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Optimization of the performances of textured segmented solar cells: achievements and challenges

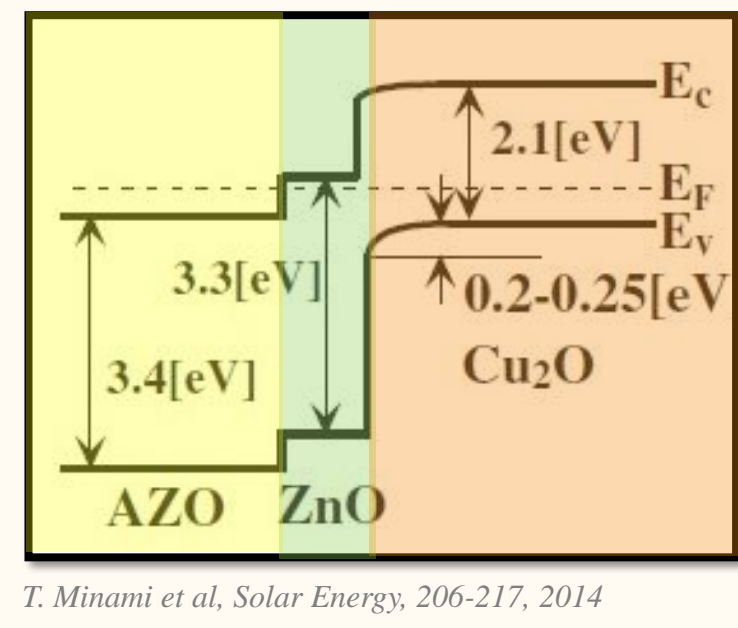
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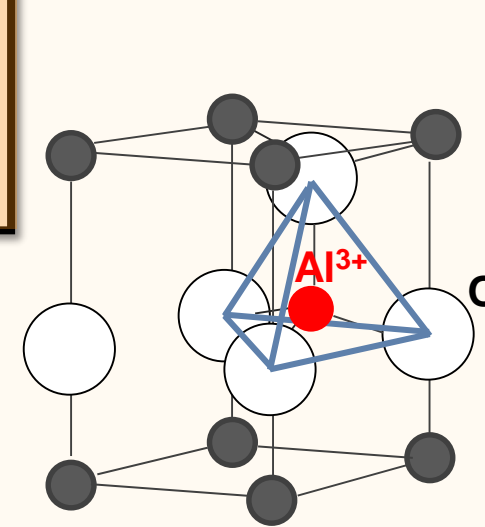
Introduction

This work aims at presenting a strategy to optimize the performance of thin film solar cells based on p-Cu₂O/n-ZnO junctions using wide bandgap semiconductors already optimized in previous works: zinc oxide (ZnO), aluminum doped ZnO (AZO) and cuprous oxide (Cu₂O). Additionally, the glass substrates were patterned using direct laser interference (DLIP) in order to increase light trapping and thus the photocurrent.



