Silicon heterojunction solar cells using aluminum doped zinc oxide as back contact: sputtering and ALD

G. Christmann[1], D. Sacchetto[1], L. Sansonnens[1], L. A. A. Duval[2], M. Creatore[2], W. M. M. Kessels[2], G. Wahli[3], L. Barraud[1], A. Descoeudres[1], B. Paviet-Salomon[1], N. Badel[1], B. Strahm[3], M. Despeisse[1], S. Nicolay[1], and C. Ballif[1,4]

[1] Centre Suisse d'Électronique et de Microtechnique (CSEM), PV-center, Neuchâtel, Switzerland

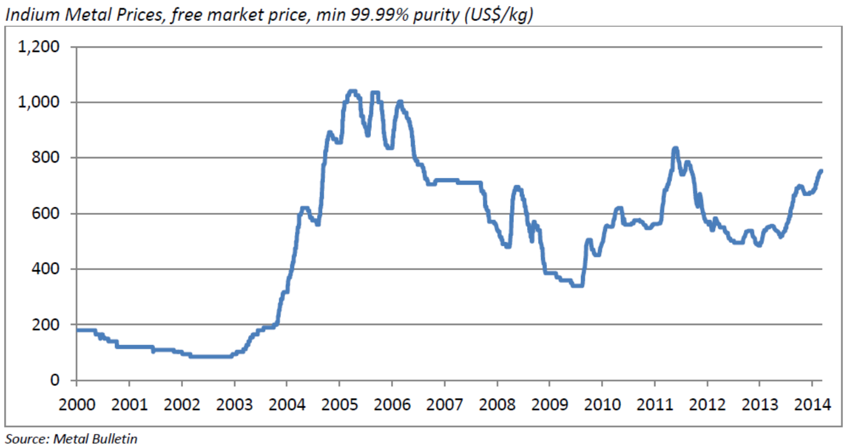
[2] Eindhoven University of Technology, Eindhoven, The Netherlands

[3] Meyer Burger Research, Hauterive, Switzerland

[4] École Polytechnique Fédérale de Lausanne (EPFL), Institute of Microengineering (IMT), Photovoltaics and Thin Film Electronics Laboratory, Neuchâtel, Switzerland

Motivation

- Heterojunction technology (HJT) solar cells requires transparent conducting oxides for contacts, generally ITO is used
- Indium is a high cost strategic resource with limited supplies



Source: European Commission Materials Information System (https://setis.ec.europa.eu/mis/gallery-all-graphics-images/material/indium)

➔It is highly desirable to replace ITO with indium free alternatives

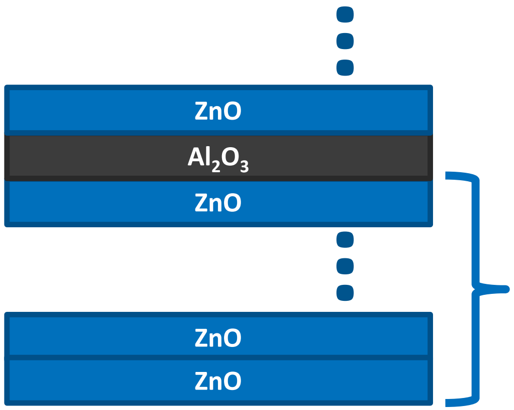
ZnO is a good candidate thanks to its high bandgap and ability to be doped

