] CNR National Research Council – Institute of Structure of Matter (CNR-ISM), via del Fosso del Cavaliere 100, 00133 Rome (Italy)
federica.cappelluti@polito.it

Keywords: *tandem, multiterminal, monolithic, end-of-life, space*

Abstract:

The transition toward scalable and cost-effective solar technologies for space applications may, in the long term, be addressed by rethinking conventional multijunction architectures and materials. While III-V two-terminal series-connected cells currently dominate the space photovoltaic landscape due to their high efficiency and radiation tolerance, their cost and supply constraints limit broader deployment. Inorganic thin-film technologies — such as CIGS, CdTe, and perovskites — offer promising alternatives due to their high power-to-weight ratio, tunable bandgaps, and potential radiation resilience [1–4]. From the perspective of device architecture, multi-terminal approaches may offer some advantages for sustaining high efficiency at end-of-life (EOL), particularly when the simplicity of a monolithic structure can be preserved.

This contribution investigates the potential of three-terminal tandem architectures to enhance EOL performance in space environments, offering benefits comparable to four-terminal devices but with reduced system complexity and added weight. Three-terminal tandem configurations retain the monolithic structure of two-terminal devices, yet allow for independent operation of the sub-cells, thereby mitigating the impact of their different degradation rates [5,6]. We present detailed balance calculations to assess the advantages of three-terminal devices in terms of extended EOL efficiency compared to two-terminal tandems. Finally, building upon our previous work on perovskite/silicon tandems [7], we discuss the three-terminal transistor-like design, an architecture that can be adapted to other thin-film-materials based tandems, including all-perovskite and perovskite-on-inorganic thin-film materials such as CIGS and CdTe. This approach could also provide a platform to develop lightweight, radiation hard, and monolithically integrated three-terminal triple-junction cells for space applications.

Conflicts of Interest

The authors declare that they have no known conflict of interest.

Funding

This study was carried out within the «CLAIRE» project – funded by European Union – Next Generation EU within the PRIN 2022 program (D.D. 104 - 02/02/2022 Ministero dell'Università e della Ricerca). This manuscript reflects only the authors' views and opinions, and the Ministry cannot be considered responsible for them.

References

[1] Ho-Baillie, A. W. Y., et al. *Nat. Rev. Mater.*, **2024**, 9.11: 759-761.
[2] Hepp, A. F., et al., *Photovoltaics Beyond Silicon*, *Elsevier*, **2024**, 675-766.
[3] Kirmani A. R., et al., *Nature Commun.,* **2024**, 15.1: 696.
[4] Verduci, R., et al., *Adv. Energy Mater.,* **2022**, 12.29: 2200125.
[5] Alberi, K., et al., *Joule*, **2024**, 8.3: 658-692.
[6] Martí, A., et al., *Proc. ESPC, IEEE,* **2019**, 1-5.
[7] Giliberti, G., et al., *EPJ Photovoltaics* **2023**, 14, 37.