Levitrack ALD

For perovskite tandem solar cell manufacturing

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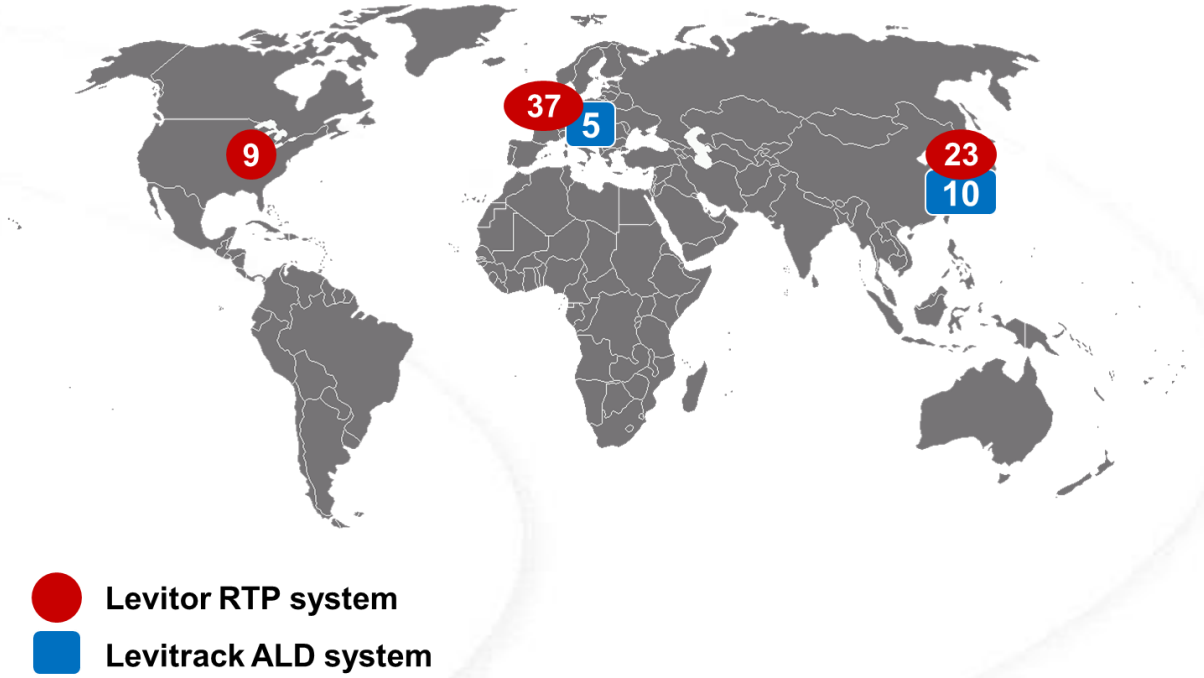
Introduction to

LEVITECH

- Levitech BV
  - Founded in 2009
  - Spin-off from ASM International NV
  - Located in Almere, the Netherlands
  - Subsidiaries / agents worldwide

- Core technologies
  - Floating substrates
  - Spatial ALD
  - RTP via conductive heating & cooling



