

# Ethanol sensing at room temperature via ZnS nanostructure-based optical approach

*Houyem Trabelsi<sup>1,2</sup>, Isabel Gràcia<sup>1</sup>, Khaled Alouani<sup>2</sup>, Carles Cané<sup>1</sup>, Stella Vallejos<sup>\*,1</sup>*

<sup>1</sup> *Institute of Microelectronics of Barcelona (IMB-CNM, CSIC), Barcelona, Spain*

<sup>2</sup> *University of Tunis El Manar, Faculty of Science, Tunis, Tunisia*

\* [stella.vallejos@imb-cnm.csic.es](mailto:stella.vallejos@imb-cnm.csic.es)

## 1. Summary

A novel approach for synthesizing zinc sulfide (ZnS) nanostructures via aerosol-assisted chemical vapor deposition (AACVD) technique is developed. These ZnS structures are characterized and tested upon a series of gases, demonstrating optical responses to ethanol at room temperature (RT).

**Keywords:** Optical sensor, ZnS nanostructures, Ethanol, AACVD

## 2. Background and motivation

Metal sulfide (MS) materials have gained significant attention for gas sensing applications due to their tunable optoelectronic properties, high surface reactivity, and capability to function at room temperature [1,2]. Among these materials, zinc sulfide (ZnS) stands out with its wide bandgap (3.5 - 3.7 eV), chemical stability, and exceptional optical properties [3]. These characteristics make ZnS not only an excellent candidate for conventional resistive gas sensors but also a promising material for alternative optical sensing techniques, particularly due to its potential to operate effectively at room temperature (RT). Despite these advantages the use of ZnS in optical gas sensors has been scarcely reported in the literature. Additionally, the synthesis of ZnS structures via AACVD remains largely unexplored. To address these gaps, this study presents a novel route for synthesizing ZnS structures using the AACVD technique, and evaluates their performance as optical gas sensors at RT.

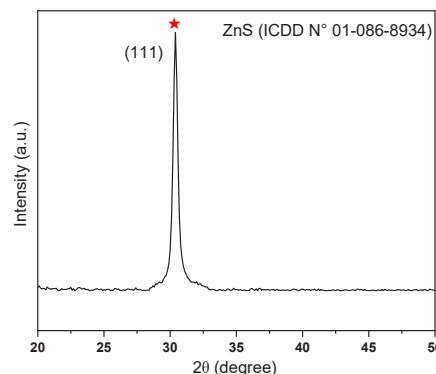
## 3. Results and discussion

### 3.1. Films characterization

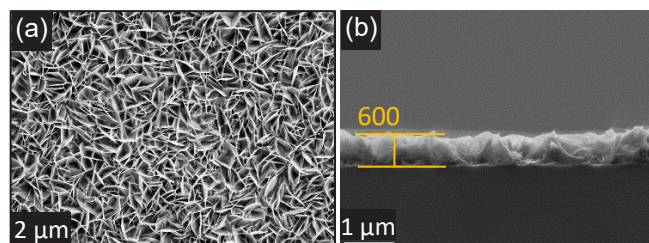
ZnS nanostructures were successfully deposited on silicon substrates at 450 °C using a mixture of ZnCl<sub>2</sub> and Et<sub>4</sub>P<sub>2</sub>S<sub>2</sub> ligands via the AACVD technique.

X-ray diffraction (XRD) analysis confirmed the crystalline nature of the material, with diffraction peaks corresponding to the cubic phase (ICDD card no. 01-086-8934) and a preferred orientation along the [111] direction (Figure 1).

Top-view and cross-sectional SEM images of the ZnS nanostructures revealed leaf-like morphology with an approximate length of 600 nm (Figure 2).

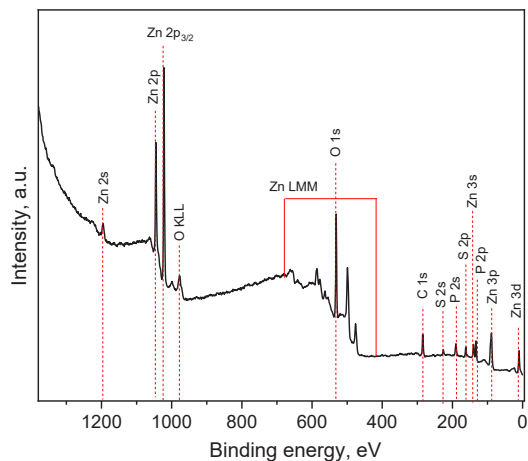


**Figure 1.** XRD pattern of ZnS deposited on Si substrates by AACVD at 450 °C.



**Figure 2.** (a) Top view and (b) cross-sectional SEM images of ZnS structures deposited on Si substrates by AACVD at 450 °C.