Cystallographic structure

ZnO: Hexagonal wurtzite structure



(AZO): Al doped ZnO

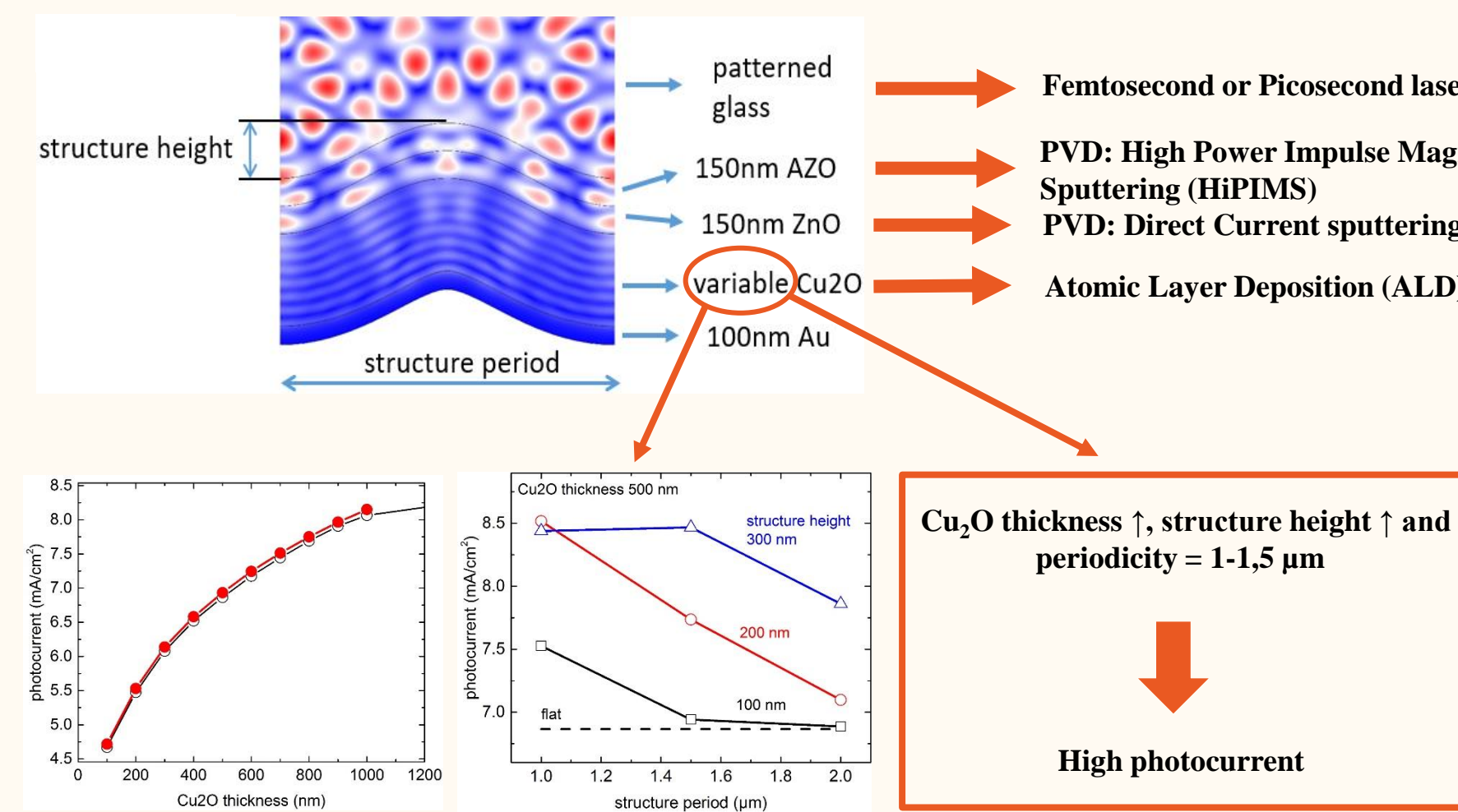
Al in tetrahedral position

Properties

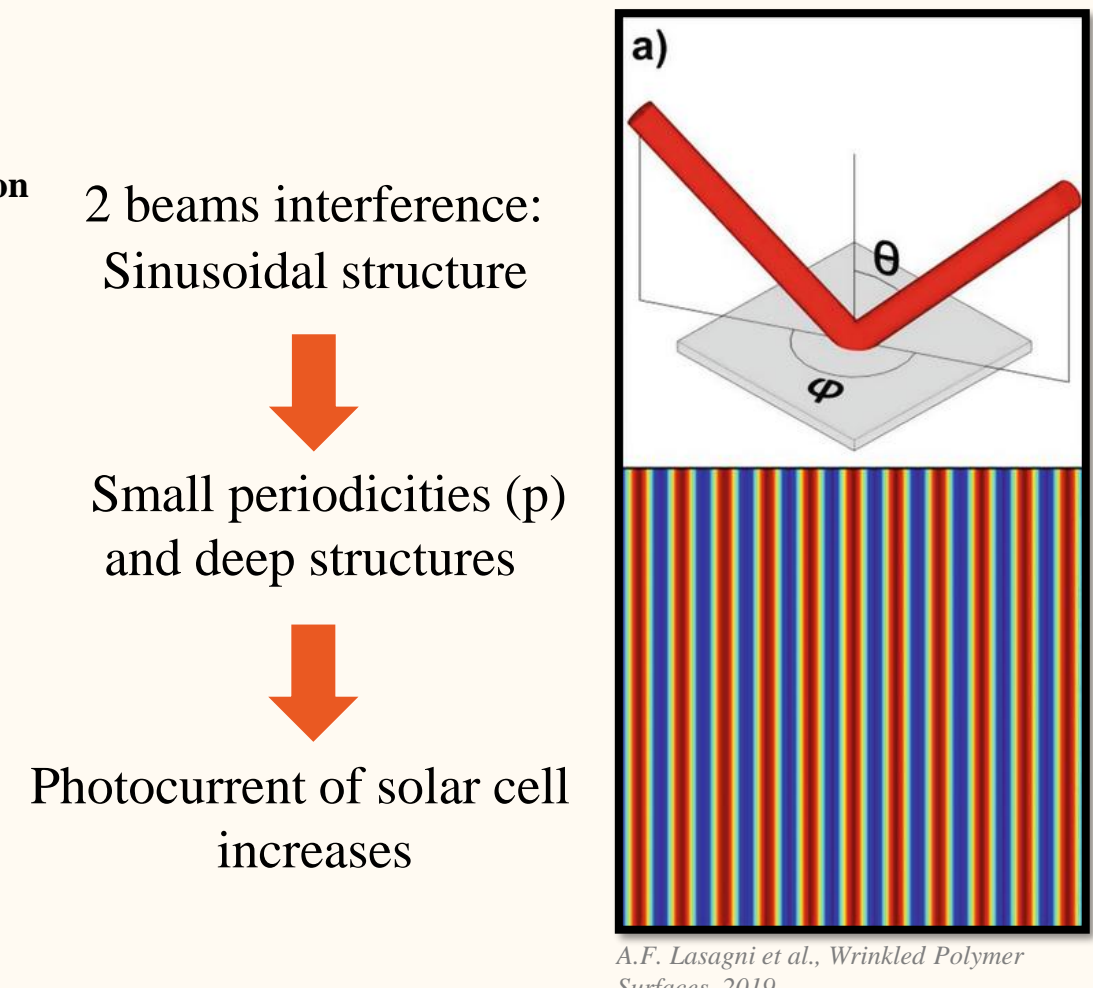
- Zn and Al: Low cost and abundant materials to replace the scarce, expensive and toxic (ITO).
- ZnO with wide band gap near 3.3 eV.
- Zn doped with group III elements such as Al → Low resistivity.

