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

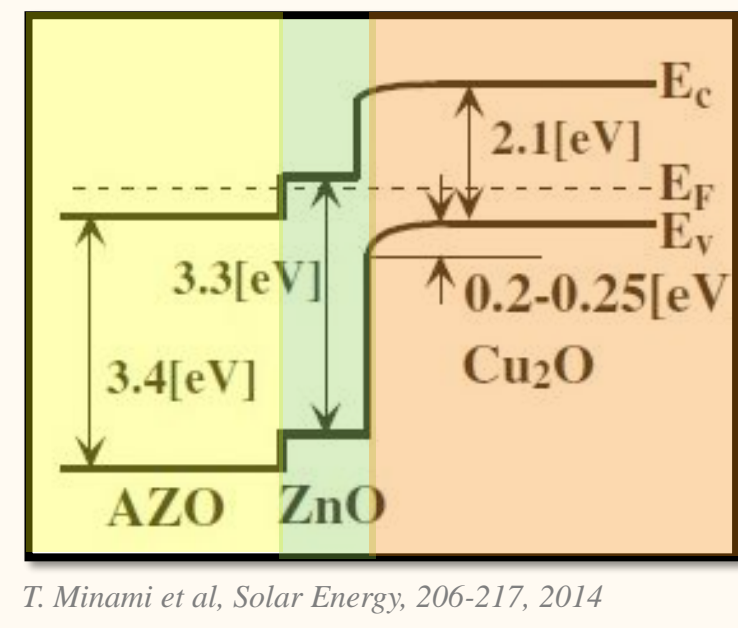
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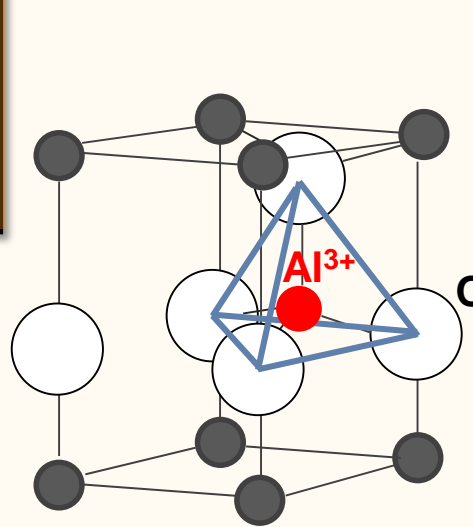
Introduction

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.