The surface of the nanostructures was examined using XPS analysis, as shown in Figure 3. The survey scan of the ZnS films identifies the main elements (Zn 2p and S 2p) present in the film, with minor phosphorus contamination attributed to the ligand Et<sub>4</sub>P<sub>2</sub>S<sub>2</sub>.



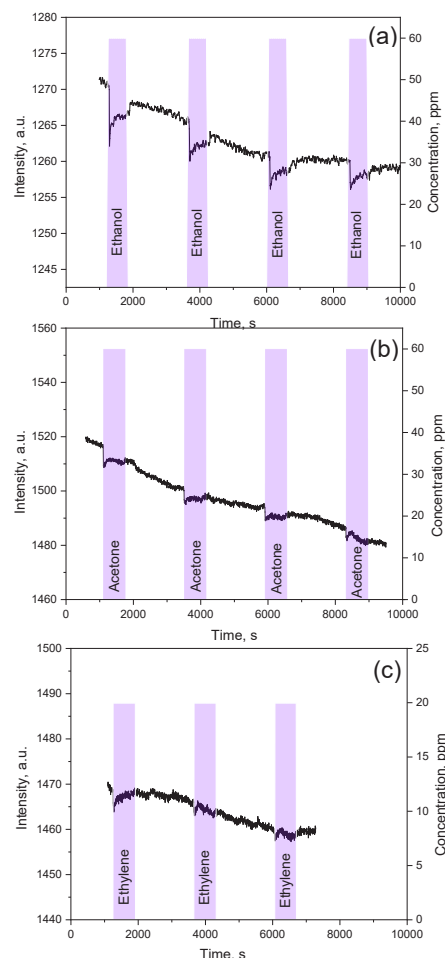
**Figure 3.** XPS survey scan of ZnS structures deposited on Si substrates by AACVD at 450 °C.

### 3.2. Gas sensing test

ZnS structures were deposited onto ITO/glass substrates and evaluated as gas-sensors towards ethanol, acetone, and ethylene at room temperature in dry air. The measurements were performed under illumination from a light source covering a wavelength range of 200–1100 nm, and the response was recorded as the transmittance intensity.

The sensor demonstrated a significant response in the 355–380 nm wavelength range, showing a noticeable change in intensity upon exposure to 60 ppm of ethanol (Figure 4.a), while displaying negligible sensitivity to acetone (Figure 4.b). Moreover, no detectable response was observed for 20 ppm of ethylene (Figure 4.c). These findings highlight the sensor's sensitivity and selectivity toward ethanol.

This study demonstrate that ZnS can optically sense ethanol at RT offering a significant advantage in terms of power consumption. Unlike earlier approaches that relied on electrical resistance measurements, which required high operating temperatures or additional functionalization with catalytic nanoparticles like gold [4].



**Figure 4.** Typical optical responses recorded on the ZnS nanostructure to (a) ethanol, (b) acetone, and (c) ethylene at RT. The purple bars represent the periods of gas injection and its concentration.

### References

- [1] B. Chatterjee y A. Bandyopadhyay, *Materials Science and Engineering: B*, vol. 297, p. 116781, nov. 2023, doi: 10.1016/j.mseb.2023.116781.
- [2] H. Tang, L. N. Sacco, S. Vollebregt, H. Ye, X. Fan, y G. Zhang, *J. Mater. Chem. A*, vol. 8, n.º 47, pp. 24943-24976, 2020, doi: 10.1039/D0TA08190F.
- [3] M. Alzaid, W. S. Mohamed, M. El-Hagary, E. R. Shaaban, y N. M. A. Hadia, *Optical Materials*, vol. 118, p. 111228, ago. 2021, doi: 10.1016/j.optmat.2021.111228.
- [4] L. Zhang, R. Dong, Z. Zhu, y S. Wang, *Sensors and Actuators B: Chemical*, vol. 245, pp. 112-121, jun. 2017, doi: 10.1016/j.snb.2017.01.179.

### Acknowledgements

This work was carried out under the AGRARSENSE project, funded by the Chips JU and its members via Grant Agreement No. 101095835, the MCIN/AEI/10.13039/501100011033 via Grant PCI2022-135006-2, and the European Union Next Generation EU/PRTR. Support through the María de Maeztu grant CEX2023-001397-M, funded by MICIU/AEI/10.13039/501100011033, is also acknowledged.