SPATIAL ALD INNOVATORS

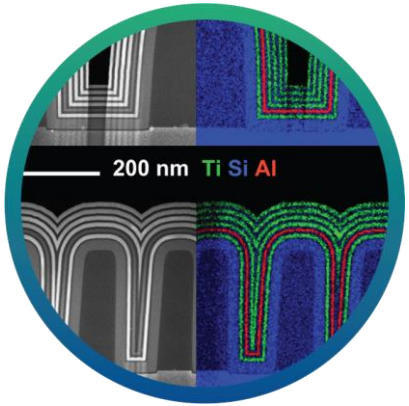
Enabling green markets with nanolayer coatings by Spatial ALD

Erik Kremers

Explore. Develop. Integrate. **Together.**

Meet **SALD**

- Based in Eindhoven, the Netherlands
- Specialists in functional conformal thin films
- Over 10 years of industrial experience in Spatial Atomic Layer Deposition



Courtesy of Atomic Limits

Status

- Already >3.5 billion wafers processed with our spatial ALD tools

  Real high volume production experience from the PV industry

- Core team: **16 people, experts** with each > 10 years of experience in Spatial ALD and industrial equipment development.
- Own lab for material research and customer demonstration
- Product portfolio in Spatial ALD systems

Product portfolio

Highest quality, modular design, for every application and with low TCO

R&D Systems and **pilot-production**

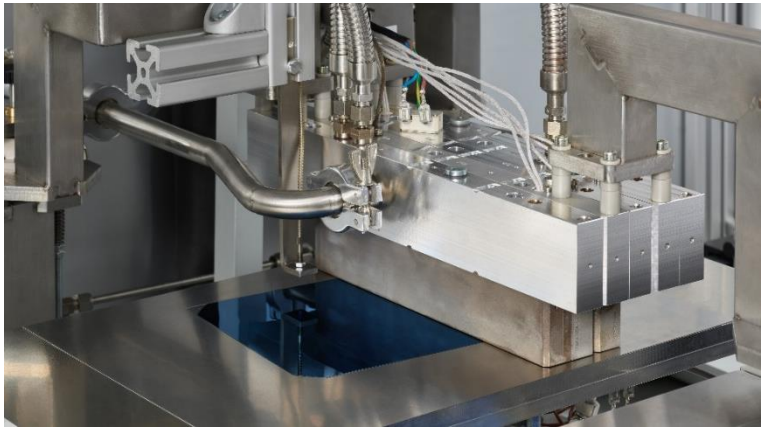
High Volume production

Systems, Roll-to-Roll

Deposition technology

Gas nozzles of the deposition head:

- **Stainless steel 3d print technology**
- **High uptime**
  - >120 hrs @ continuous production
  - Replaceable within 5 minutes
- **Easy cleaning**
- **Design flexibility**
  - R&D: modular gas nozzle design
  - Integrated modular plasma source
  - HVM: application specific design



Nanolayer coatings for green markets

- **Batteries** (cathodes, (silicon) anodes and solid-state batteries)
- **Solar cells** (silicon, perovskites, tandems)
- **Foils** for packaging (food packaging, vacuum sealing)
- **Green Hydrogen** (fuel cells and electrolysers)
- **Textiles and membranes** (barrier coatings)

All these markets have enormous **growth potential!**

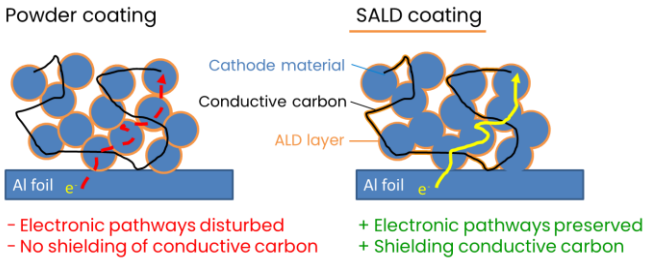


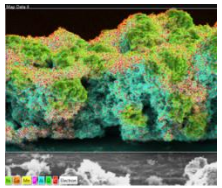


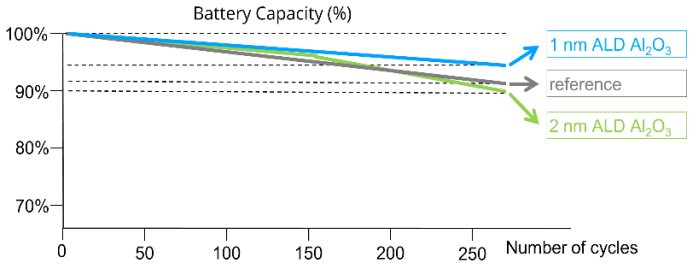
Battery improvement

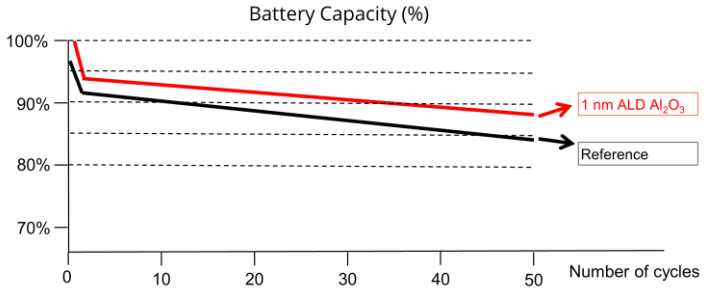
Coatings in batteries

- Electrode coating (NMC, graphite anodes)
  - Long life cycle improvement
- Nextgen electrode coating (silicon anodes)
  - Cycle test ongoing