Levitech product portfolio

Levitor RTP

- Semiconductor industry

Levitrack ALD

- Photovoltaic (PV) industry
- …

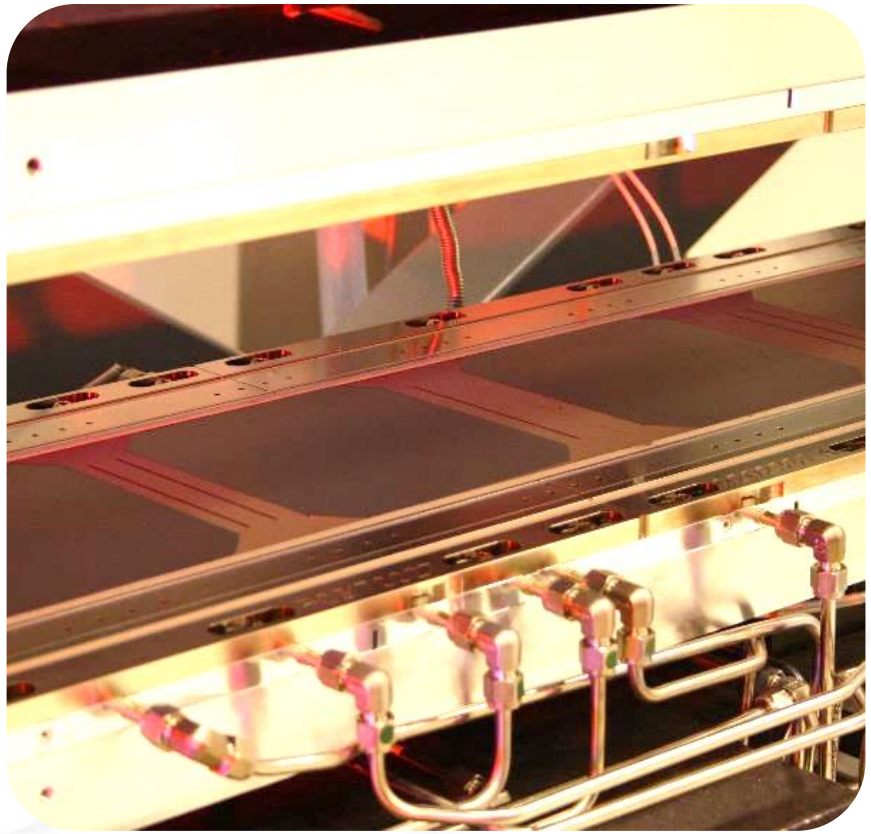
LEVITECH

High volume manufacturing system

LEVITRACK ALD

LEVITRACK ALD

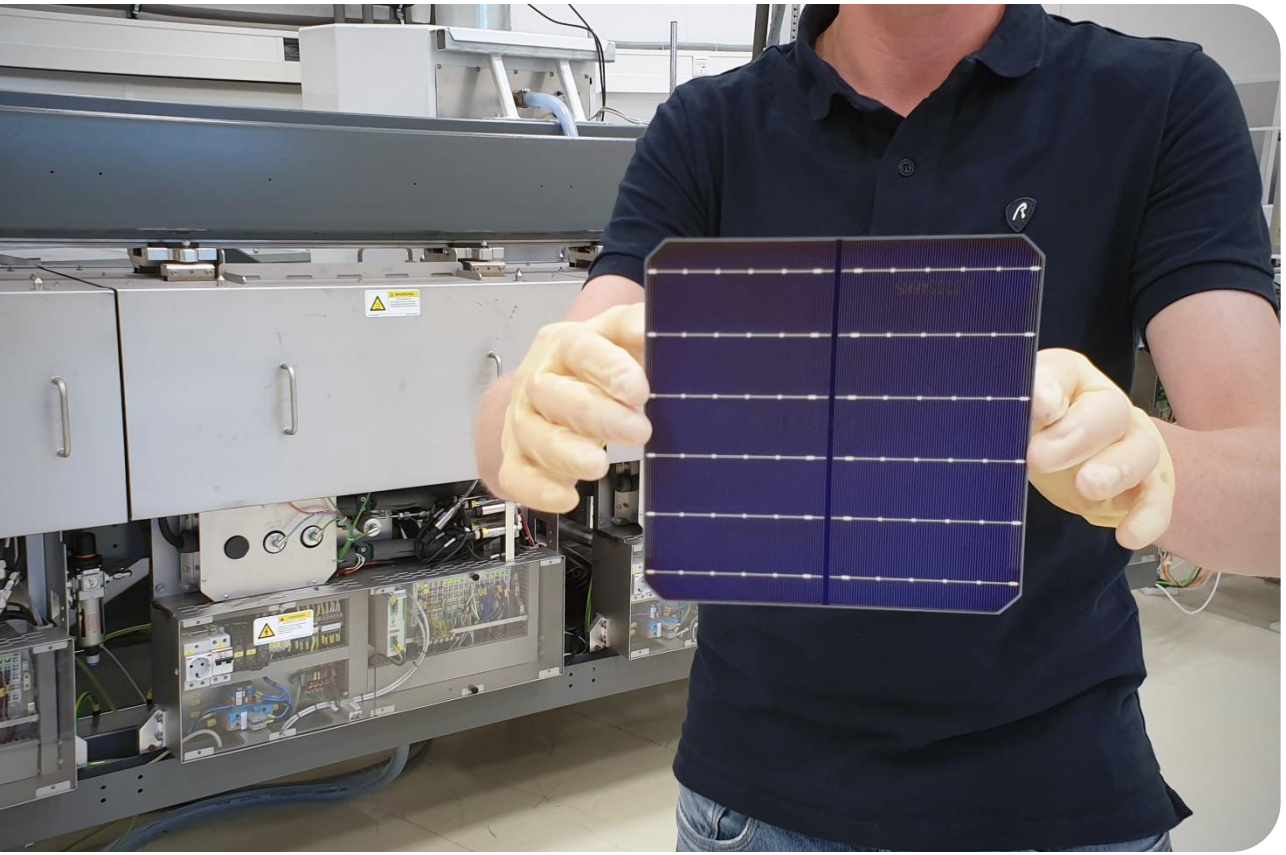
- Patented ‘Spatial ALD’:
  - Precursor separation in space instead of conventional separation in time (batch)
  - Substrate supported on gas bearing enabling contactless transport
- Mass production solutions for PV:
  - Aluminum oxide (Al_2O_3)
  - Titanium oxide (TiO_2)
  - Tin oxide (SnO_2)
- More processes and applications in development



