ALUMINUM ZINC OXIDE LAYERS BY HIGH-PRESSURE SPUTTERING FOR SOLAR CELLS APPLICATION.

2025 PhDay Físicas

S. Duarte-Cano[1*], R. García-Hernansanz[1], F. Pérez-Zenteno[1], R. Benítez-Fernandez[1], I. Martil[1] E. García-Hemme[1], J. Olea[1], D. Pastor[1], A. del Prado[1], E. San Andrés[1], S. Algaidy[2]
[1]Dpto. EMFTEL, Fac. CC. Físicas, Univ. Complutense de Madrid, 28040, Madrid, Spain; *seduarte@ucm.es,
[2] Instituto de Energía Solar, Universidad Politécnica de Madrid, E.T.S.I. Telecomunicación, 28040 Madrid, Spain

MOTIVATION

•**ITO limitations:** High cost and scarcity of indium restrict large-scale use of ITO in transparent electrodes.

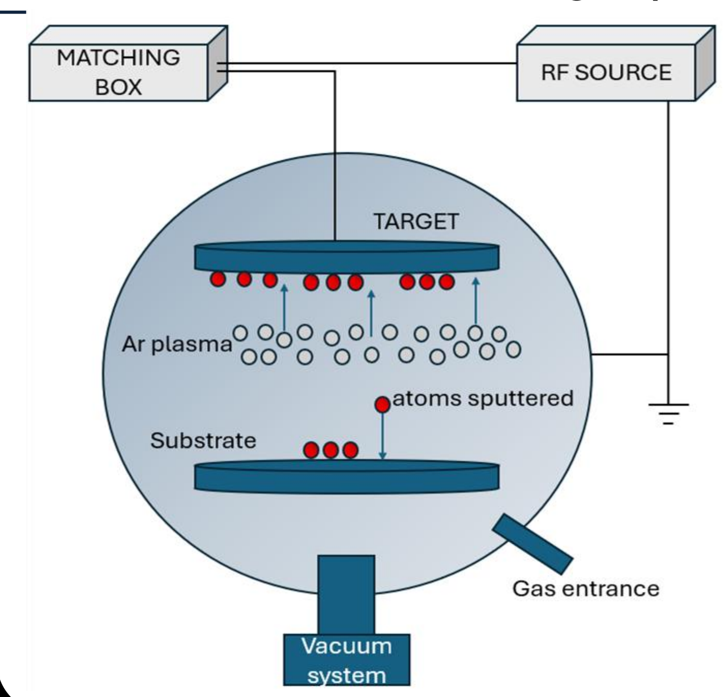
•**AZO advantages:** Aluminum-doped ZnO is abundant, low-cost, non-toxic, highly transparent, and combines good conductivity with stability.

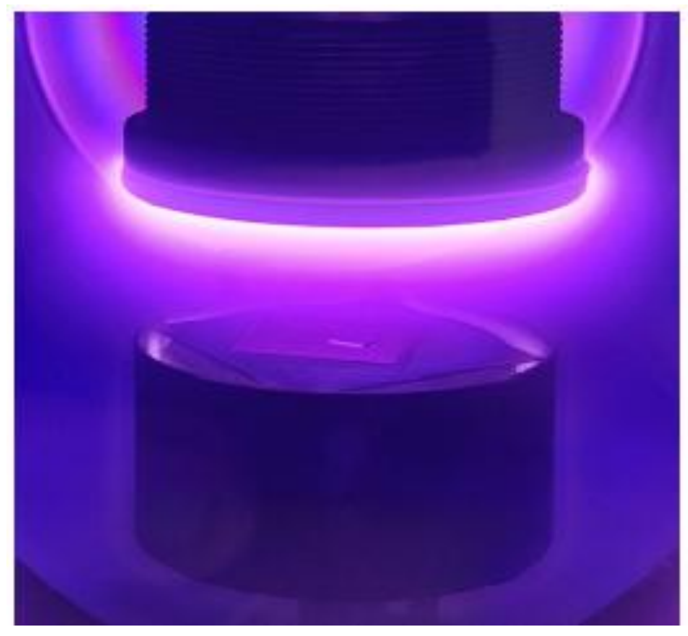
•**Common AZO deposition methods**: low-pressure magnetron sputtering, Pulsed Laser Deposition (PLD), or Chemical Vapor Deposition (CVD).