Cristallographic structure

ZnO: Hexagonal wurtzite structure



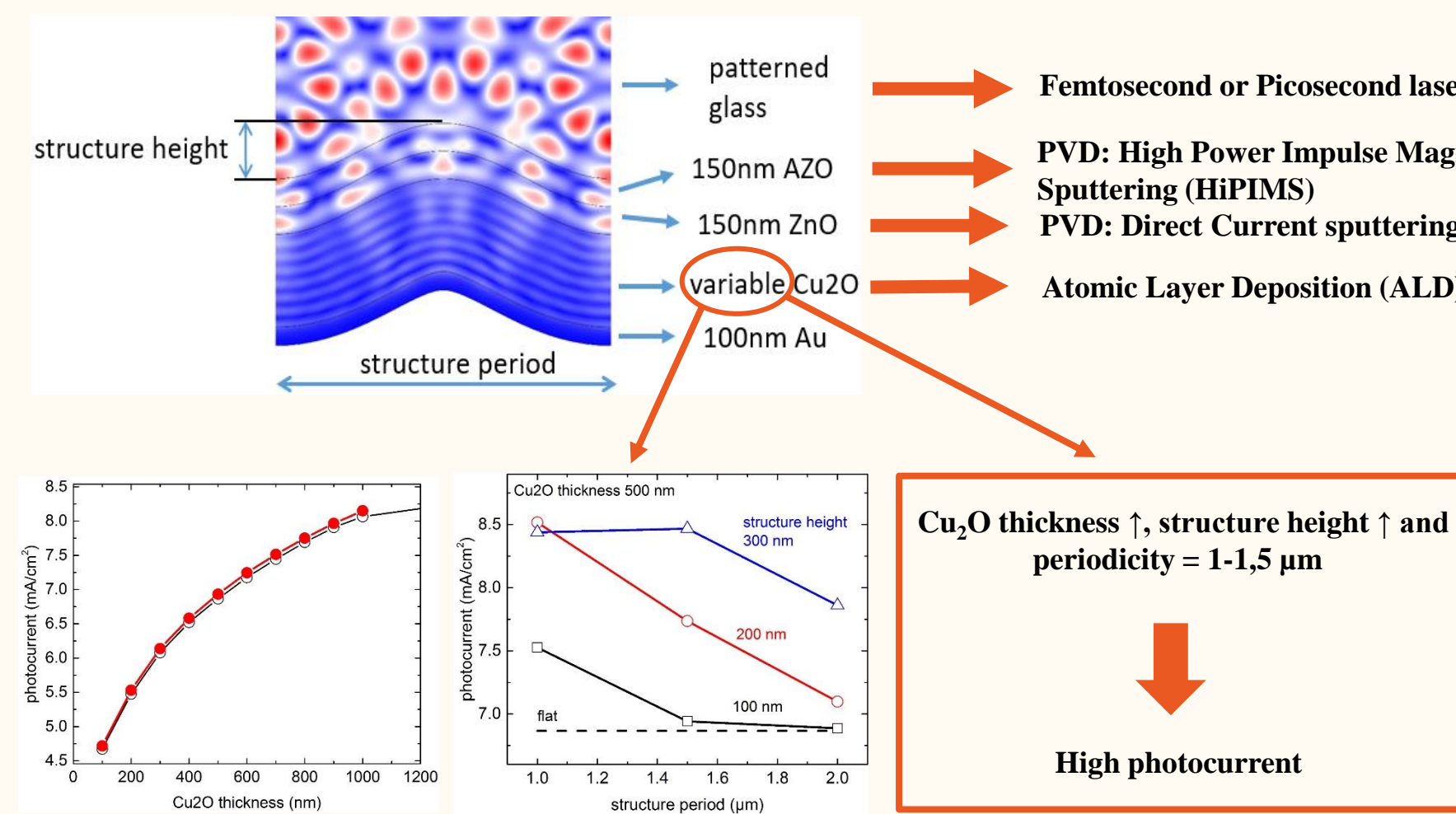
(AZO): Al doped ZnO

Properties

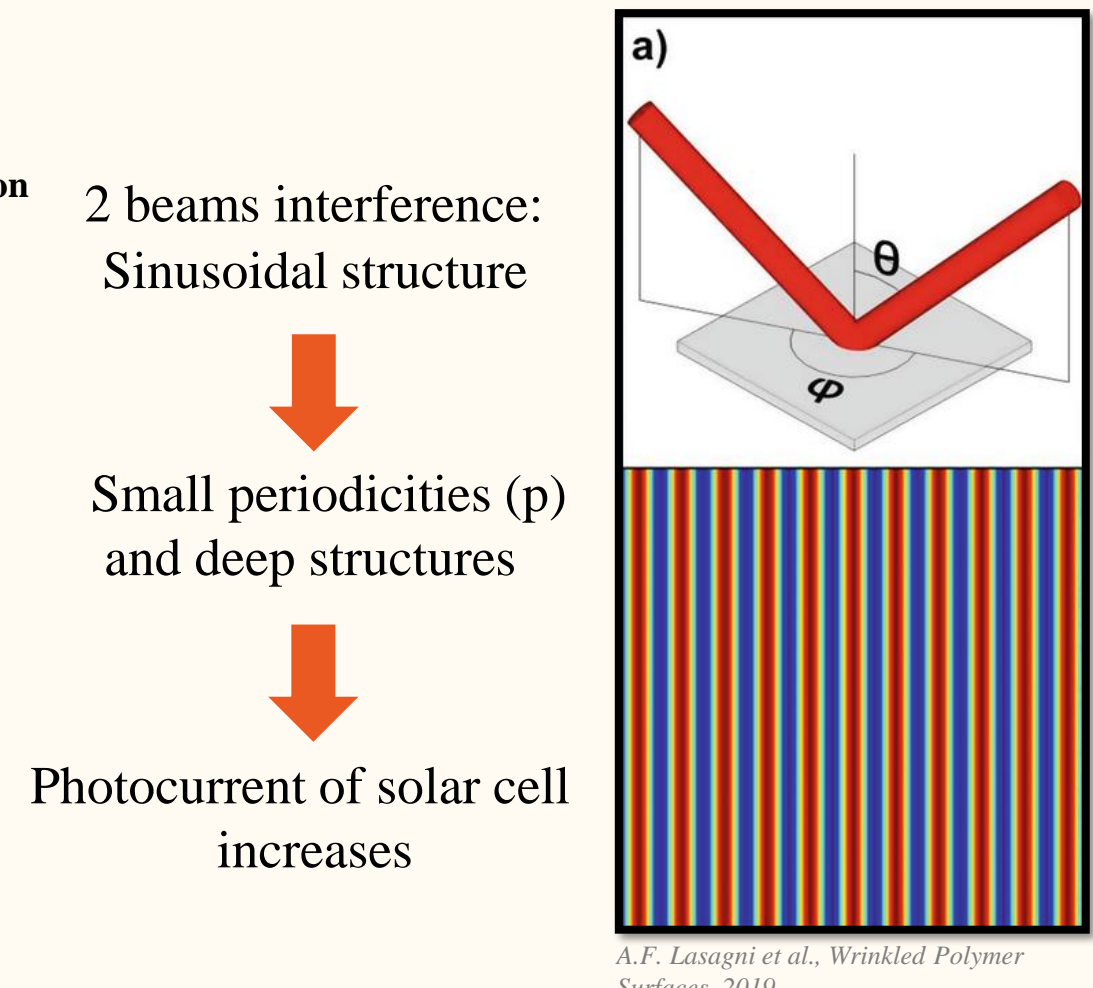
- Zn and Al: Low cost and abundant materials to replace the scarce, expensive and toxic (ITO).
- ZnO with wide band gap near 3.3 eV.
- Zn doped with group III elements such as Al → Low resistivity.