Solar cells

- Tools delivered for perovskite research and pilot production

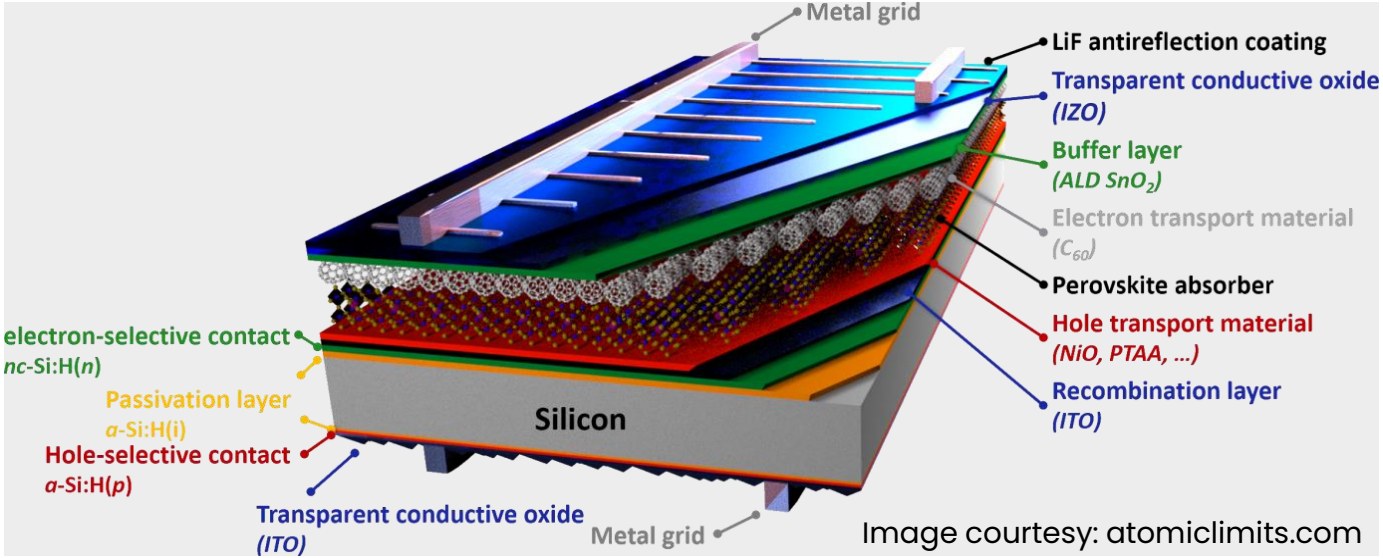


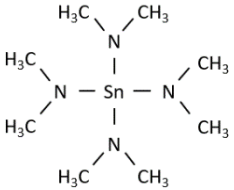
Image courtesy: atomiclimits.com

Solar cells

- **Track record** with **SnO_2** for stabilizing perovskite
- Soft deposition on C60 material important for lifetime
- Spatial ALD process of SnO2 established in glovebox system on 2x M6 wafers

SnO_2 process:

- TDMASn and H_2O (bubbling)
- T_{dep} = 120 °C
- $V_{substrate}$ =10 - 100 cm/s

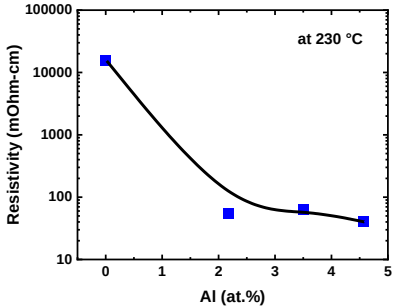


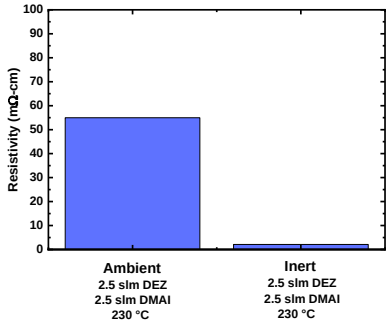
Visual inspection: excellent uniformity on deposited region

✓ Good film properties
✓ Excellent uniformity & scalable process

Solar cells

- Recombination junction & TCO (ZnO:Al)
  - Resistivity can be tuned with co-dosing DMAI to the DEZ. Environment is important!