Levitrack 8m-system

- Modular Levitrack design
  - Integrated fast wafer heat-up and cool-down (100-200°C)
  - Single-pass deposition (6nm)
  - Selectable modules
  - Temperature gradient
  - Multi-layers stack
  - Co-dosing

Levitrack 4m-system



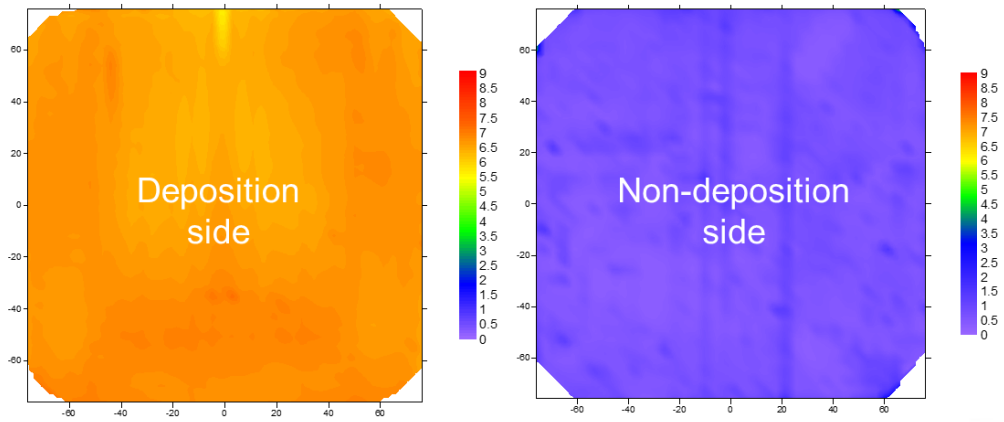
- R&D 4m-system on-site at Levitech (NL)
  - Available for process development and sampling
  - Up to 16x ALD cycles
    - *Multi-pass for thicker layers*
  - Configurable to handle various substrates
    - *Solar wafers up to M6 size*
    - *Foils using roll-to-roll handling units*

Excellent layer performance

- Uniform, conformal and dense coatings
- Atmospheric processing enables optimal surface coverage
- Single side processing (top or bottom side)

High volume manufacturing

- Substrate speed up to 330mm/sec (20m/min)
- Efficient precursor usage
- Integrated (multiple) precursor gas supply and abatement system