Towards textured segmented solar cells

Solar cell simulation



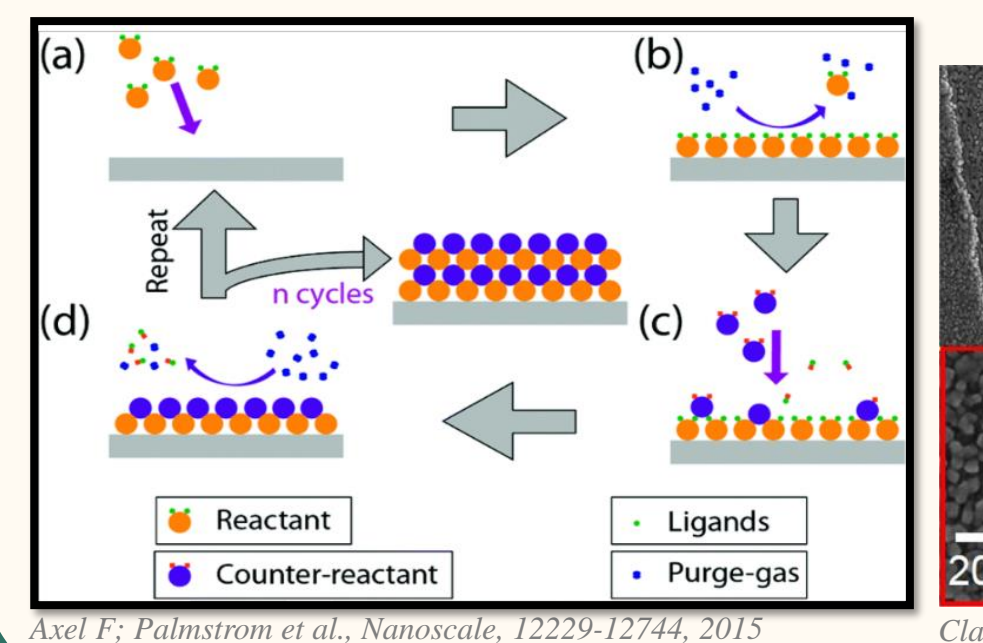
DLIP principle



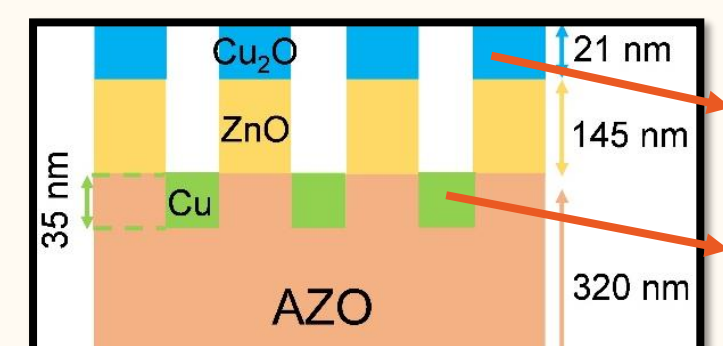
Selected area growth of Cu₂O and Cu

ALD Principle

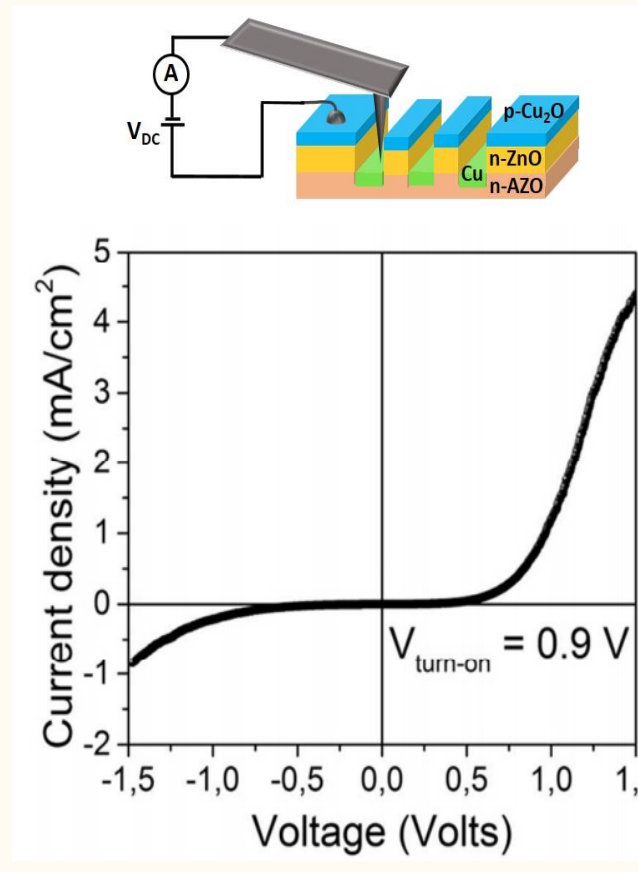
- High quality thin films are obtained
- Self-limiting growth mechanism
- Excellent and conformal surface coverage



Area selective deposition

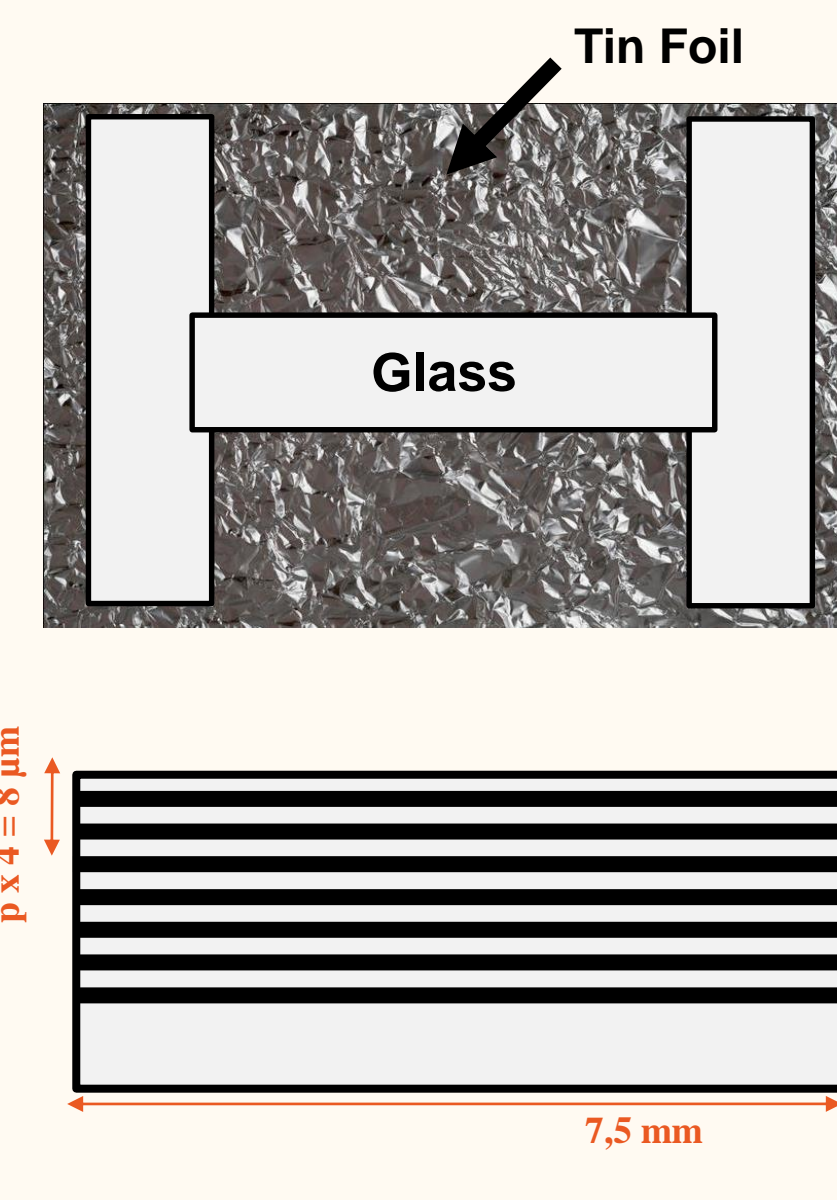
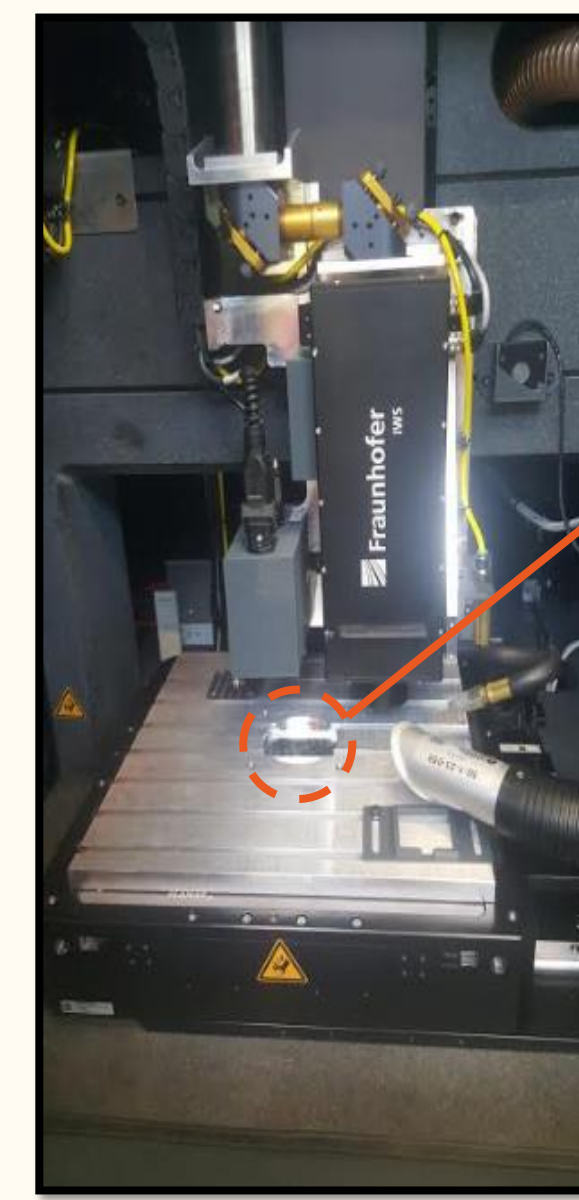