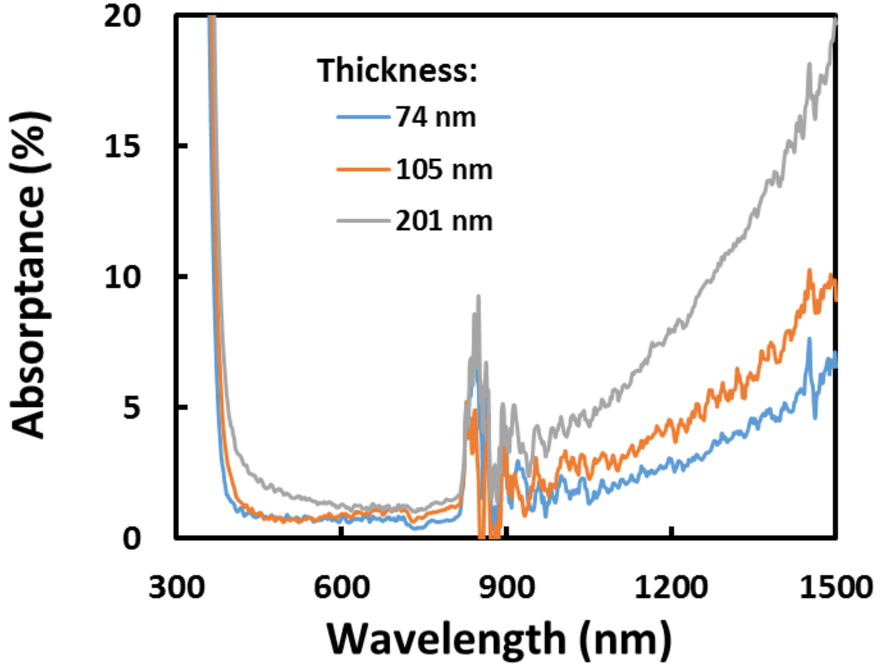
K. Ellmer, J. Phys. D: Appl. Phys. **34** 3097 (2001)

AZO by thermal Atomic Layer Deposition: properties

ALD supercycle :

