# Low temperature deposition of In-free TCO using Spatial ALD for application to HET cells

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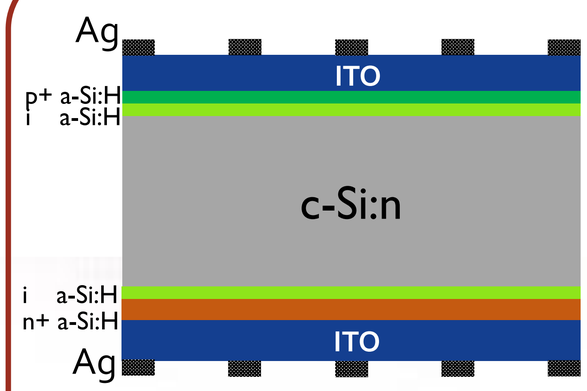
## Motivation




*Schematic view of an amorphous silicon/crystalline silicon heterojunction (HET) cell*

Amorphous/crystalline silicon heterojunction (HET) technology allows high energy conversion efficiency (> 22 % at INES [1]) thanks to excellent passivation quality of a-Si:H/c-Si interface.

**Indium Tin Oxide (ITO)**

- Containing a rare element, Indium
- ITO deposition method: magnetron sputtering

➔ damage to the a-Si:H/c-Si interface [2].

Replaced by

**ZnO based TCOs**

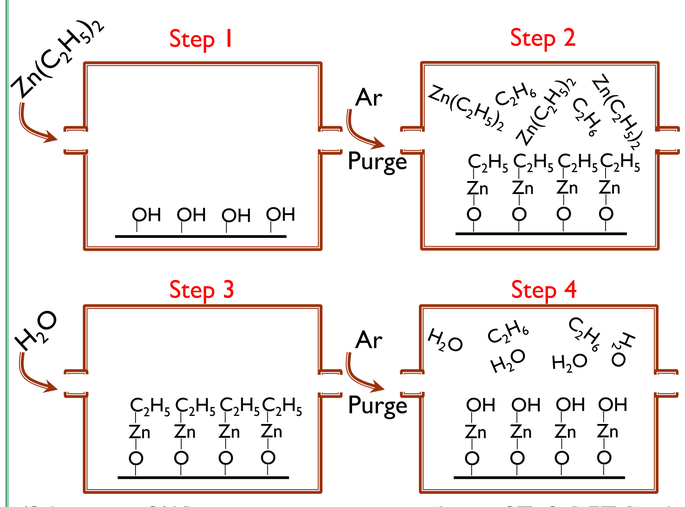
- Low-cost Transparent Conductive Oxides (TCOs)
- Low-damage deposition technique: Spatial Atomic Layer Deposition (SALD)

**Objectives:** Deposit Indium-free TCOs by fast, low temperature, scalable method (SALD)

## Spatial Atomic Layer Deposition

### Conventional ALD

Precursors separated in **time**




*(Schematic of ALD process to grow a monolayer of ZnO, DEZ: Diethyl Zinc)*

A cycle consists of:

Step 1: Precursor injection into reactor. A monolayer formed on surface by chemisorption

➔ self-terminating process

Step 2: Purge (*remove excess precursor*)

Step 3: Injection of second precursor.

➔ Reaction with monolayer of first precursor

Step 4: Purge

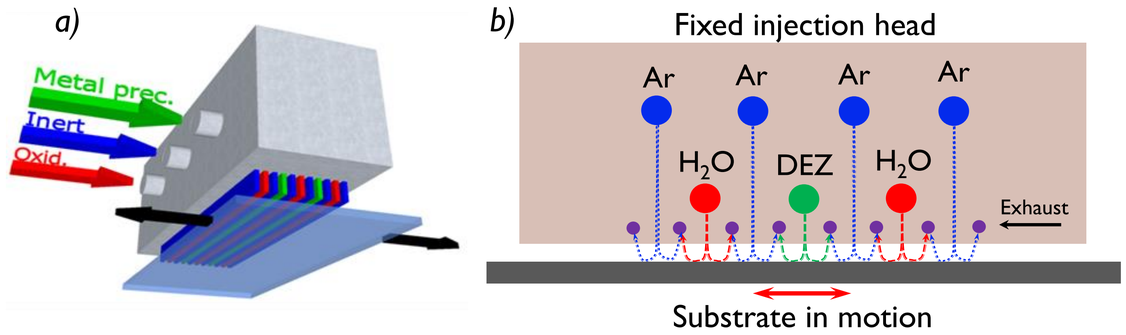
→ Repeating this cycle several times to reach the desired thickness.