A non-linear rectifying behavior characteristic of a p-n junction formed between Cu₂O and ZnO

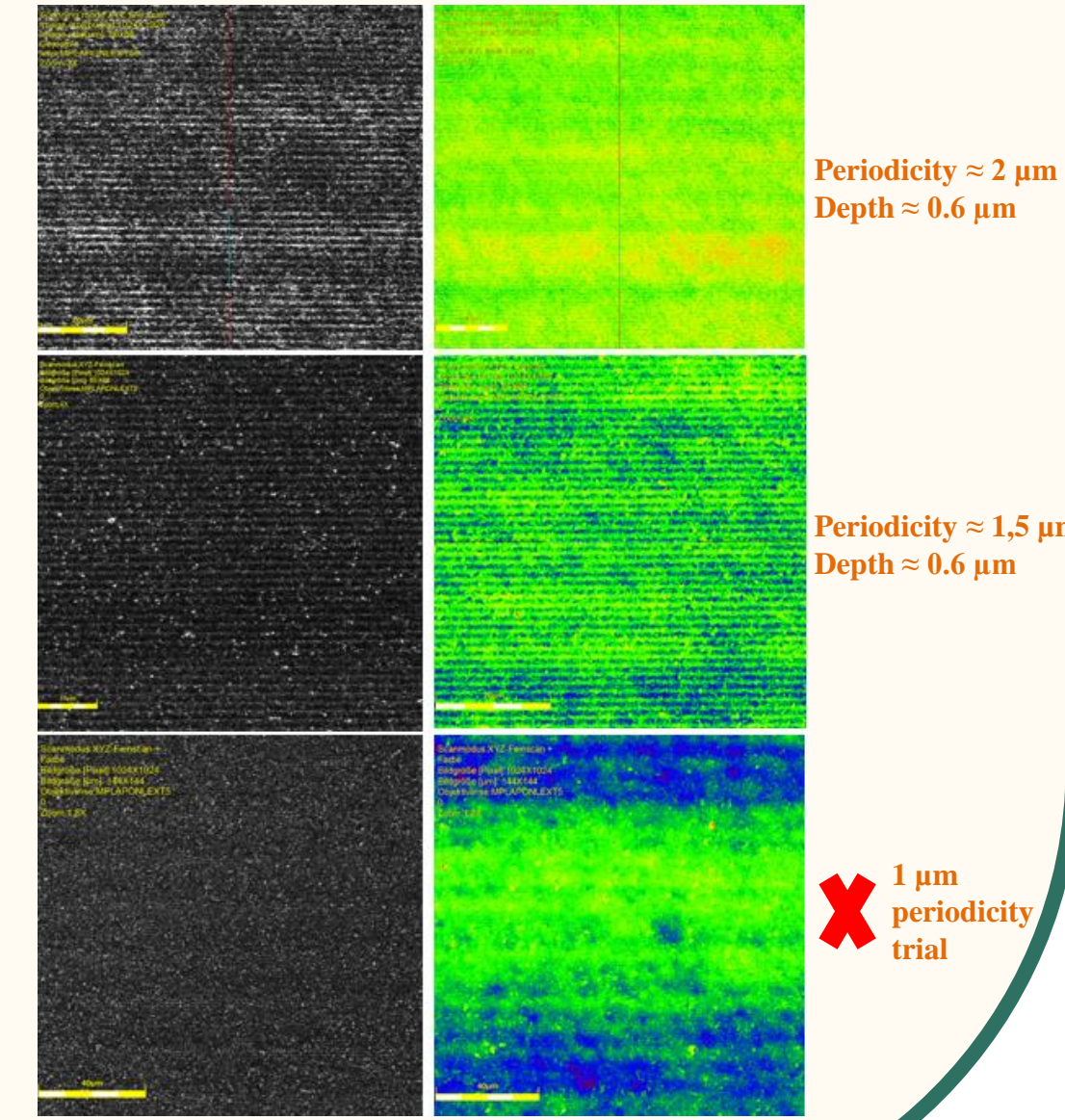


Current density - voltage (J-V) curve measured on dark at room temperature by C-AFM

