

# Optimization of thin film encapsulation layers by ALD and SALD for perovskite-silicon tandem solar cells

Aubin Parmentier<sup>a,b</sup>, Damien Coutancier<sup>a</sup>, Timéa Bejat<sup>c</sup>, Stéphane Cros<sup>c</sup>, David Munoz-Rojas<sup>b</sup>, Nathanaelle Schneider<sup>a</sup>

<sup>a</sup>Institut Photovoltaïque d'Île de France (IPVF), UMR CNRS 9006, 18 boulevard Thomas Gobert, 91120 Palaiseau

<sup>b</sup>Laboratoire des Matériaux et du Génie Physique (LMGP), UMR CNRS 5628, 3 parvis Louis Néel - CS 50257 - 38016 Grenoble cedex 1

<sup>c</sup>Commissariat aux Energies Atomique et Alternatives (CEA) Liten, INES, 50 Avenue du Lac Léman 73370 Le Lac du Bourget

[aubin.parmentier@cnrs.fr](mailto:aubin.parmentier@cnrs.fr), [damien.coutancier@cnrs.fr](mailto:damien.coutancier@cnrs.fr), [timea.bejat@cea.fr](mailto:timea.bejat@cea.fr), [stephane.cros@cea.fr](mailto:stephane.cros@cea.fr), [david.munoz-rojas@grenoble-inp.fr](mailto:david.munoz-rojas@grenoble-inp.fr), [nathanaelle.schneider@cnrs.fr](mailto:nathanaelle.schneider@cnrs.fr)

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## References:

- [1] NREL Cell-Efficiency Page. <https://www.nrel.gov/pv/cell-efficiency.html> (accessed 2024-02-13).
- [2] Zhang, Y et al. Research Progress of Buffer Layer and Encapsulation Layer Prepared by Atomic Layer Deposition to Improve the Stability of Perovskite Solar Cells. *Solar RRL* **2022**, 6 (12), 2200823. <https://doi.org/10.1002/solr.202200823>.
- [3] Johnson, R. W. et al. A Brief Review of Atomic Layer Deposition: From Fundamentals to Applications. *Materials Today* **2014**, 17 (5), 236–246.
- [4] Ramos, F. J. et al. Versatile Perovskite Solar Cell Encapsulation by Low-Temperature ALD-Al<sub>2</sub>O<sub>3</sub> with Long-Term Stability Improvement. *Sustainable Energy Fuels* **2018**, 2 (11), 2468–2479. <https://doi.org/10.1039/C8SE00282G>.
- [5] Uddin, A. et al. Encapsulation of Organic and Perovskite Solar Cells: A Review. *Coatings* **2019**, 9 (2), 65. <https://doi.org/10.3390/coatings9020065>.
- [6] Wang, L. et al. Enhanced Moisture Barrier Performance for ALD-Encapsulated OLEDs by Introducing an Organic Protective Layer. *J. Mater. Chem. C* **2017**, 5 (16), 4017–4024. <https://doi.org/10.1039/c7tc00903h>.
- [7] Park, J.-S. et al. Thin Film Encapsulation for Flexible AM-OLED: A Review. *Semicond. Sci. Technol.* **2011**, 26 (3), 034001. <https://doi.org/10.1088/0268-1242/26/3/034001>.
- [8] Van De Kerckhove, K. et al. Molecular Layer Deposition of “Titanicone”, a Titanium-Based Hybrid Material, as an Electrode for Lithium-Ion Batteries. *Dalton Trans.* **2016**, 45 (3), 1176–1184. <https://doi.org/10.1039/C5DT03840E>.
- [9] Meyer, J. et al. Al<sub>2</sub>O<sub>3</sub>/ZrO<sub>2</sub> Nanolaminates as Ultrahigh Gas-Diffusion Barriers—A Strategy for Reliable Encapsulation of Organic Electronics. *Advanced Materials* **2009**, 21 (18), 1845–1849. <https://doi.org/10.1002/adma.200803440>.
- [10] Li, M. et al. Realization of Al<sub>2</sub>O<sub>3</sub>/MgO Laminated Structure at Low Temperature for Thin Film Encapsulation in Organic Light-Emitting Diodes. *Nanotechnology* **2016**, 27 (49), 494003. <https://doi.org/10.1088/0957-4484/27/49/494003>.
- [11] Schiessl, S. et al. Nanocomposite Coatings Based on Polyvinyl Alcohol and Montmorillonite for High-Barrier Food Packaging. *Front. Nutr.* **2022**, 9, 790157. <https://doi.org/10.3389/fnut.2022.790157>.
- [12] Muñoz-Rojas, D. et al. Spatial Atmospheric Atomic Layer Deposition: A New Laboratory and Industrial Tool for Low-Cost Photovoltaics. *Mater. Horiz.* **2014**, 1 (3), 314–320. <https://doi.org/10.1039/C3MH00136A>.