High control of thickness, unique conformality, low temperature

But very slow, not easy to scale

### Spatial ALD

Precursors separated in **space**




- Precursors are constantly injected in different locations, as shown in a), [3]
- Substrate moves through different gas flows, as shown in b).
- Small gap (50µm – 200µm) between injector and substrate, as well as the inert gas channels, prevent different precursors from mixing.

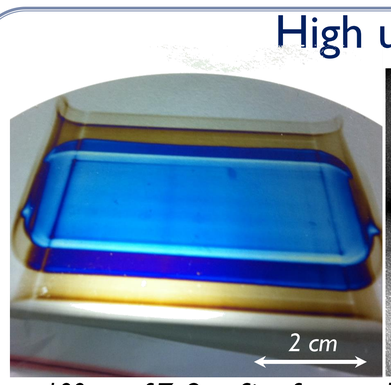
➔ Substrate will be exposed sequentially to oxidant, inert gas, metal precursor, then inert gas again and so on. This allows reproducing the cycles in conventional ALD.

Same advantages as conventional ALD

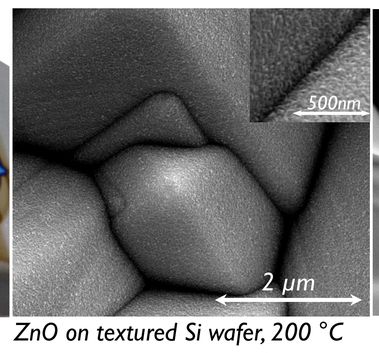
Faster, easier and cheaper to scale (atmospheric processing)

## Results & discussion

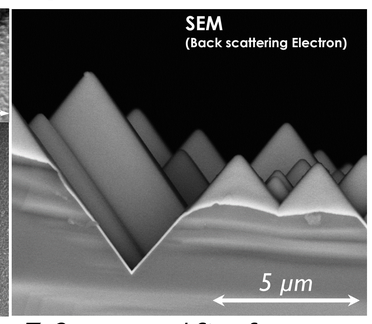
### High uniformity, conformity




*100 nm of ZnO on Si wafer*

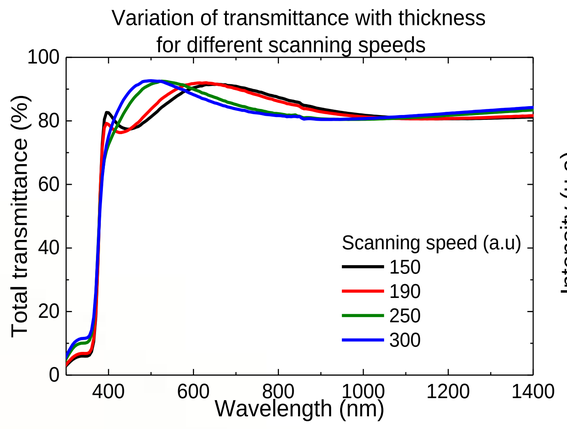



*ZnO on textured Si wafer, 200 °C*
*Top view images with SEM*



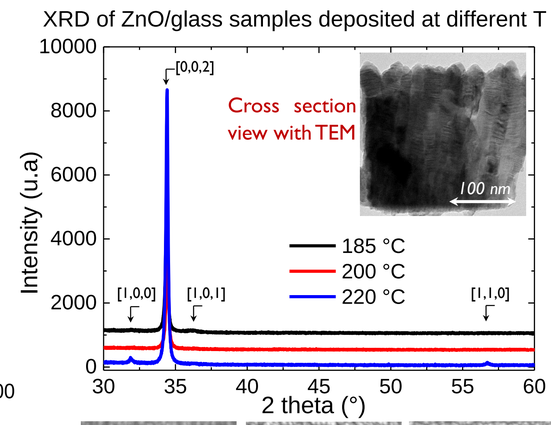

*ZnO on textured Si wafer, cross-section view image with SEM*

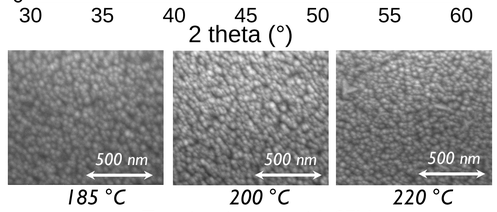
### Transparency




- High transmission (85% - 90%) achieved
- Slower scanning speed ➔ thicker film
- Eg = 3,28 eV (calculated with Tauc formula)