Experimental method: Picosecond laser



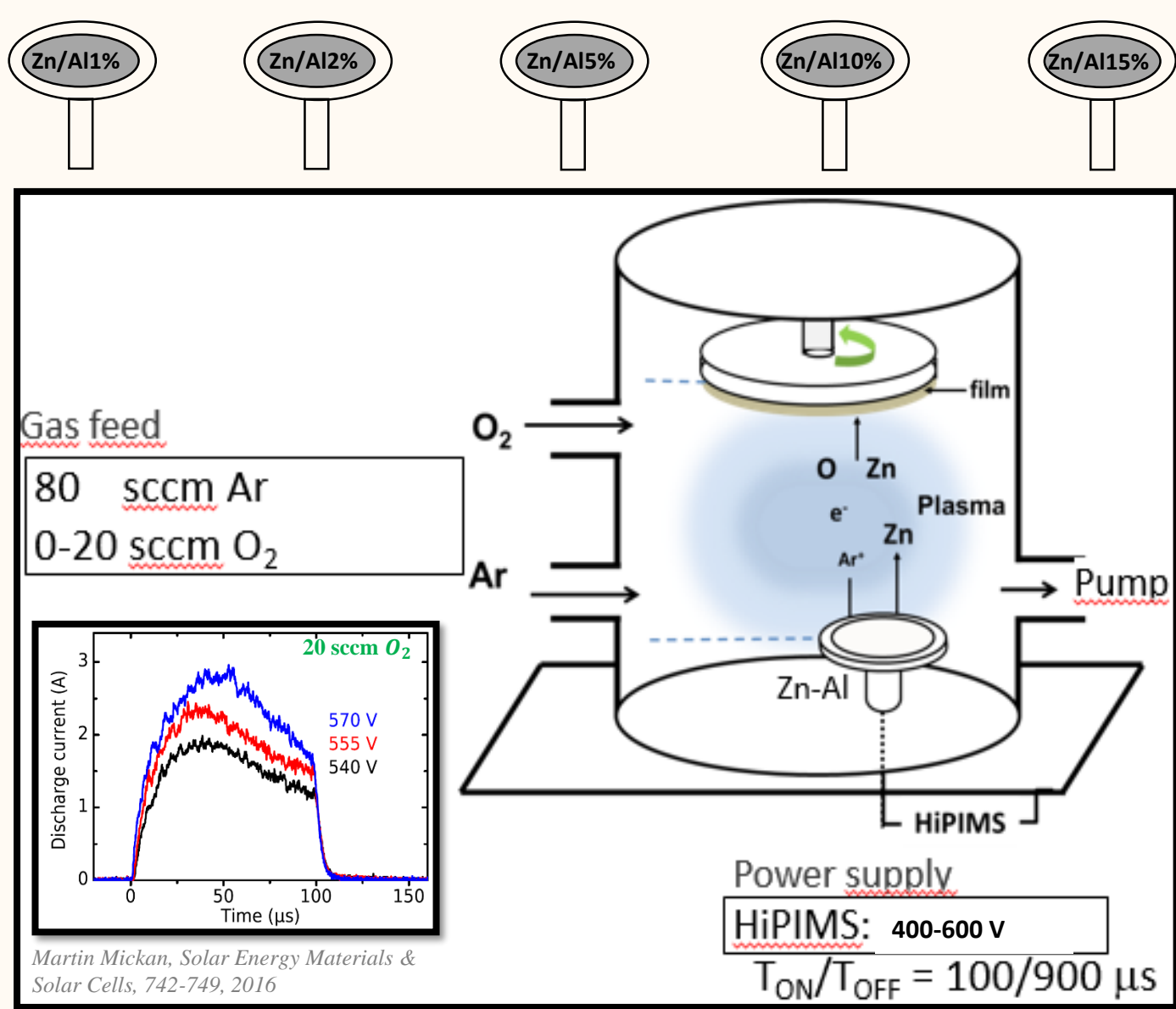
Results



Optimization of the transparent electrode

Experimental method: PVD