- 23 cycles DEZ and H_2O
- 1 cycle TMA and H_2O

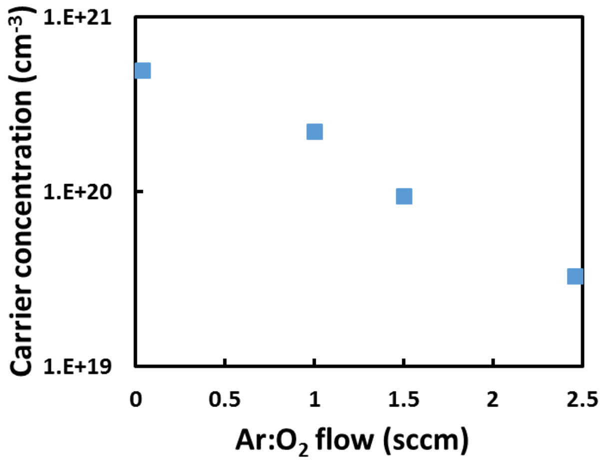


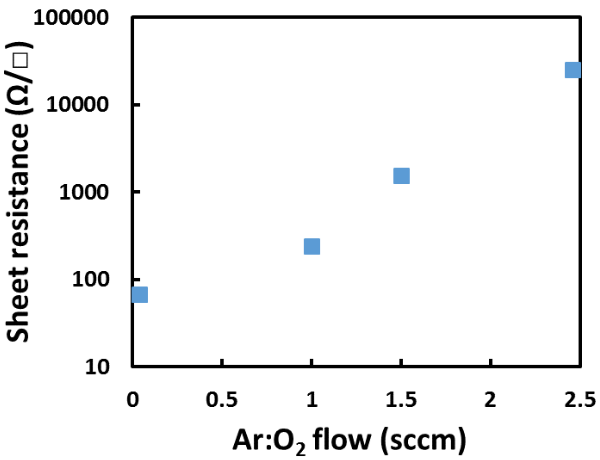


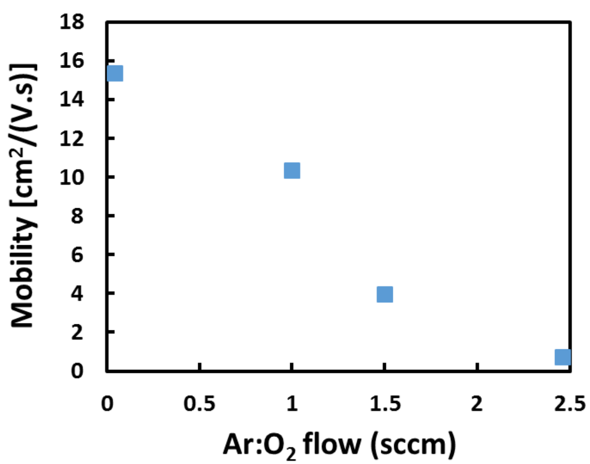
t (nm)	Mobility ($cm^2/(V.s)$)	Carrier concentration (cm^{-3})	R_{sheet} (Ω/□)
74	23	$1.7{\cdot}10^{20}$	278
105	7	$6.1{\cdot}10^{20}$	187
201	10	$5.2\ {\cdot}10^{20}$	76

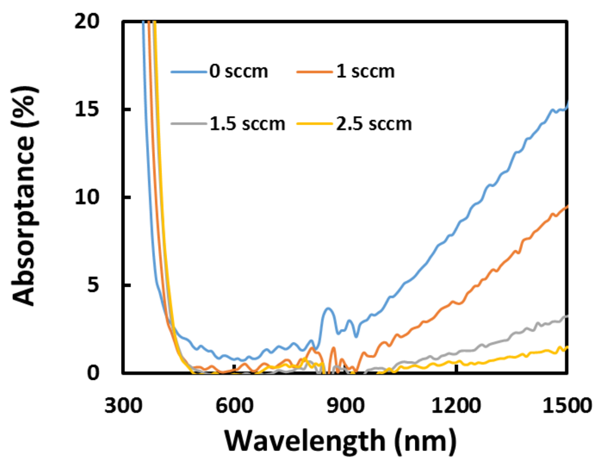
Wu et al., J.Appl.Phys. **114**, 024308-1 (2013)

AZO by sputtering: properties (~100 nm thick)