•**High-pressure sputtering (HPS):** At mbar pressures, thermalized species reduce substrate damage and enable dense, conductive films even at low substrate temperatures. $\lambda = \frac{kT}{\sqrt{2}\pi d^2 p}$

EXPERIMENTAL

- Sputtering pressure: **0.46-2.2 mbar**
- **Power:** 100W, **AZO** target **(ZnO/Al_2O_3), x6 Ar atmosphere**



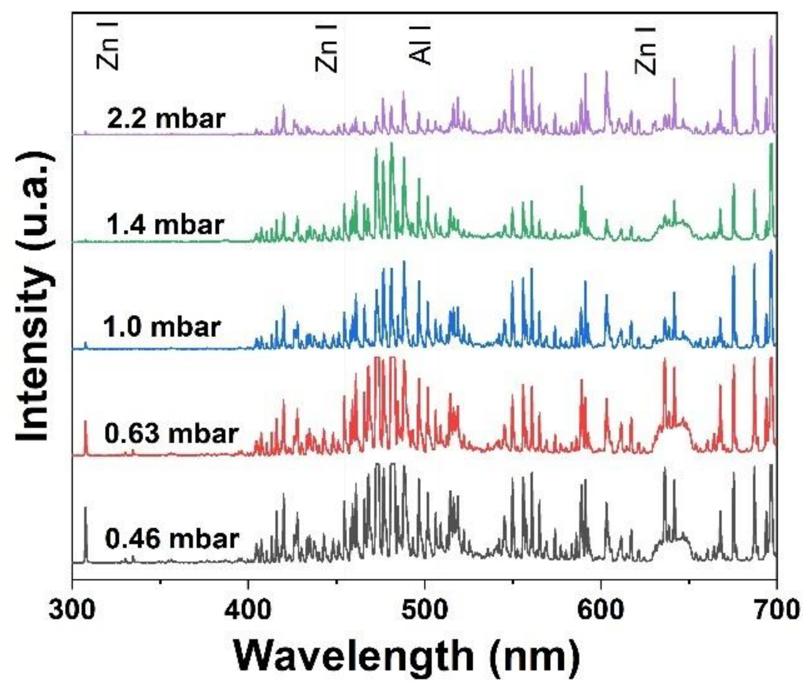


Characterization techniques

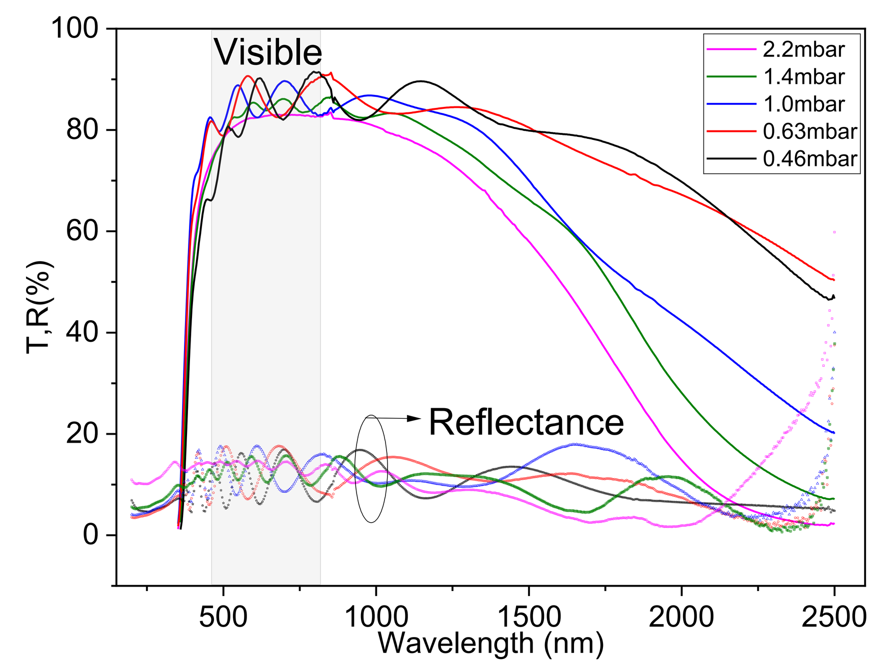
- •OES✓
- •Ellipsometry ✓
- •Transmittance ✓
- •Reflectance ✓
- •XPS ✓
- •GIXRD ✓
- •AFM ✓
- •Resistivity ✓
- •Carrier concentration ✓
- •Mobility✓