Towards textured segmented solar cells

Solar cell simulation



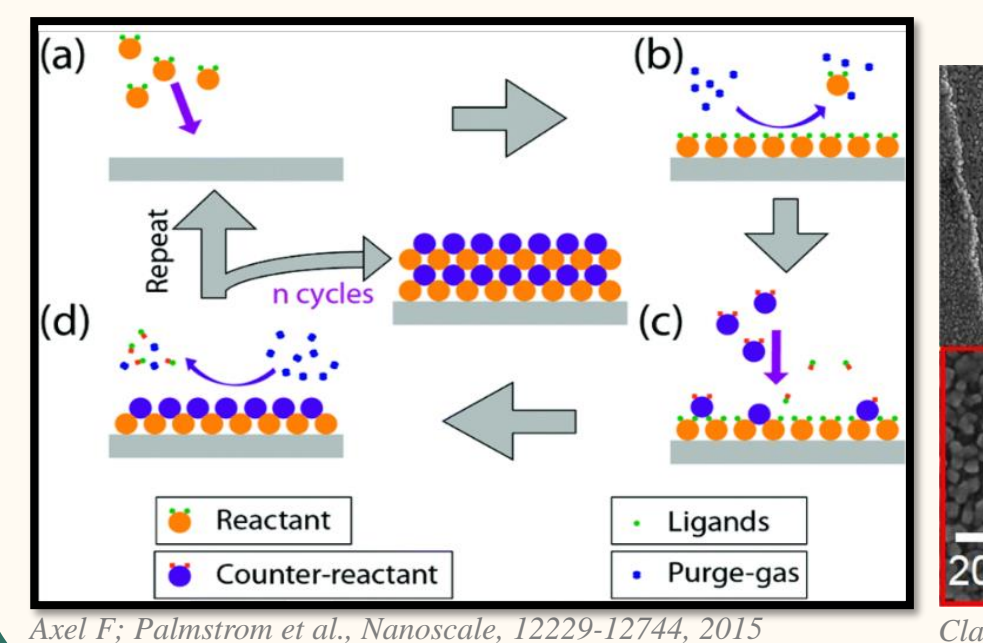
DLIP principle



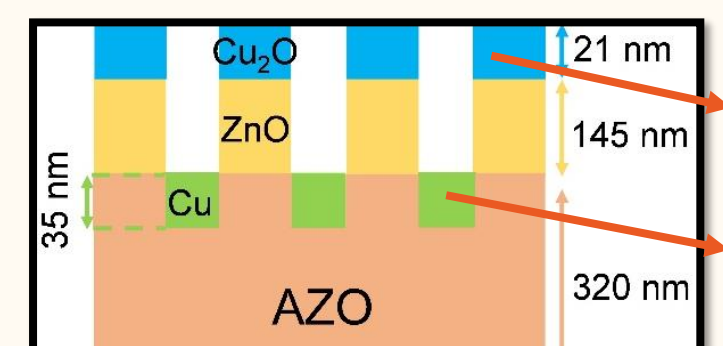
Selected area growth of Cu₂O and Cu

ALD Principle

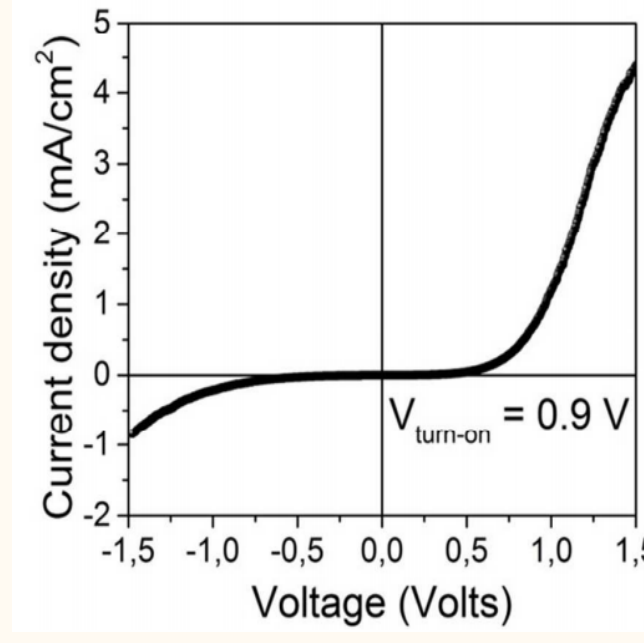
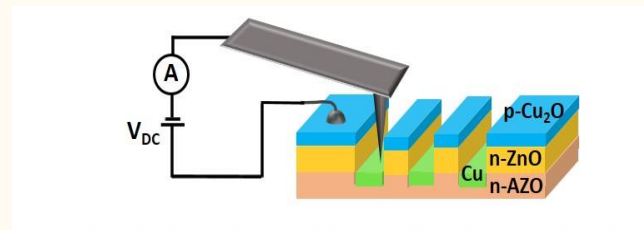
- High quality thin films are obtained
- Self-limiting growth mechanism
- Excellent and conformal surface coverage



Area selective deposition

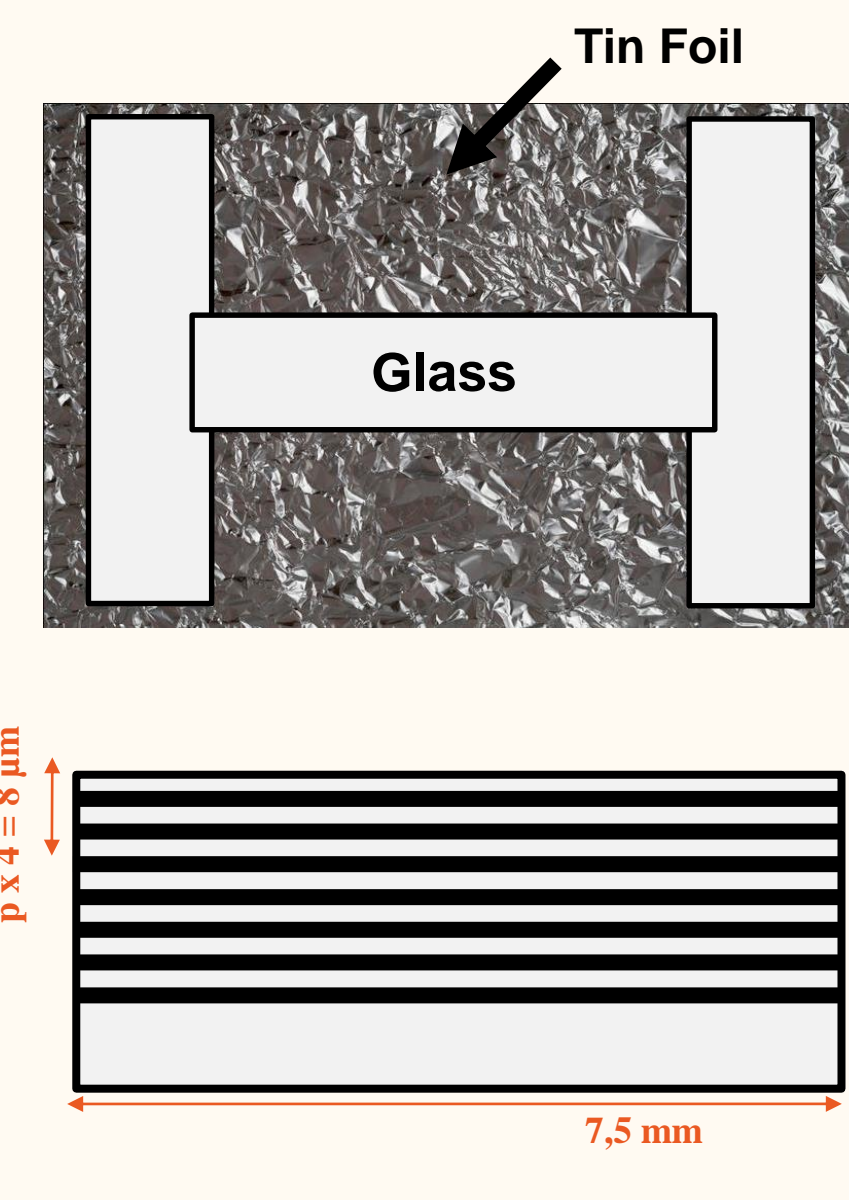
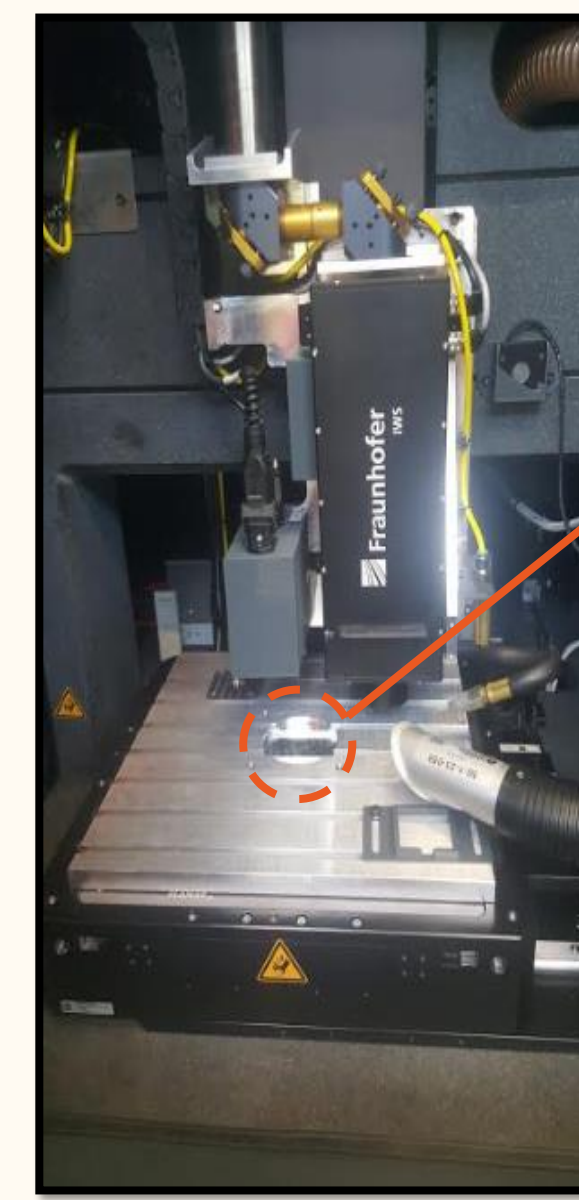