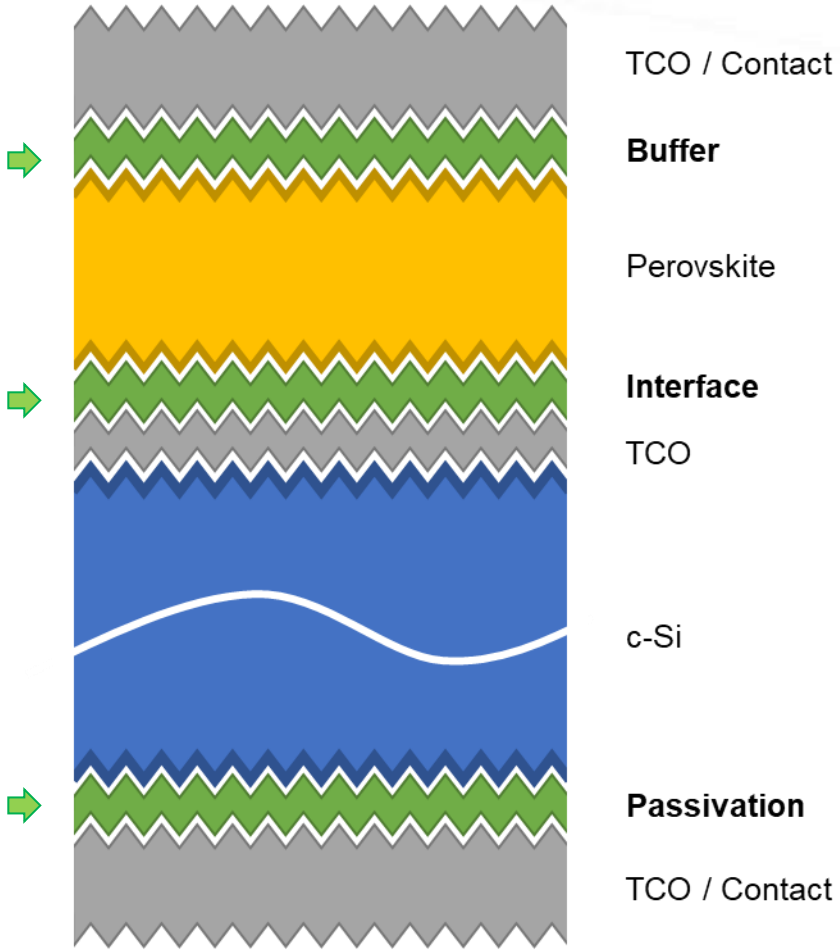


LEVITECH

Levitrack ALD

PEROVSKITE TANDEM MANUFACTURING

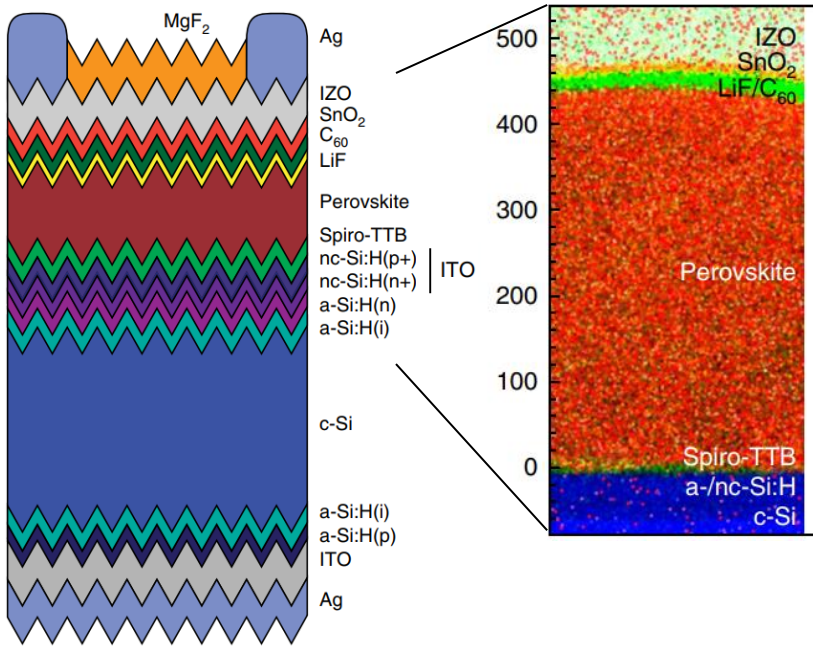
ALD applications for PV



- Buffer layers: Al_2O_3, TiO_2, SnO_2
  - Interface engineering
  - Selective contact layer
- Interface layers: TiO_2, ZnO, Al_2O_3
  - Recombination layer
  - Compact layer
  - Selective contact layer
- Surface passivation: Al_2O_3, TiO_2
  - Surface passivation
  - Passivating contact
  - Hydrogenation