RESULTS

OPTICAL EMISSION SPECTROMETRY

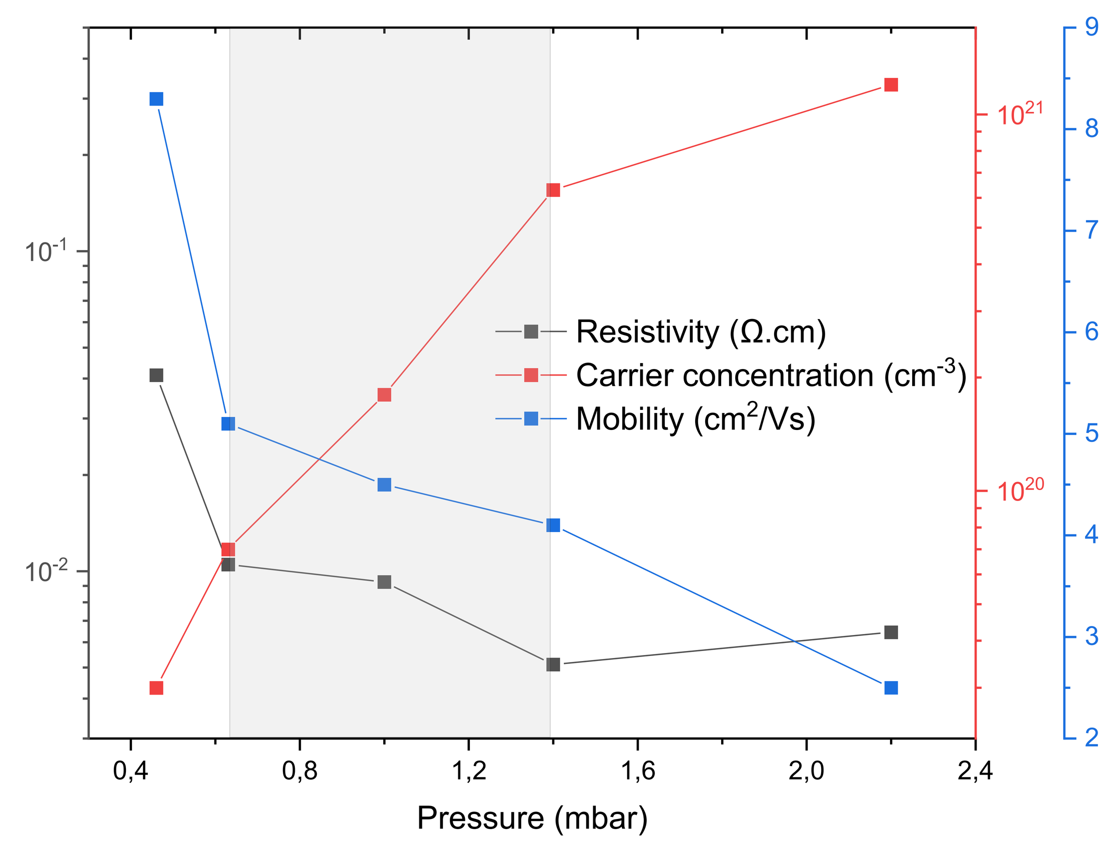


TRANSMITTANCE & REFLECTANCE



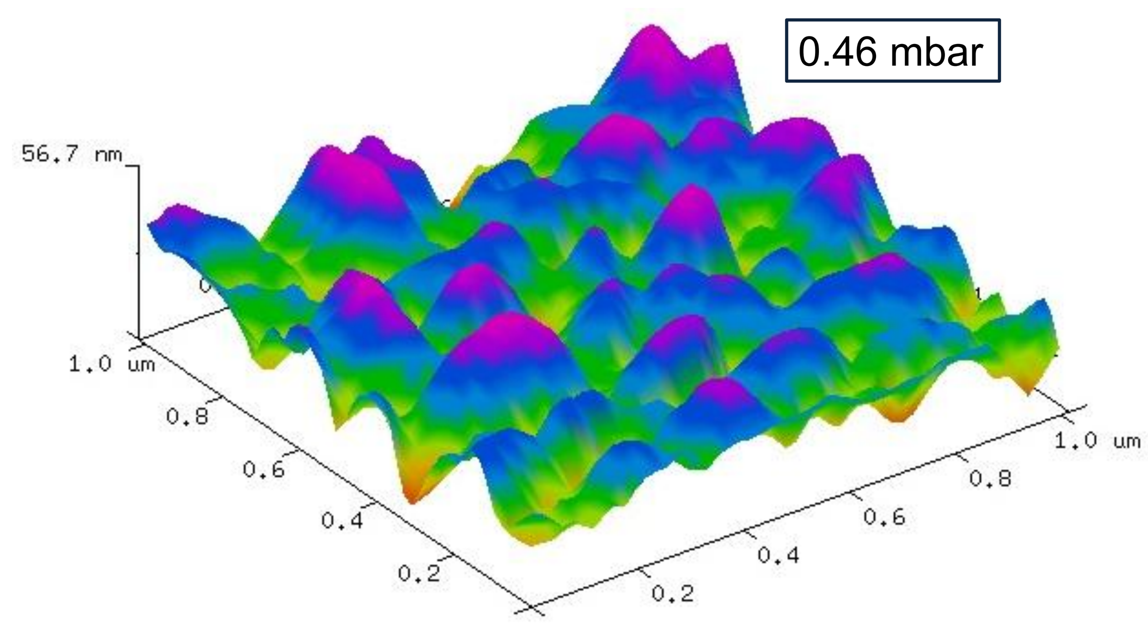
- Average T: **~80–83%, stable across pressures.**
- Low, smooth R(λ) and high flat T(λ) indicate limited light scattering, **consistent with a dense, low-roughness AZO film** suitable for TCO use.