Targets to be used for finding the optimum values



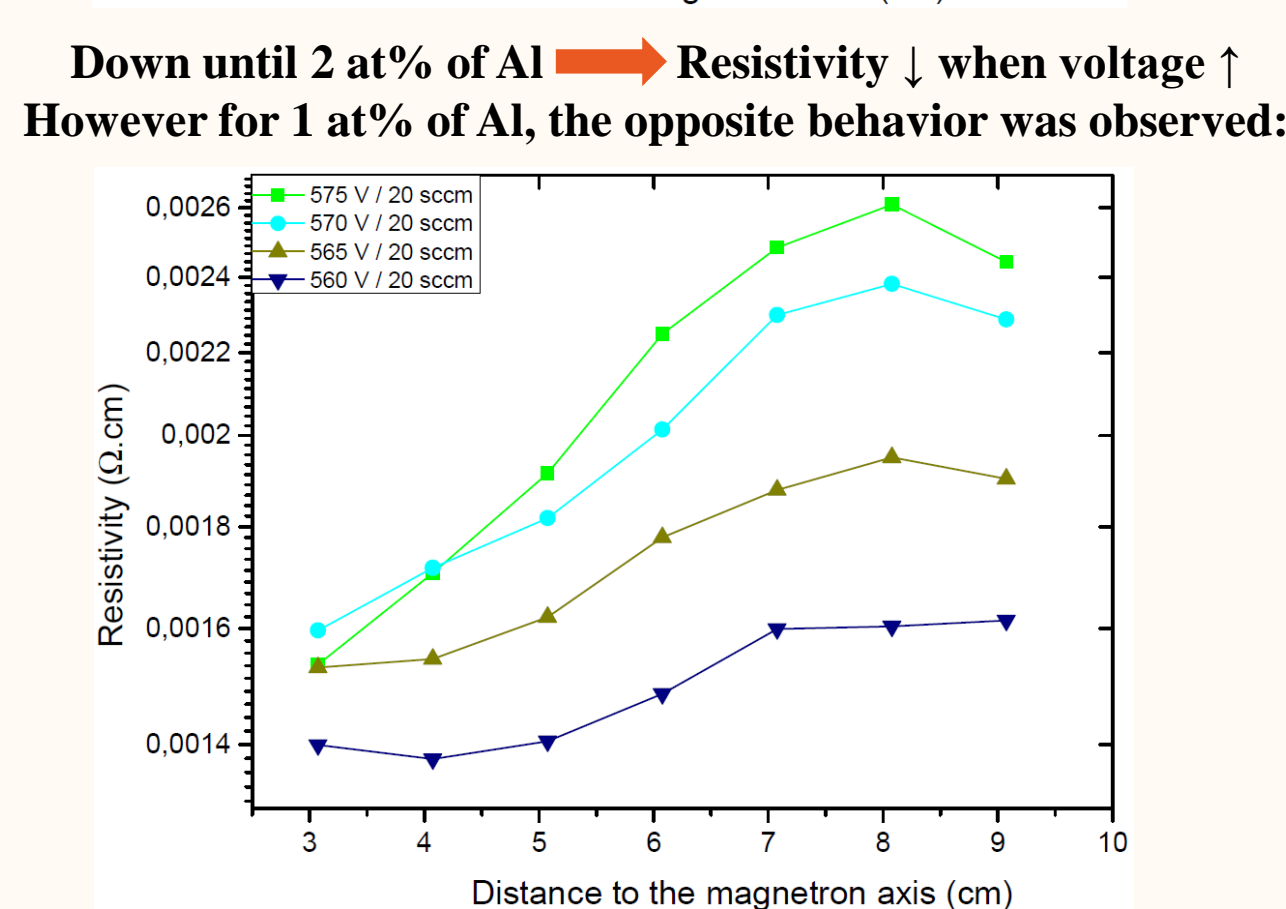
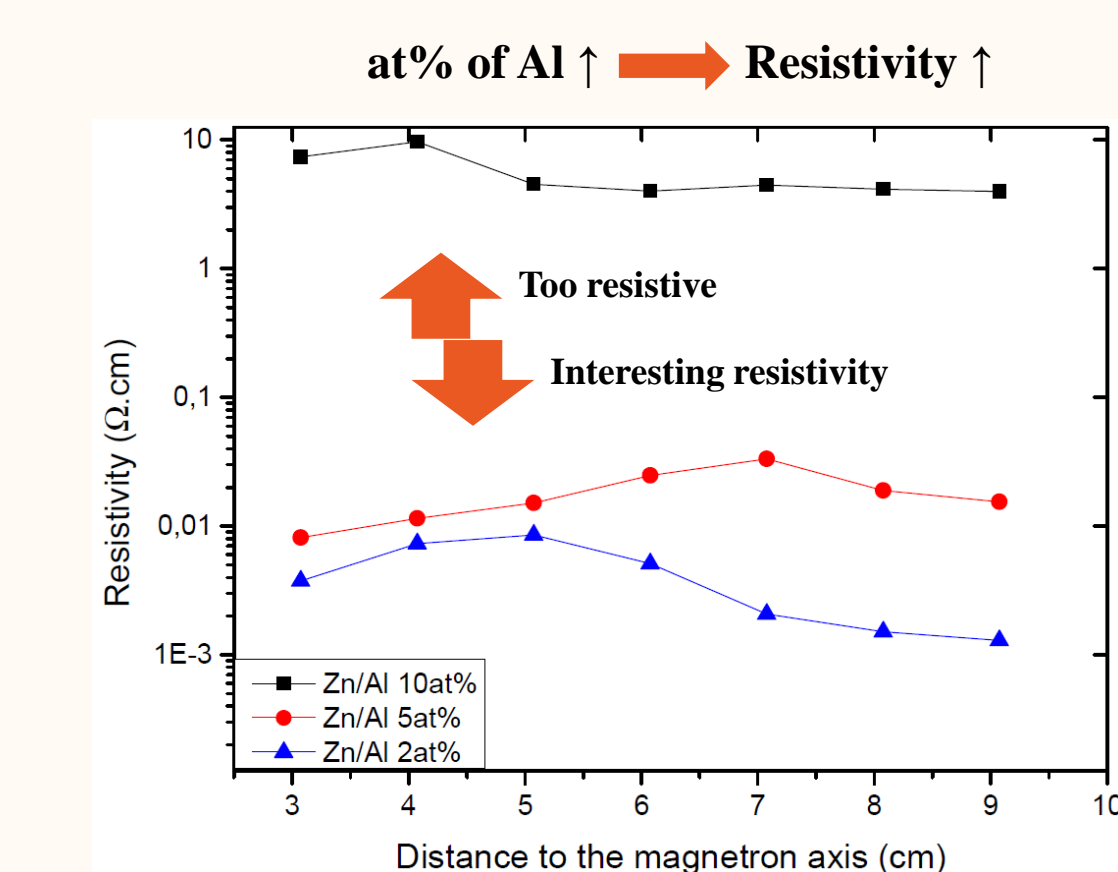
Goal: Find AZO films both transparent and conductive