A non-linear rectifying behavior characteristic of a p-n junction formed between Cu₂O and ZnO

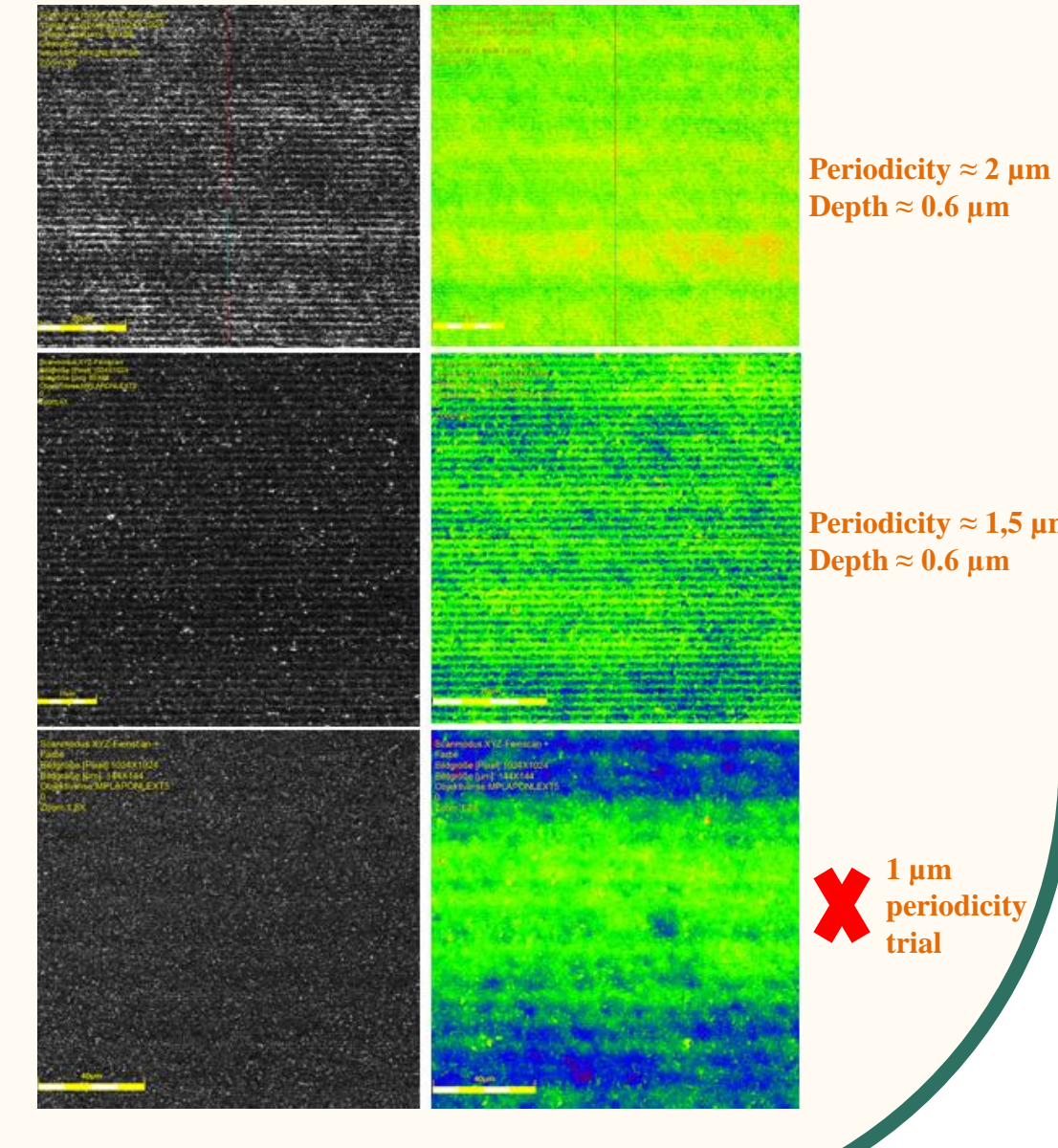


Current density - voltage (J-V) curve measured on dark at room temperature by C-AFM