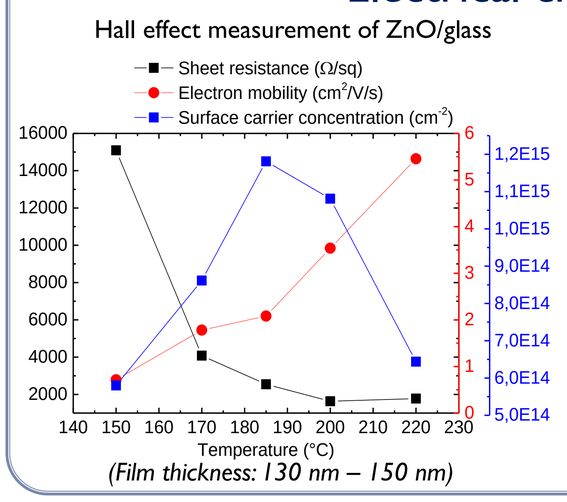
### Cristallinity




Top view images with SEM

### Electrical characterization




*(Film thickness: 130 nm – 150 nm)*

Intrinsic ZnO film deposited by SALD exhibits low resistivity (~2,5E-2 Ωcm at deposition temperature of 200 °C). However, TCOs application requires a better conductivity.

Aluminium doped Zinc Oxide (AZO)

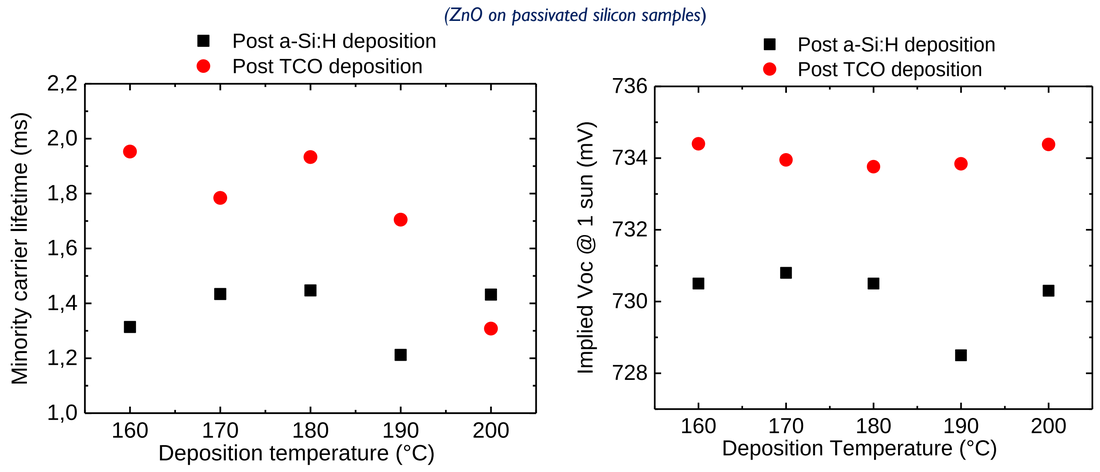
*T= 200 °C, film thickness: 200 nm*

| Material | Sheet Resistance ($\Omega/\square$) | Electron mobility ($cm^2V^{-1}s^{-1}$) | Carrier concentration ($cm^{-3}$) |
|---|---|---|---|
| ZnO | 1634 | 3,54 | 5,4E+19 |
| AZO | 472 | 1,49 | 4,5E+20 |

*Result from first AZO depositions*
*(Study in progress)*

### Passivation measurements

*(ZnO on passivated silicon samples)*




ZnO deposition by SALD keeps a high passivation level

## Conclusions

- SALD is a fast and scalable technique which can provide high uniformity, conformity of thin film over large areas at low temperature and under atmospheric pressure.
- High transparency and low resistivity ZnO film has been obtained by SALD.
- SALD is a promising technique for TCOs deposition because it allows keeping high passivation quality in HET solar cell.

**Perspectives:** Study on Al-doped ZnO to improve film conductivity.

## References

[1] P. Carroy et al, *Proceedings of 31st EU-PVSEC*, Hamburg, 359, 2015

[2] D. Zhang et al, *Energy Procedia* 8, 207–213, 2011

[3] D. Muñoz-Rojas and J.Driscoll, *Mater Horiz.*, V1, p314, 2014

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