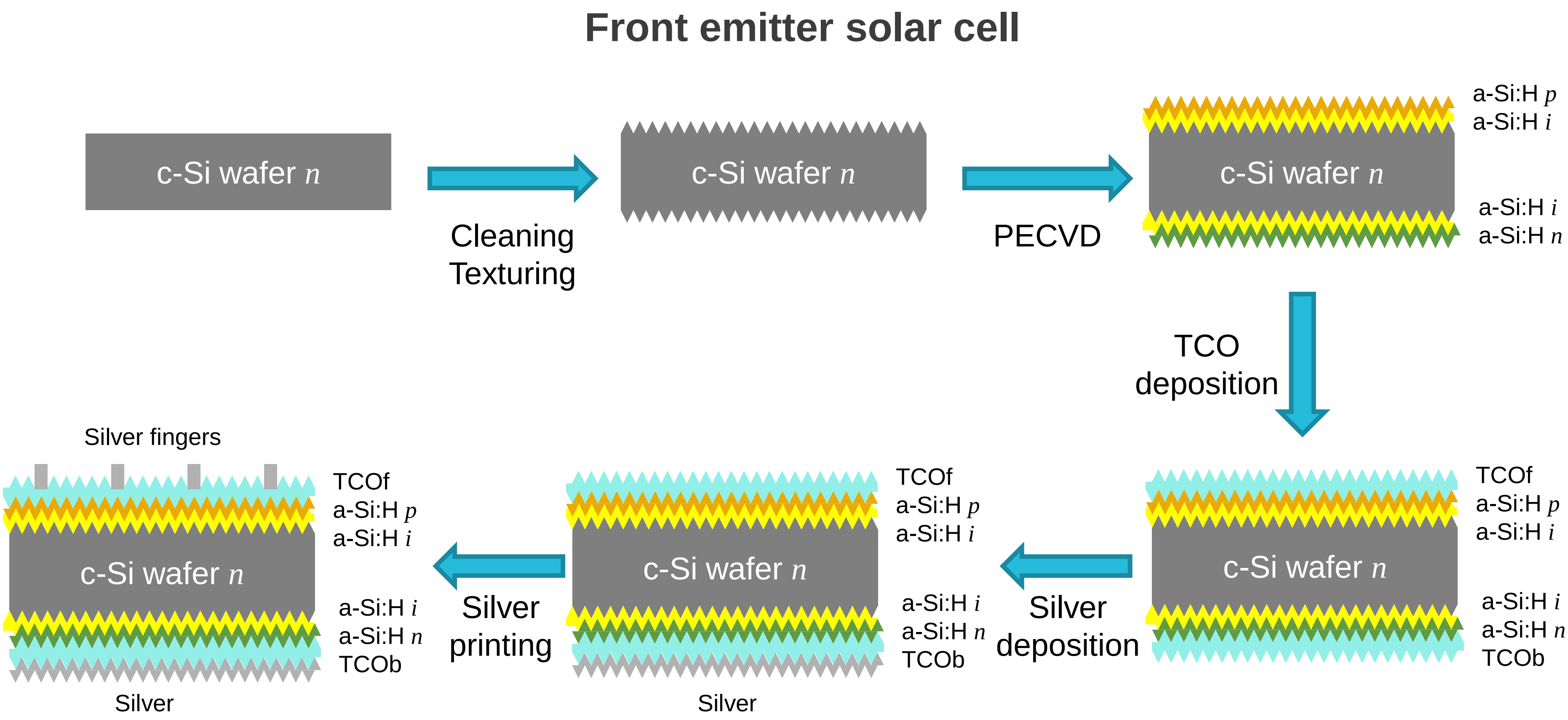






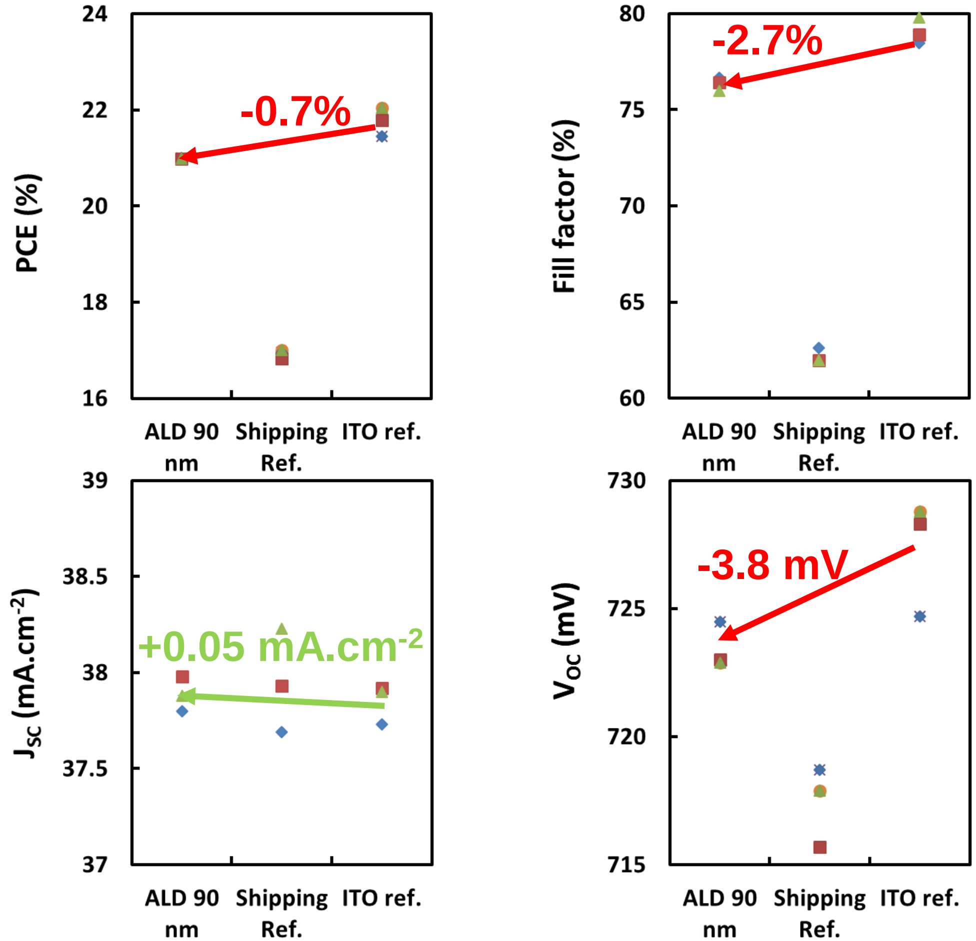
Advantage: Easily tunable electrical and optical properties