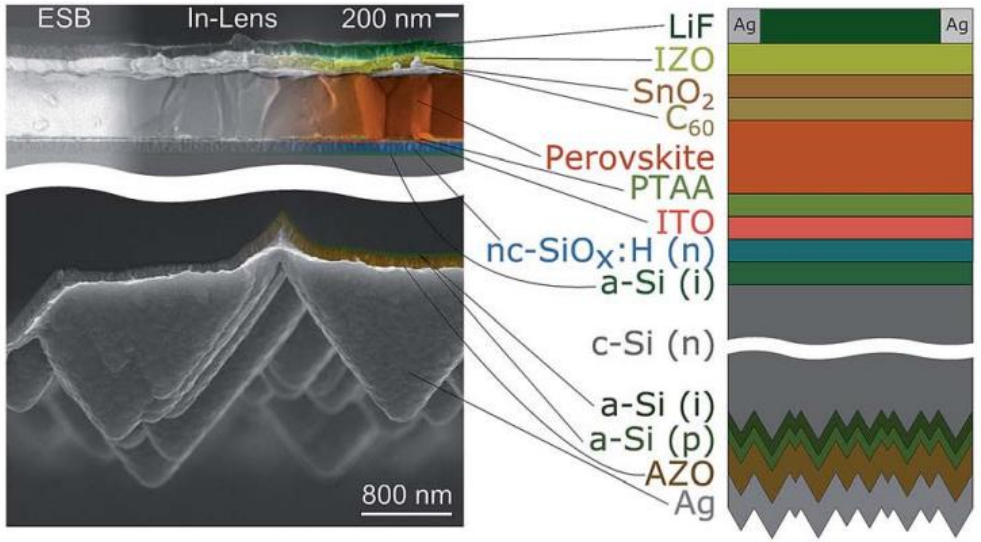
Sahli – EPFL – 2018

- A buffer layer of 10nm of SnO2 was deposited by ALD at 100°C using TDMASn and H2O as precursors
- a certified steady-state efficiency of 25.2%



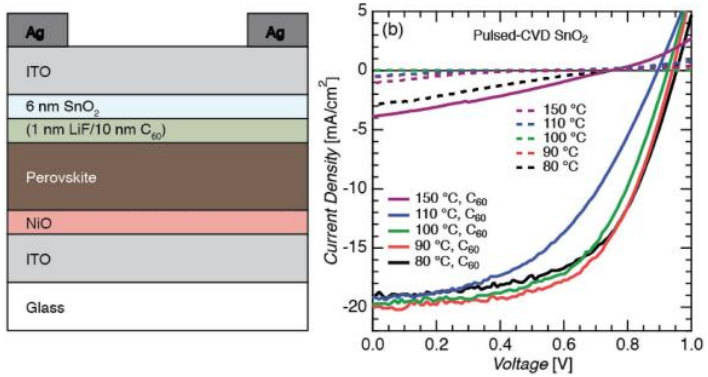
Al-Ashouri – HZB – 2020

- a 20 nm ALD SnO2 layer is deposited at 100°C
- HZB has produced a PVK/Si tandem solar cell with a world record efficiency of 29.8% (2021)