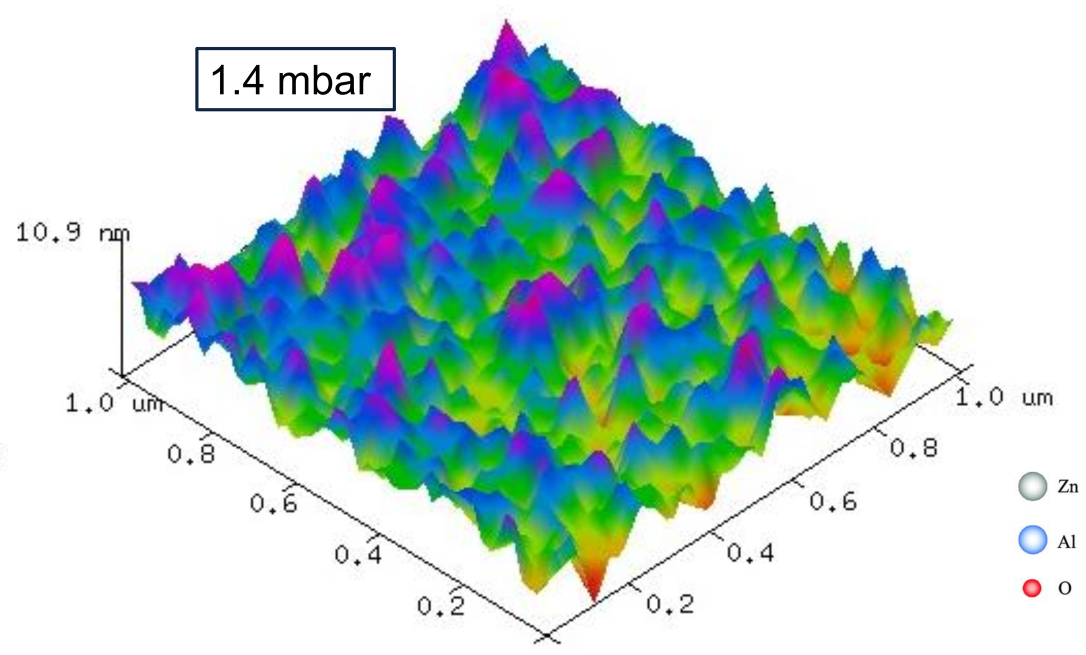
ELECTRICAL CHARACTERIZATION



- Carrier concentration **increases with pressure,** leading to higher conductivity. Increased collisions between carriers, **decreasing mobility (μ).**
- Higher pressures promote the formation of more defects in the film, leading to a **decrease in carrier mobility**