Semiconductor heterojunction solar cell process flow



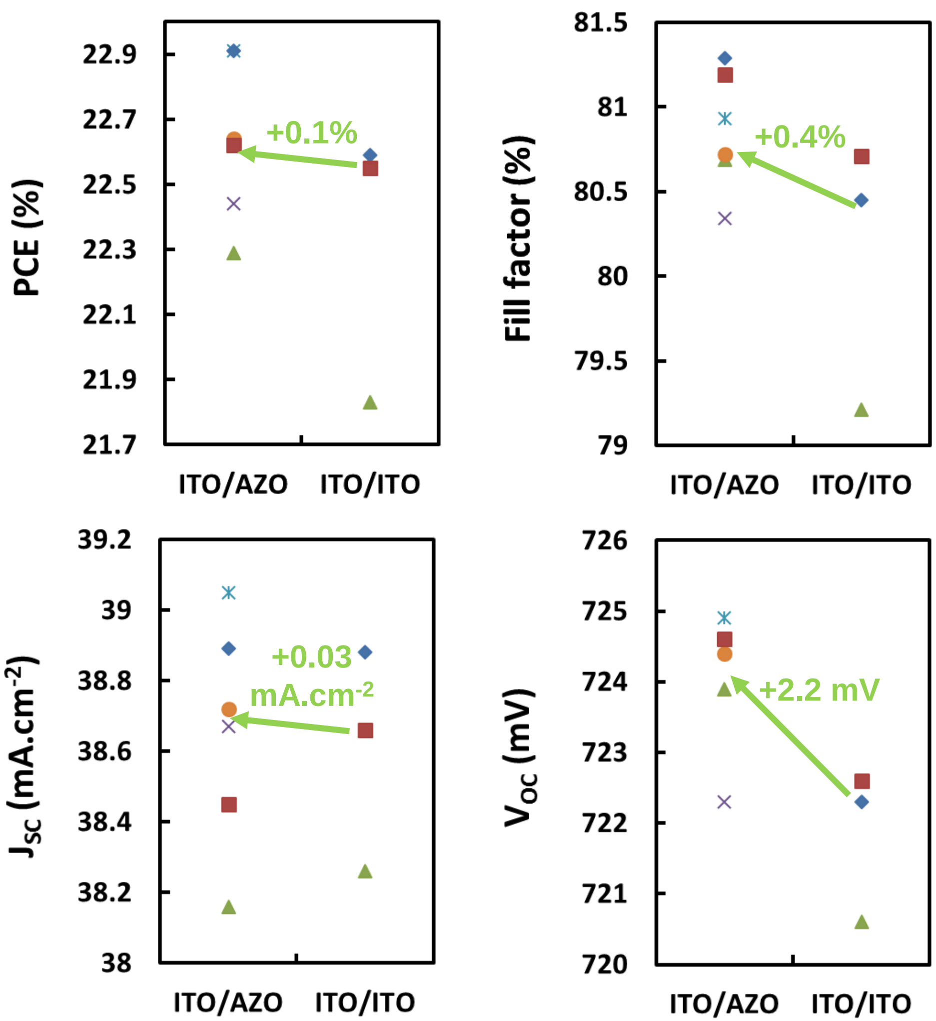
AZO by Atomic Layer Deposition: results

Underdeposition from back deposition but no shunts

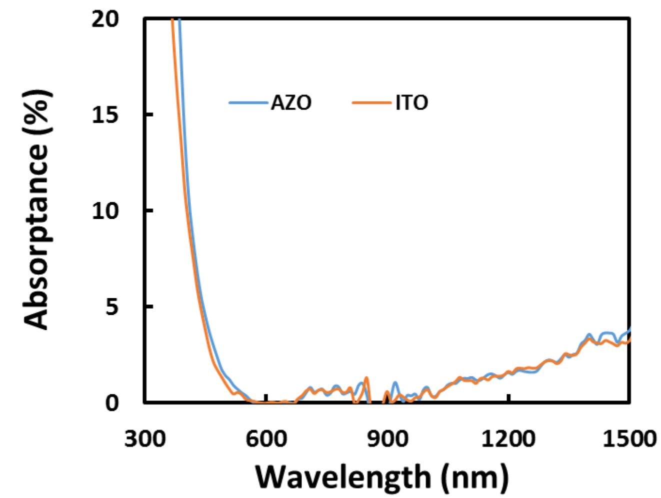


η of cells with ALD AZO is 0.7% below reference value

AZO by sputtering: Results