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

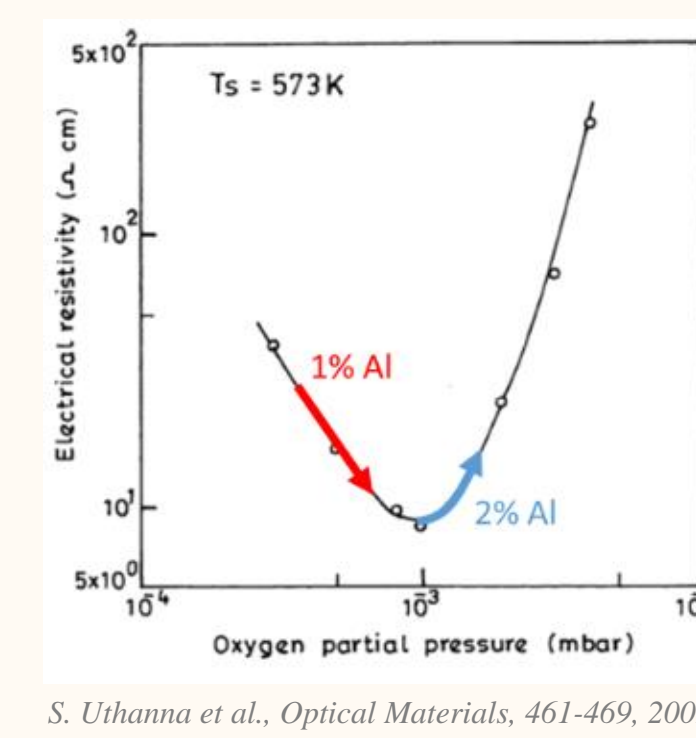
Optical and electrical properties

Resistivity



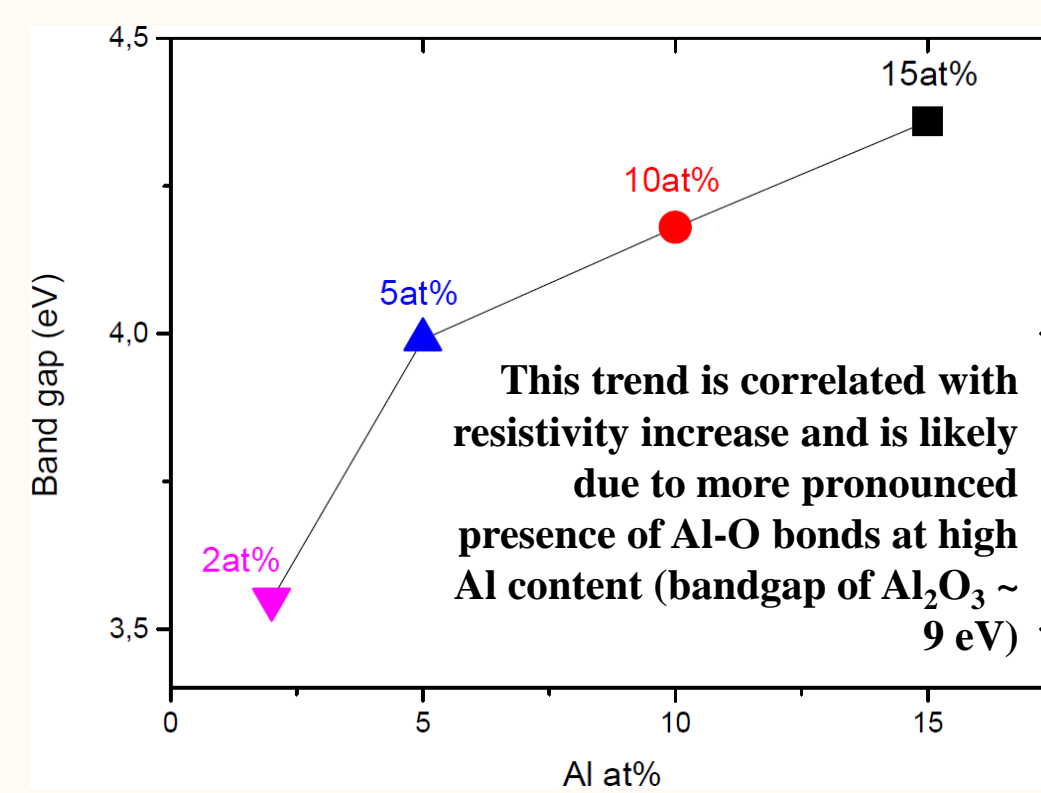
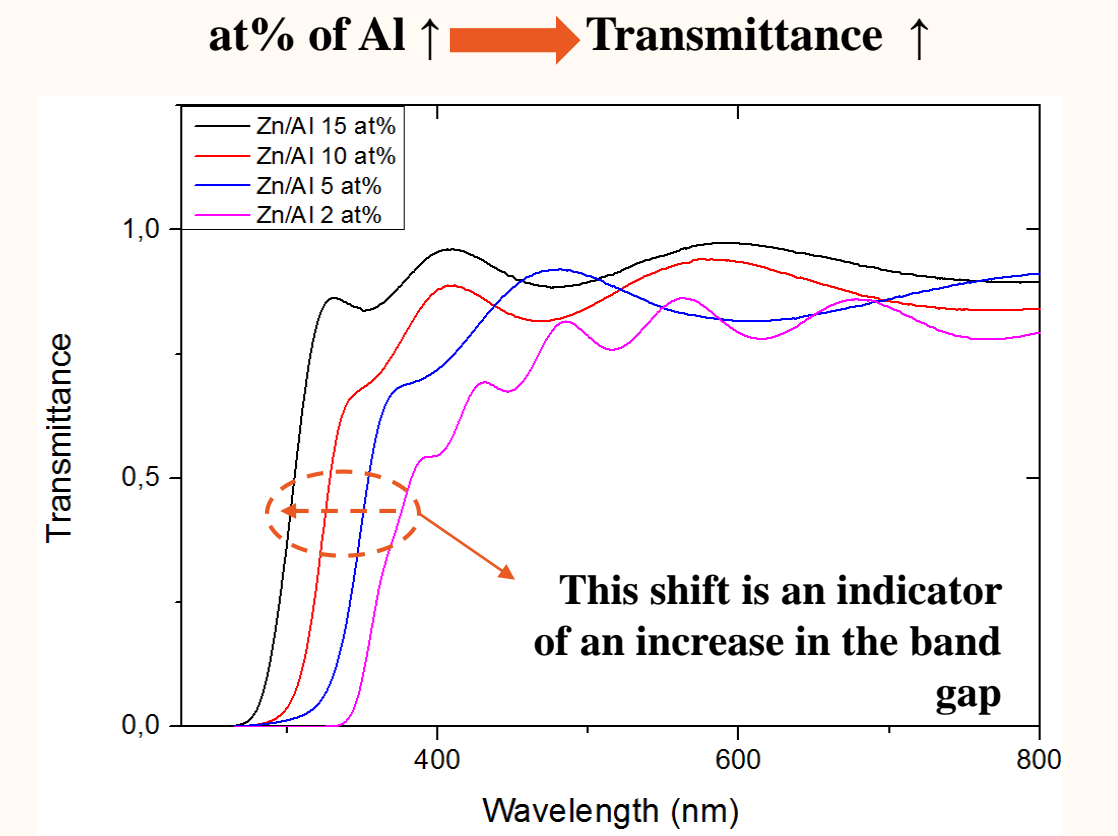
This change could be due to:

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



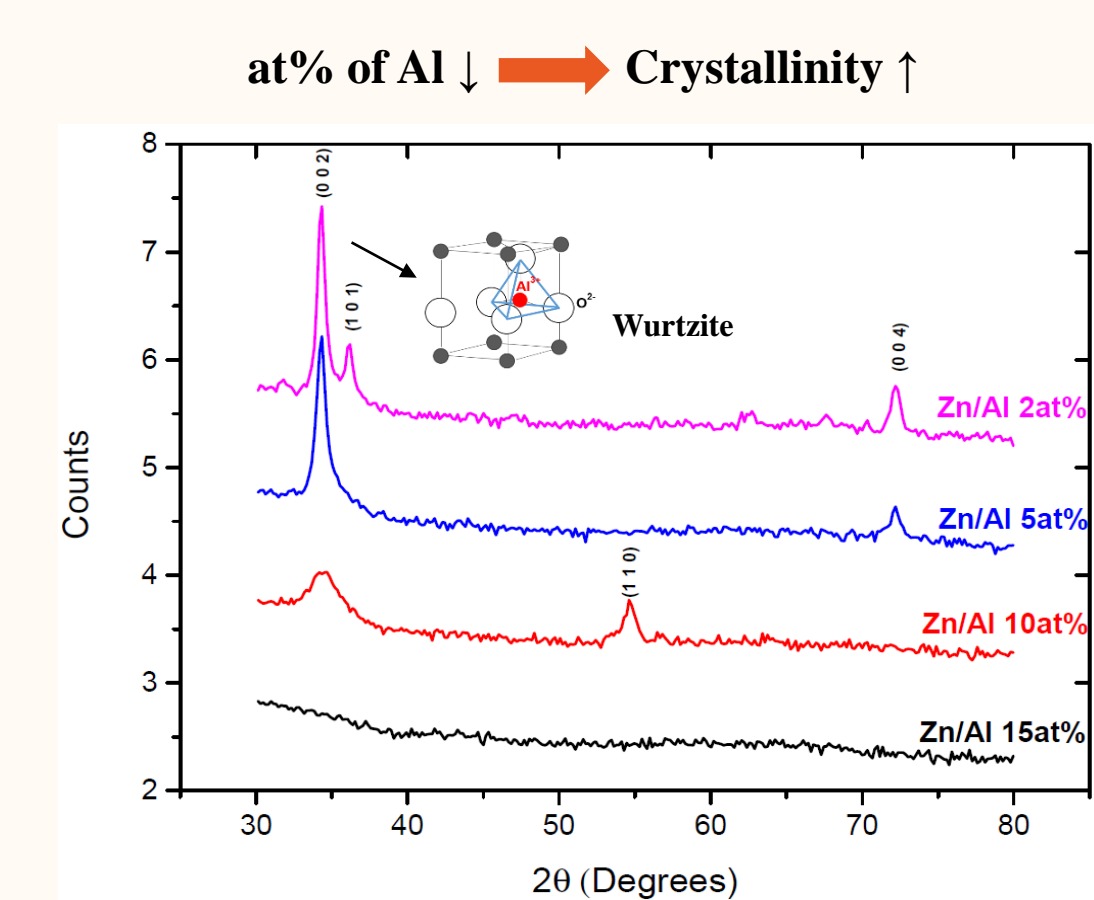
If we consider this graph, we can explain the variation of the resistivity with the voltage increase for 1 at% of Al (red arrow) and ≥ 2 at% of Al (blue arrow)