ATOMIC FORCE MICROSCOPY

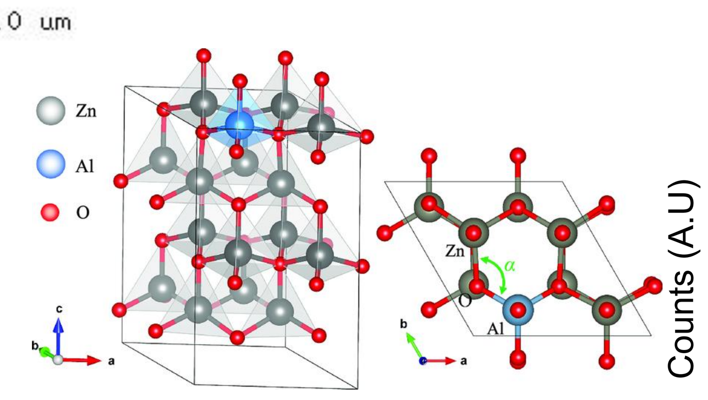


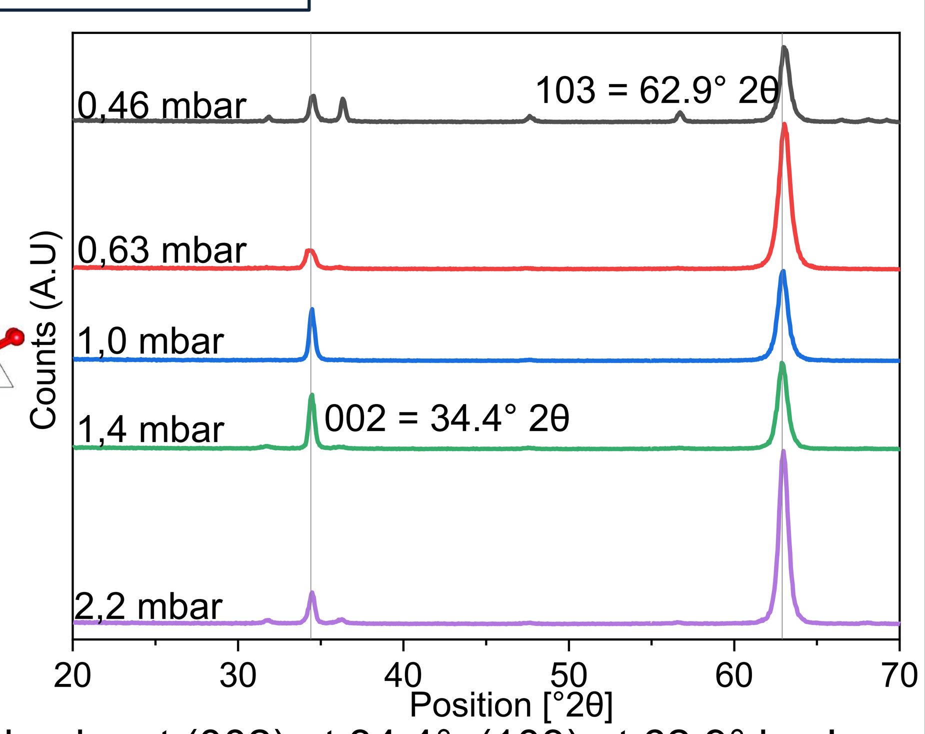


- Roughness decreases from 0.46 → 1.0–1.4 mbar, yielding more uniform, high-quality films.
- Optimal window: 1.0–1.4 mbar (smooth, dense morphology; controlled growth).
- *At 2.2 mbar the roughness increases → deposition becomes less controlled, not ideal for smooth surfaces.