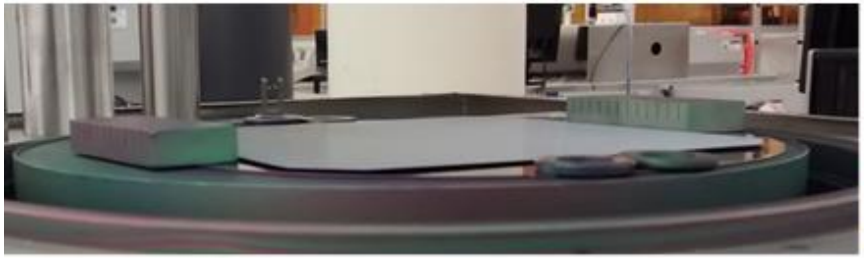
Material	d (nm)	Rs (Ω/□)	μ (cm²/(V.s))	n (cm⁻²)
ITO	103	421.6	16.76	8.58E+19
AZO	109	3712	2.204	7.00E+19

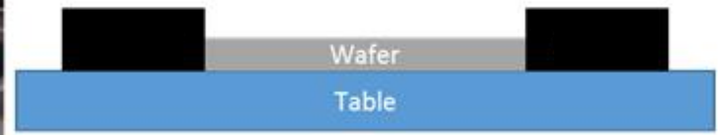


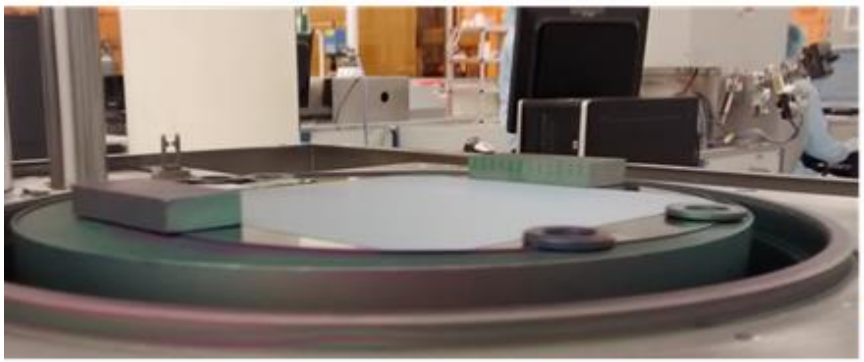
Slightly better efficiency with AZO back contact compared to reference.

Higher V_{OC} and fill factor.

