

Scalable Pulsed Laser Deposition of Inorganic Charge Transport Layers for Perovskite-on-Silicon Tandem Solar Cells

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The power conversion efficiency (PCE) of **halogenated perovskite-on-silicon (PK/Si) tandem solar cells** has recently increased from 23.6% to 33.9% on small areas^[1], exceeding the 30% theoretical limit for crystalline silicon cells. The **inverted p-i-n configuration** of perovskite solar cells (PSC) is ideal for tandem integration with silicon heterojunction cells, particularly due to its low fabrication temperature. This study investigates the room temperature, precursor-free deposition of **SnO₂^[2] and NiO_x^[3] as inorganic electron and hole transport layers (ETL/HTL) using **pulsed laser deposition (PLD)**. This wafer-based technique provides **low substrate damage** and **uniform coverage across large areas**, with a **competitive deposition rate** compared to atomic layer deposition (ALD) and RF magnetron sputtering. Non-textured **PK/Si tandem cells with PLD-grown SnO₂ and NiO_x** achieved remarkable peak PCEs of **23.1% and 21.8%** on a **9 cm²** area under one-sun illumination, without anti-reflective coating or passivation. Perspectives include **upcoming combined integration of PLD-grown selective layers and electrodes** (SnO₂, NiO_x, ITO), as well as **ongoing development of a PLD-deposited perovskite absorber**. To this end, we report a first **successful single junction integration of PLD-CsPbI₂Br on top of PLD-NiO_x**.**

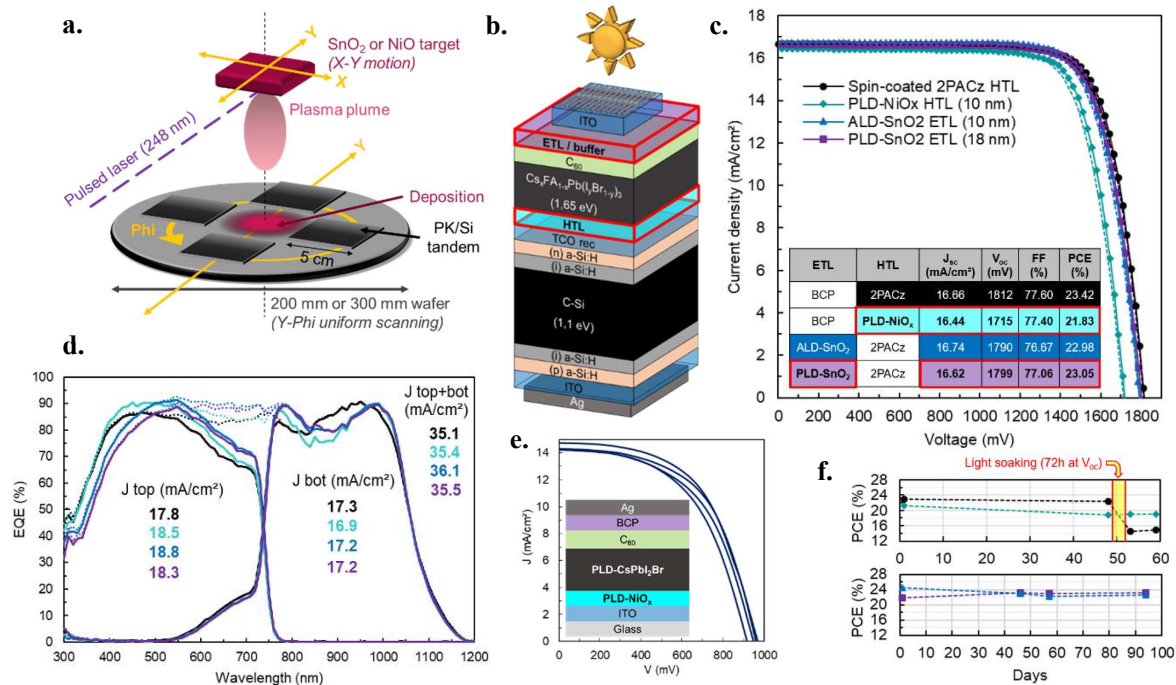


Figure 1. *a.* Schematic of employed large-area pulsed laser deposition (PLD) technique, *b.* Monolithic PK/Si-heterojunction p-i-n tandem solar cell (9 cm² active area), *c.* J-V reverse curves under AM1.5 1000 W/m² of tandem cells integrating PLD-SnO₂ or NiO_x vs lab benchmarks (forward in dotted lines) with J-V parameters summary, *d.* External Quantum Efficiencies of tandem cells with integrated photocurrents, *e.* J-V curves under one-sun of p-i-n single junction cells integrating PLD-CsPbI₂Br and NiO_x together, *f.* Stability of tandem cells in N₂-storage (showing 1sun illumination ageing for NiO_x vs 2PACz).

[1] National Renewable Energy Laboratory, 2024.

[2] W. Soltanpoor, A. Bracesco, N. Rodkey, M. Creatore, M. Morales-Masis, *Solar RRL* **2023**, 7, 2300616.

[3] J.H. Park, J. Seo, S. Park, S.S. Shin, Y.C. Kim, N.J. Jeon, H.-W. Shin, T.K. Ahn, J.H. Noh, S.C. Yoon, C.S. Hwang, S.I. Seok, *Advanced Materials* **2015**, 27, 4013.