Experimental method: Picosecond laser



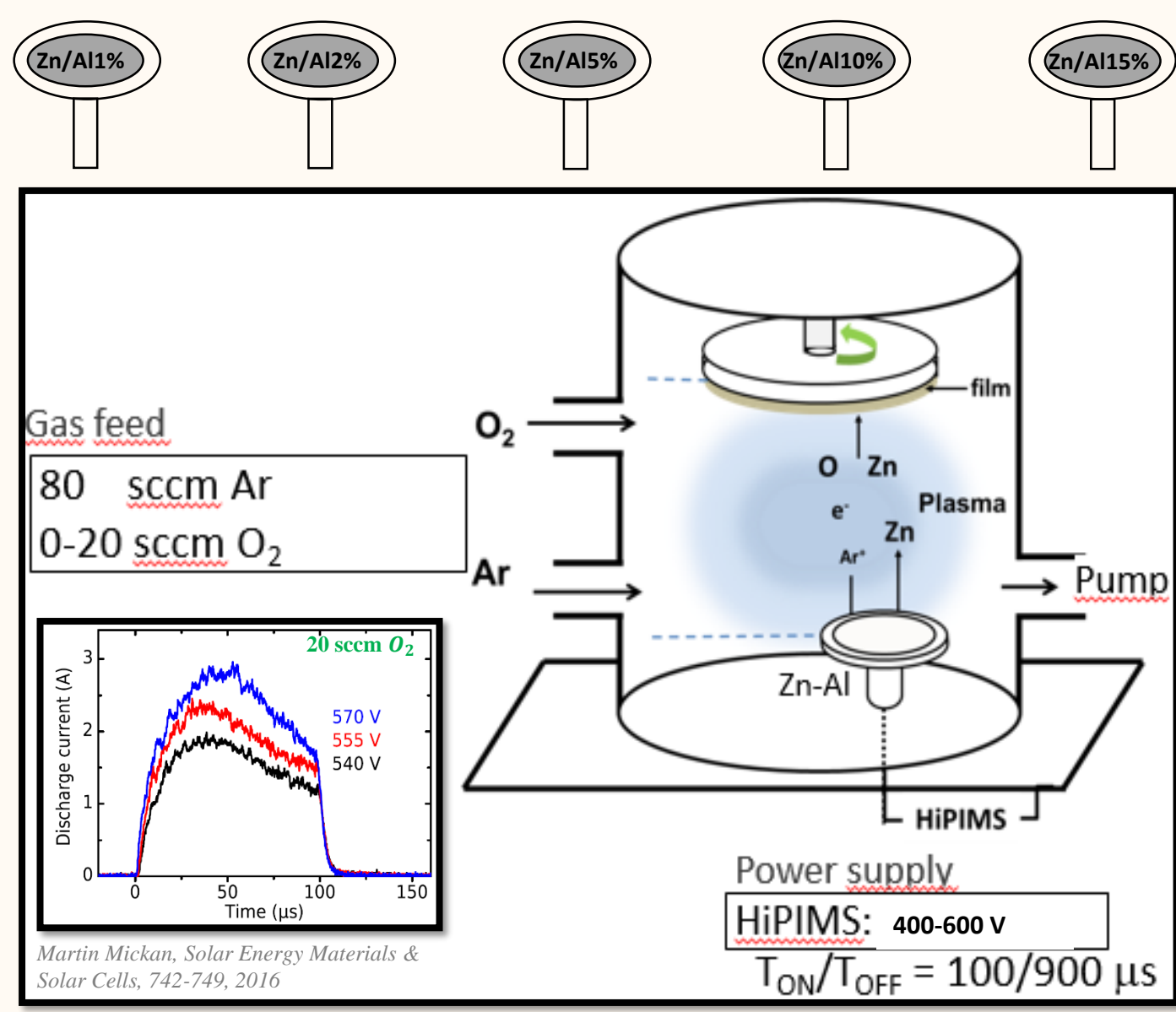
Results



Optimization of the transparent electrode

Experimental method: PVD

Targets to be used for finding the optimum values



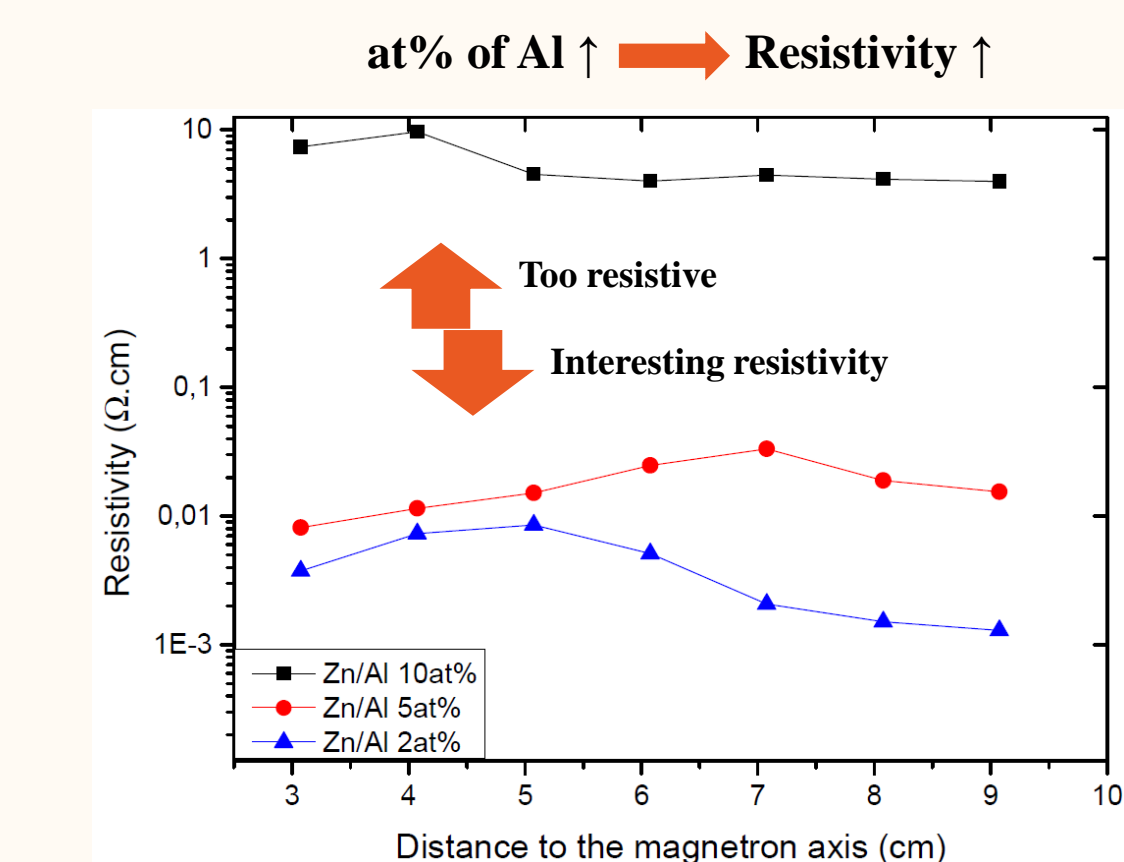
Goal: Find AZO films both transparent and conductive