Transfer on industrial scale device: ALD underdeposition



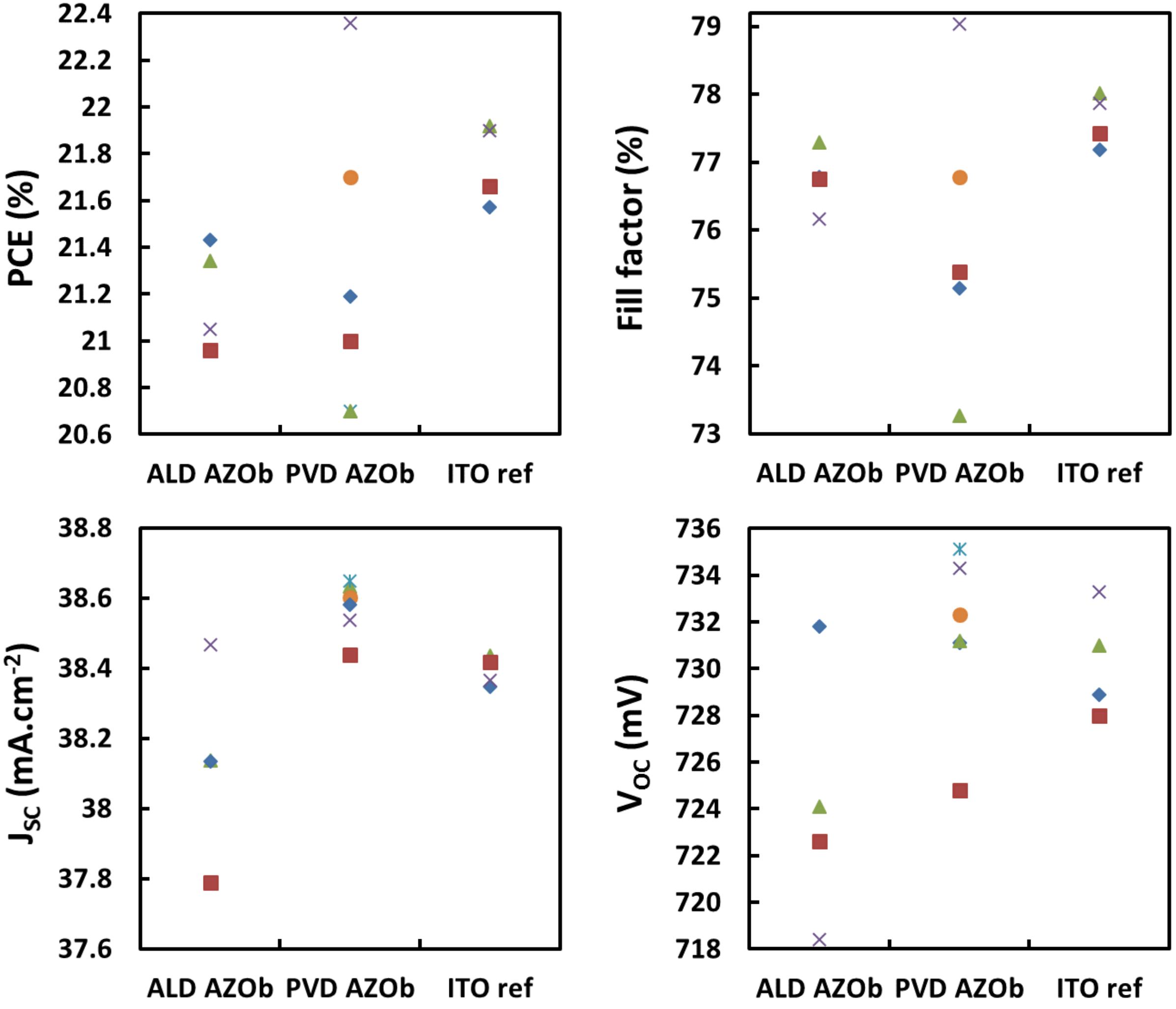




Large wafers tend to bend leading to significant underdeposition

Metal blocks were used to flatten the wafers
Shunts are then manually removed with HCl