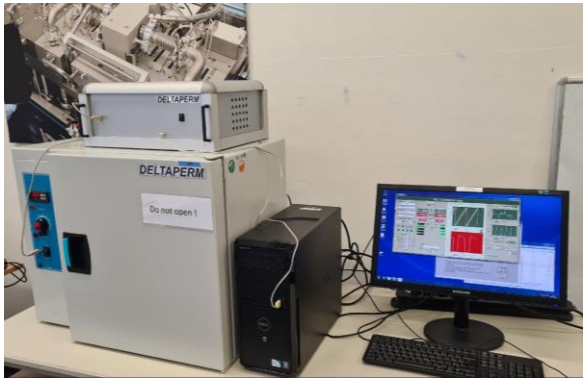




  - These results contributed to the work of Eindhoven University of Technology, submitted for publication in Sol. Energy Mater. Sol. Cells:
    B. Macco et al. *Temporal and Spatial Atomic Layer Deposition of Al-Doped Zinc Oxide as a Passivating Conductive Contact for Silicon Solar Cells.*
- Hole transport layer (NiO)
  - First depositions are scheduled.

Packaging materials with barrier technology

- Plastic packaging has to be recyclable.
  New barrier technology required to replace the aluminium plating.
  This will become a large grow market



- Lab scale coatings of plastics- and paper foils for testing/demonstration possible.
- Large scale demonstration expected end of 2022

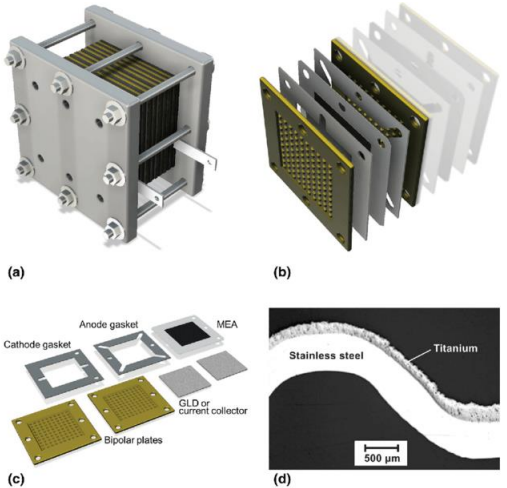
- WVTR measurements in house for qualification of barrier properties

Green hydrogen

- Improve robustness and reduce costs of electrolyser parts and flow battery parts to enable cost effective hydrogen generation

- Nano coatings on electrodes, bipolar plates and membranes to reduce the amount of expensive materials and apply them only at the surface where they are necessary.

- First tests scheduled and cost models discussed with material- and component suppliers



Summary

- Thermal and Plasma Enhanced Spatial ALD concepts for lab and pilot production and scalable into high volume production
- A Spatial ALD company with field experience in high volume production
- Integration of the unique deposition technology possible for 3rd parties
- Modular gas evaporation cabinets for evaporation and mixing of precursors
- SALD has experience with: Al_2O_3, ZnO, ZnO:Al, SnO_2, TiO_2 and plasma-enhanced SiO_2
- Experience in systems with protective environments like N_2 or Ar
- Feasibility studies and sampling for new materials and/or applications
- Collaborate to find the best thin-film solution for your application

SPATIAL ALD INNOVATORS

The future of spatial ALD is already in the market

METROPOOL REGIO EINDHOVEN

Horizon Europe

NWO

Rijksdienst voor Ondernemend Nederland

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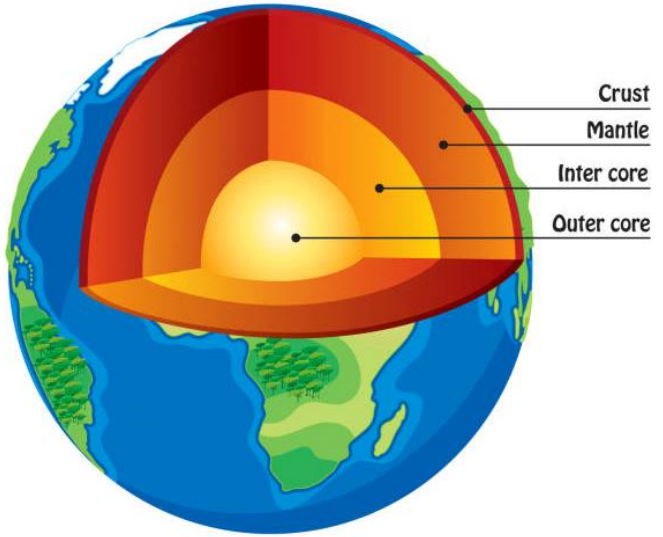

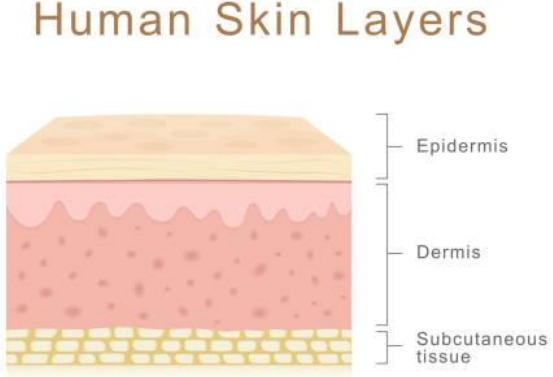

All good things come in layers