Step 1: For each target, test which Voltage/O₂ flow rate gives an optimized AZO film

Step 2: The best optimized AZO film allows us to choose the best Al at% in the target

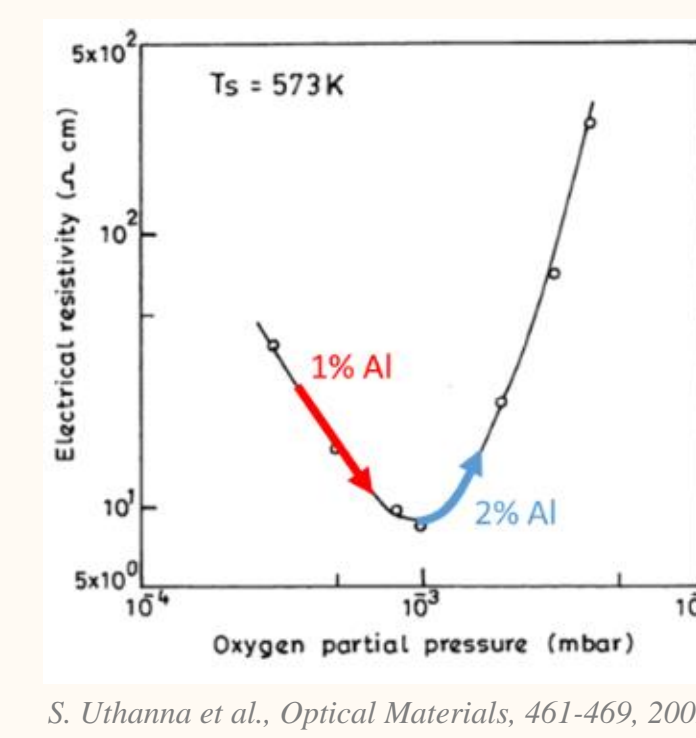
Optical and electrical properties

Resistivity



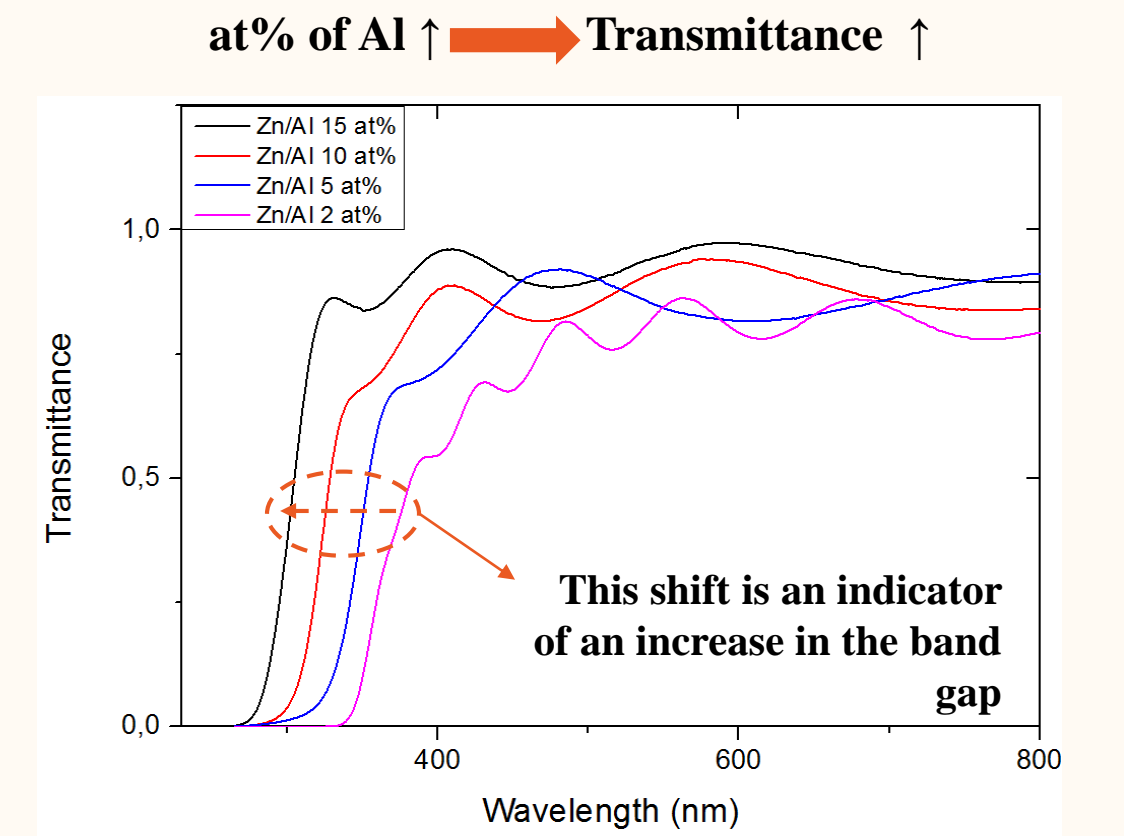
This change could be due to:

- A different dopant-oxygen interaction for low Al at%
- More sub-stoichiometric films for low Al at%