Pressure (mbar)	Resistivity (Ω.cm)	T(m) (%)	μ (cm²/Vs)	n(cm⁻³)	E_{gap} (eV)
0.46	4.1×10^{-2}	79.7	8.3	3.0×10^{19}	3.41
0.63	1.1×10^{-2}	82.6	5.1	7.0×10^{19}	3.45
1.0	9.3×10^{-3}	82.9	4.5	1.8×10^{20}	3.47
1.4	5.1×10^{-3}	79.7	4.1	6.3×10^{20}	3.52
2.2	6.5×10^{-3}	78.3	2.5	1.2×10^{21}	3.60
Ref. Value (0.001–0.012)	$\sim1\times10^{-3}$	80-92	10-35	3×10^{19} - 5×10^{20}	3.35-3.70

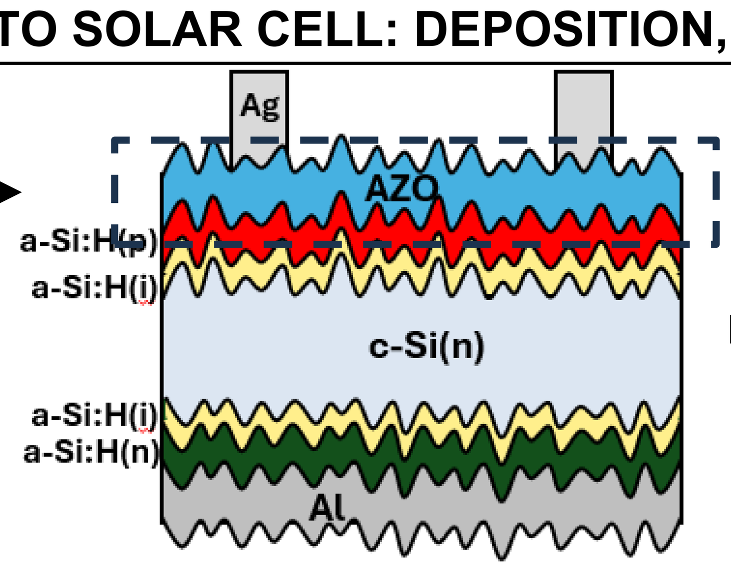
X-RAY DIFFRACTION

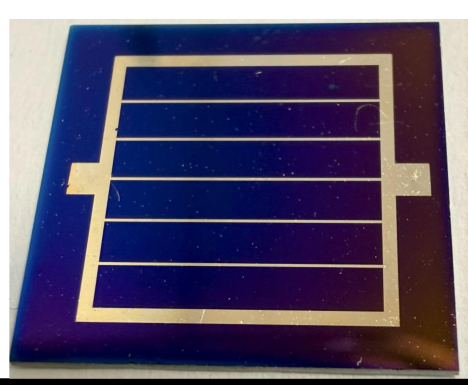




- Wurtzite ZnO with dominant (002) at 34.4°; (103) at 62.9° is also present.
- Coincidence of the peaks with the expected positions corresponds to the **hexagonal wurtzite phase**, typical of AZO
- (002) texture strengthens around 0.63–1.0 mbar, indicating better c-axis orientation.

FROM AZO FILM TO SOLAR CELL: DEPOSITION, INTEGRATION, DEVICE





- **Published Work!**
Scan QR code

CONCLUSIONS

- We have deposited AZO using High-Pressure Sputtering (HPS), and the resulting films are **suitable for use in solar cells**.
- In the pressure range of **0.63 mbar to 1 mbar**, the films produced show a favorable balance between low resistivity, high transmittance, adequate roughness and optimal AZO properties.

ACKNOWLEDGEMENT

The authors would like to acknowledge the "CAI de Técnicas Físicas, for the collaboration at various stages of this research, including measurements and characterization. This project was funded by AEI through the projects PID2020-116508RB-I00, PID2023-149369OB-C21 and TED2021-130894B-C21, and by the Comunidad Autonoma de Madrid through the project PR37/24 TEC-2024/ECO-72 F. Pérez-Zenteno acknowledges the predoctoral contract from UCM (call CT58/21-CT59/21) . R. Benítez-Fernández acknowledges the predoctoral contract from Comunidad Autónoma de Madrid (PIPF-2023/ECO-30541).

References
[1] S. Duarte-Cano et al., (2025),10.1016/j.apsusc.2025.164357.
[2] D. Caudevilla et al., (2022), 10.1016/j.mssp.2021.106189.
[3] F. Pérez-Zenteno et al, (2025), 10.1016/j.mssp.2024.109038

UNIVERSIDAD COMPLUTENSE MADRID
ESCUELA DE DOCTORADO
CENIM