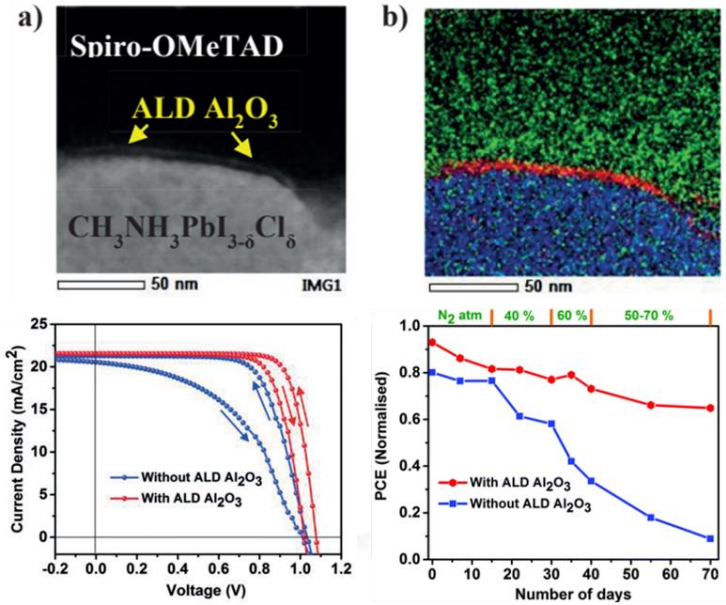
Palmstrom – Stanford – 2018

- The perovskite stability is sensitive to metal–organic TDMASn exposure .. in removal of the formamidinium cation.
- Thin fullerene layers offer improvements to perovskite stability .. and enhancement in carrier extraction.



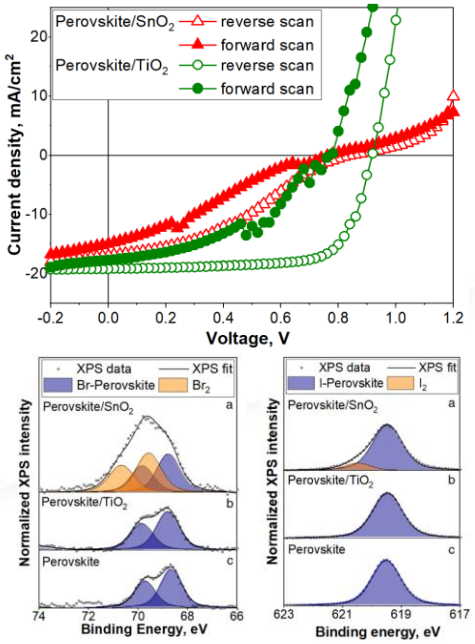
Koushik - TU/e - 2019

- 10 cycles of ALD Al2O3 deposited directly on top of the perovskite material gives superior performance with a long-term humidity-stability

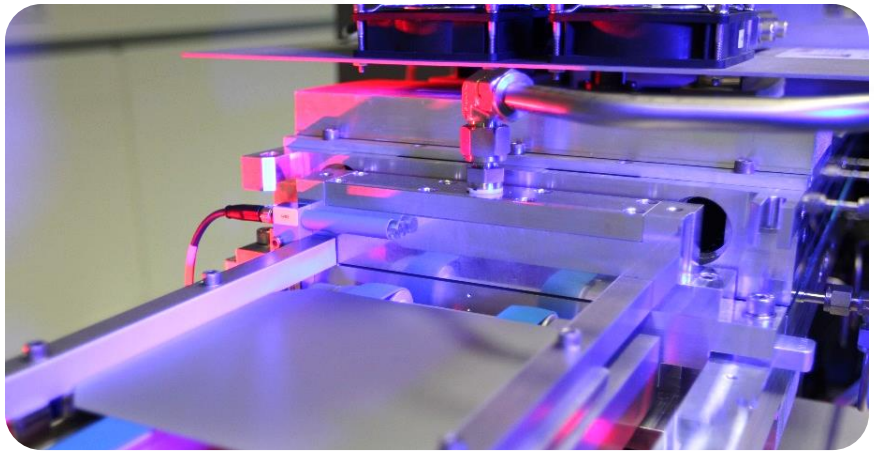


Bracesco - TU/e - 2020

- a redox reaction between the perovskite and the Sn metal center of the ALD precursor takes place .. and Sn(IV) is reduced to Sn(II).. the Ti(IV) metal center does not undergo any redox process



Summary



- Excellent device performance
- Unique ALD SnO_2 manufacturing capability
- Single-pass stack deposition (switchable)
- Proven in mass production
- Ready for current and next generation tandem cells and devices

Thank you for your attention