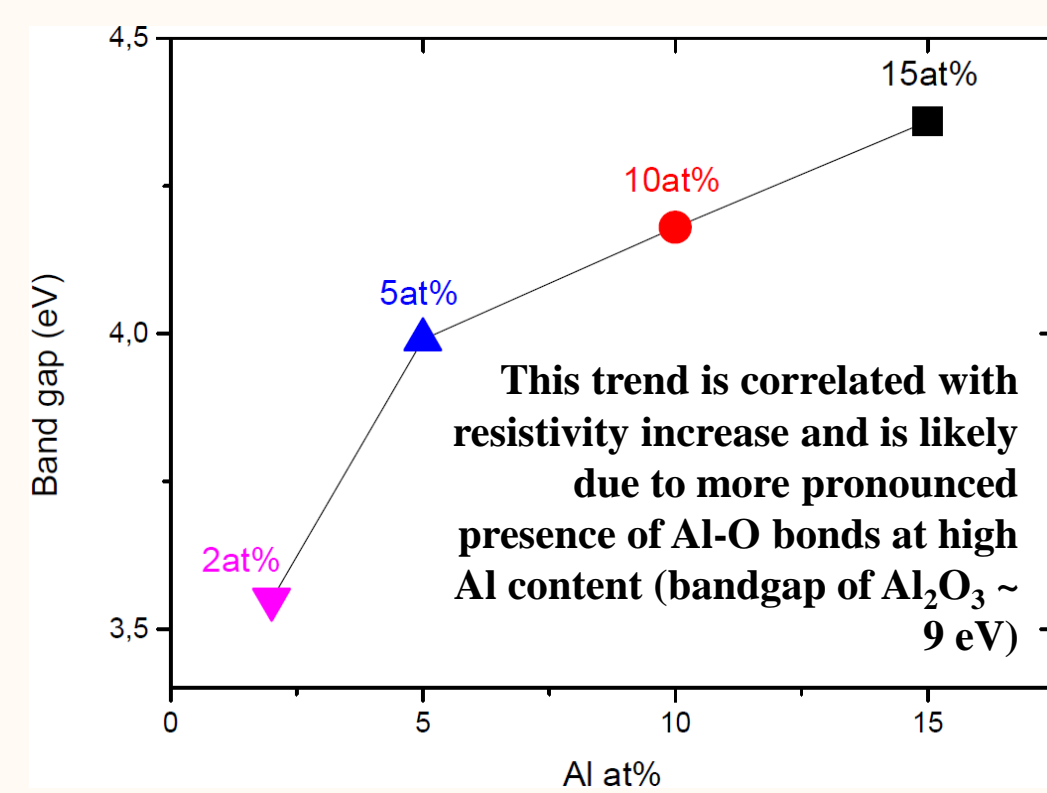


If we consider this graph, we can explain the variation of the resistivity with the voltage increase for 1 at% of Al (red arrow) and ≥ 2 at% of Al (blue arrow)

Transmittance



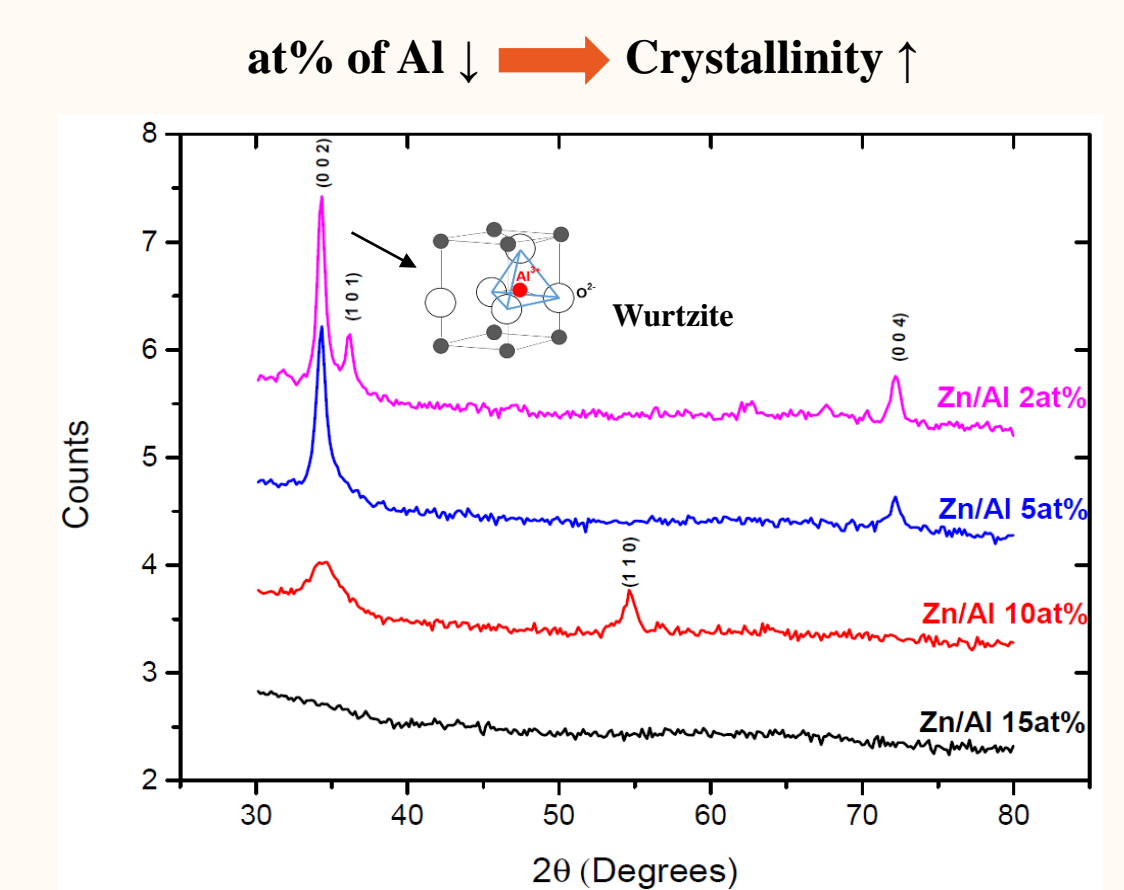
This shift is an indicator of an increase in the band gap