Transmittance

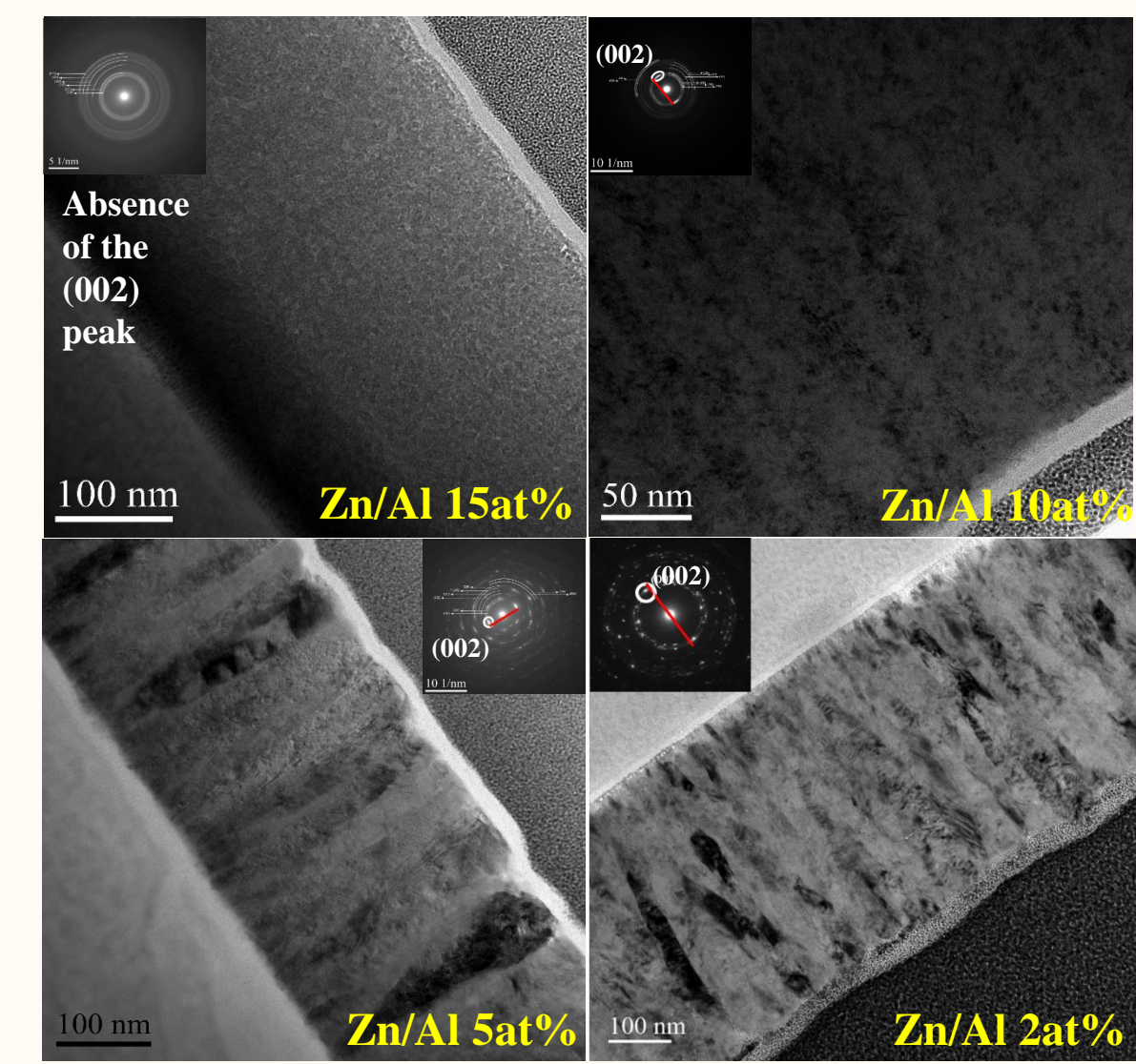


Structural and chemical analysis

XRD



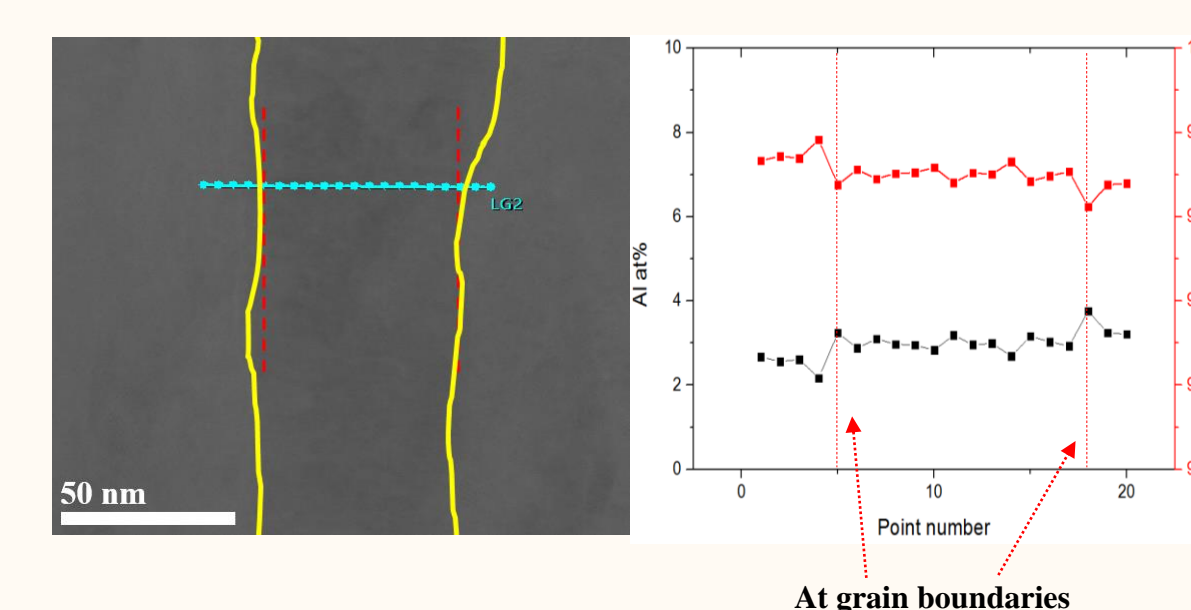
These results suggest that crystalline films are obtained for low Al at%; which can be correlated with the lower resistivity for such films. TEM was realized to confirm these XRD results



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