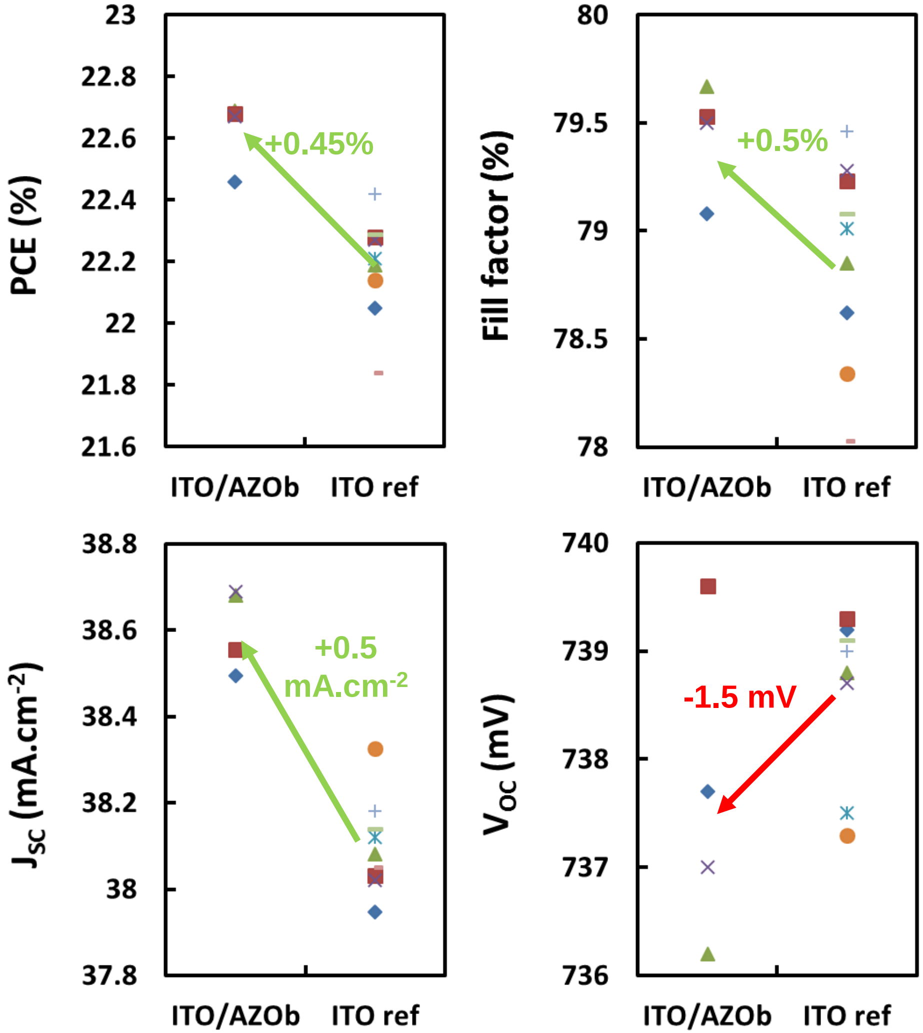
ALD and PVD: large scale cell results



Best efficiency is achieved with PVD AZO back contact

ALD AZO efficiencies are below the ones of ITO references

Transfer to Meyer Burger PVD process



Replacement of ITO back contact via AZO leads to an efficiency gain of 0.45%

AZO is a very promizing alternative to ITO for SHJ solar cell contacts

Conclusions and perspectives

Conclusions

- Sputtered AZO provides an excellent alternative for the replacement of ITO as back contact for HJT solar cells
- ALD AZO has been used as back contact for HJT solar cells, but PCE is still lower than ITO
- The sputtering process has been successfully transferred on Meyer Burger platform showing higher efficiencies than ITO references

Perspectives

- Improve the results with the ALD process
- Explore the replacement of the front ITO contact with AZO

INREP

Towards Indium free TCOs

Develop and deploy valid and robust alternatives to indium based transparent conductive electrode materials as electrodes

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 641864