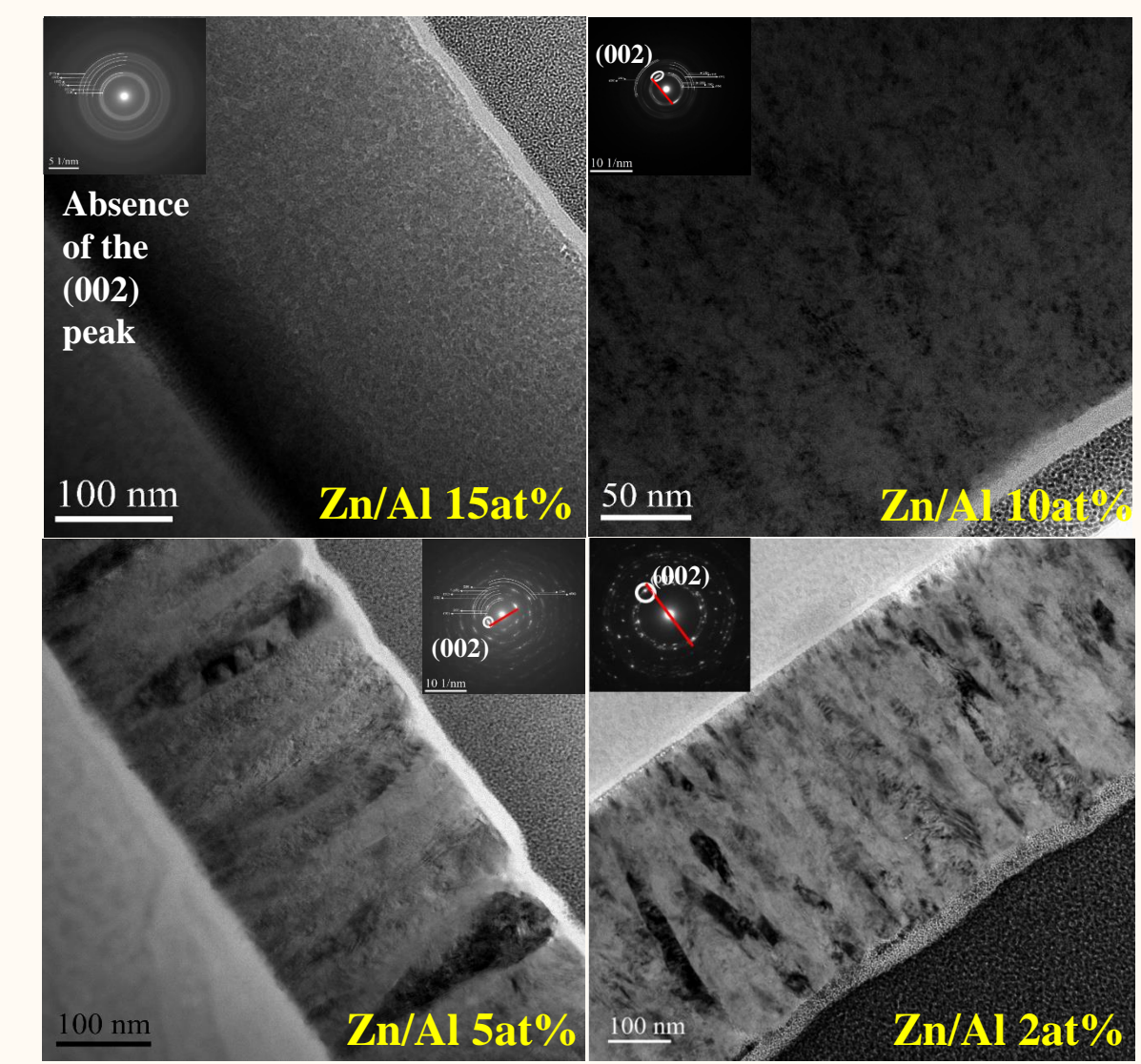
This trend is correlated with resistivity increase and is likely due to more pronounced presence of Al-O bonds at high Al content (bandgap of Al₂O₃ ~ 9 eV)

Structural and chemical analysis

XRD



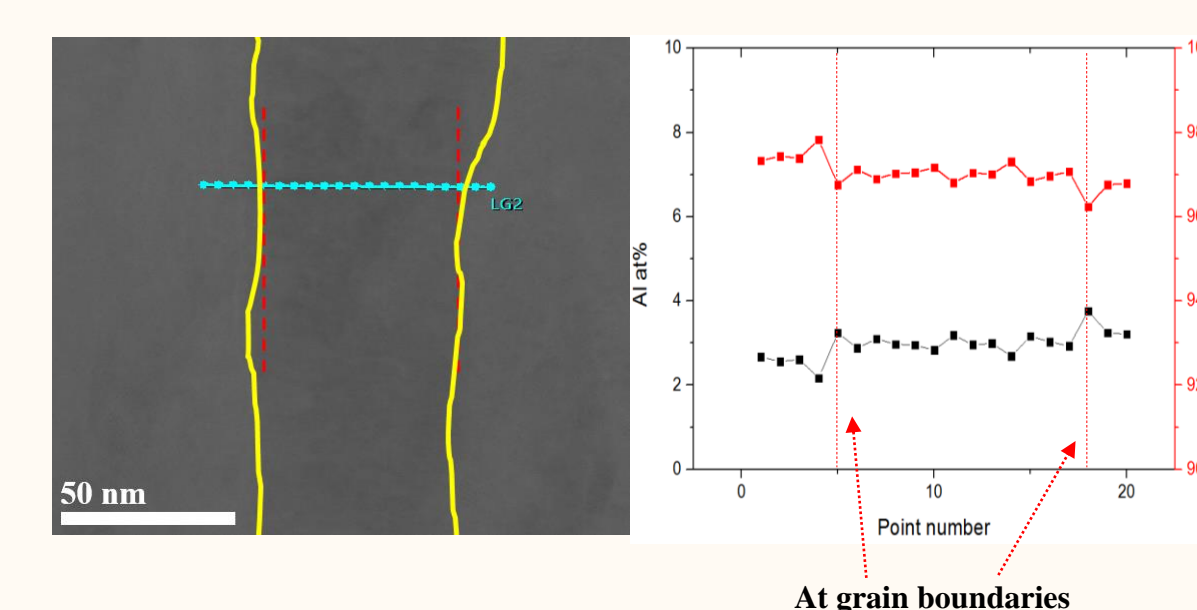
These results suggest that crystalline films are obtained for low Al at%; which can be correlated with the lower resistivity for such films. TEM was realized to confirm these XRD results



The AZO film with 15 at% of Al is not amorphous, it contains some crystallized areas; however they are not oriented in the (002) direction. For 10, 5 and 2 Al at%, the films become increasingly crystalline following a columnar growth in the (002) direction

TEM

EDS



Abrupt increase of Al in the grain boundaries
Possible presence of Al₂O₃

Conclusions

Patterning: 1,5 μm is the smallest periodicity we can achieve on glass by picosecond laser

Resistivity: Al at% ↑ → Resistivity ↑

Opposite results for the Zn/Al 1at% target → Films' characterization necessary to explain why

Microstructure: Al at% ↑ → Crystallinity ↓ → Resistivity ↑

Al highly present in the grain boundaries → HRTEM, EELS necessary to identify the element

Transmittance: Al at% ↑ → Transmittance ↑ → Band gap ↑

In conclusion, the challenge is:

- Try to better the transmittance of the film with 2 at% of Al while keeping the conductivity high enough

- Understand the results obtained for the Zn/Al 1at% target and try to achieve even better results than those obtained for the Zn/Al 2at% target