proceedings

MDPI

Abstract

Optical Interference Analysis of ZIF-8 Films for Chemical Vapor Detection †

Anna Estany-Macià [1,2,*], Sachin Navale [1,2], Ignasi Fort-Grandas [1,2,3], Nirav Joshi [1,2], Albert Romano-Rodríguez [1,2] and Mauricio Moreno-Sereno [1,2,*]

1 Department of Electronics and Biomedical Engineering, Universitat de Barcelona, 08028 Barcelona, Spain; stnavale2@ub.edu (S.N.); ignfortgra_9@ub.edu (I.F.-G.); niravjoshi@ub.edu (N.J.); albert.romano@ub.edu (A.R.-R.)
2 Institute of Nanoscience and Nanotechnology, Universitat de Barcelona (IN^{2}UB), 08028 Barcelona, Spain
3 Department of Inorganic and Organic Chemistry, Universitat de Barcelona, 08028 Barcelona, Spain
* Correspondence: anna_estany@ub.edu (A.E.-M.); mauricio.moreno@ub.edu (M.M.-S.)
† Presented at the XXXV EUROSENSORS Conference, Lecce, Italy, 10–13 September 2023.

Abstract: Metal–organic frameworks (MOFs) are materials that feature a large surface area with permanent porosity, which is an attractive property for chemical and gas sensing, making them a good candidate for sensor fabrication. In this paper, we present a sensor that employs zeolitic-imidazolate-based MOFs (ZIF-8) to detect ethanol vapors via refractive index-dependent optical interference.

Keywords: nanomaterials; gas sensor; MOFs; ZIF-8; optical detection

1. Introduction

Metal–organic frameworks (MOFs) are being regarded as an advanced material to improve some current technologies, among which are gas storage, molecule separation and chemical catalysis [1]. Their intrinsic porous characteristics have proven to be effective for chemical and gas sensing through the molecular absorption of gases into their porous structure, which translates into a change in the effective refractive index (RI) of the MOF film [2]. To this end, Zeolitic Imidazolate Framework-8 (ZIF-8) has been used to design thin films on substrates via layer-by-layer deposition to optically detect ethanol vapors at room temperature by monitoring the reflectivity spectra shift.

2. Materials and Methods

To synthesize ZIF-8, a 1:1 volume mixture solution of 2-methylimidazole (50 mM) and $Zn(NO_3)_2 \cdot 6H_2O$ (25 mM) was prepared. Each growth cycle was performed by immersing cleaned 1×1.5 cm^2 silicon substrates into the freshly made solution for 40 min at room temperature. The samples were then rinsed with pure methanol and dried with a nitrogen flow. The characterization of ZIF-8 film thickness was carried out with an optical Dektak XT profilometer by measuring a 2.5 mm long line at the substrate/ZIF8 border that was obtained by etching part of the layer in a dilute nitric acid solution (68% nitric acid: H_2O, 1:1000 (v/v)) for 5 s. The obtained results indicate that the layer's growth is in accordance with the reported deposition of 100 nm per 30 min cycle [1].

The reflectivity spectra were acquired with an Ocean Optics SD2000 spectrometer to characterize the interference fringes between ZIF-8 and the substrate, which, in the presence of ethanol vapor, experience a red shift due to an RI change. In this regard, vapor testing was performed by placing the samples inside a home-built aluminum chamber, in which 1 µL of different ethanol/water solutions were added without contacting the samples. White light was focused on a fiber optical cable and was then collimated and divided with a beam splitter. One of the beams was focused on the sample through a

check for updates

Citation: Estany-Macià, A.; Navale, S.; Fort-Grandas, I.; Joshi, N.; Romano-Rodríguez, A.; Moreno-Sereno, M. Optical Interference Analysis of ZIF-8 Films for Chemical Vapor Detection. *Proceedings* **2024**, *97*, 77. https://doi.org/10.3390/proceedings2024097077

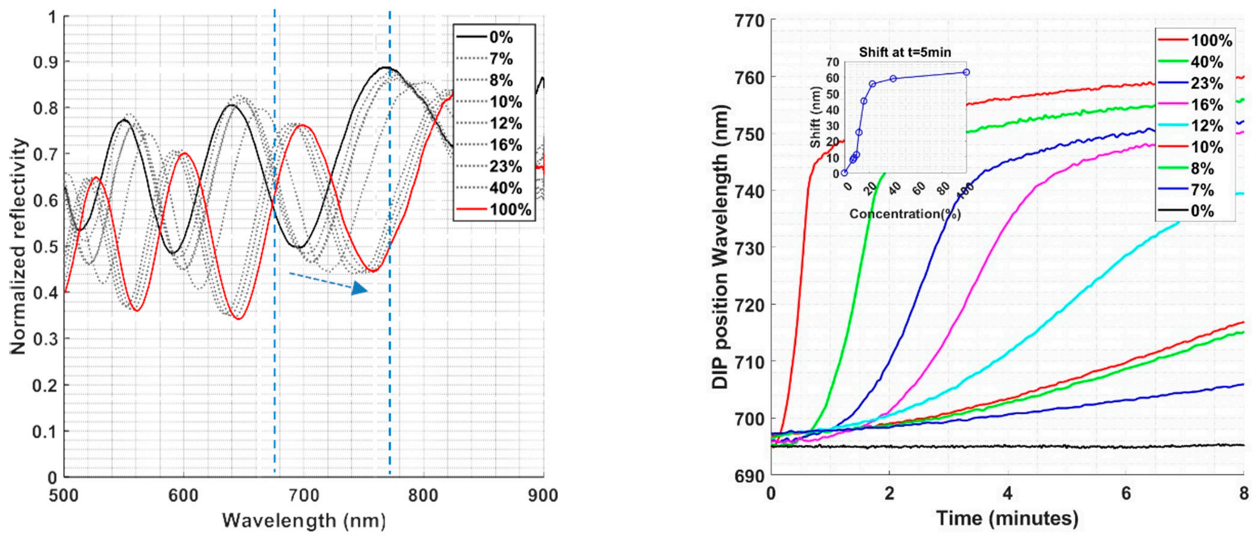
Academic Editors: Pietro Siciliano and Luca Francioso

Published: 22 March 2024

quartz window using a 4× objective lens. The reflected spectra were always normalized to a reference spectrum in a ZIF-8-free area.

3. Discussion

Room-temperature gas sensing measurements were taken at different concentrations of ethanol/water solutions with samples containing various ZIF-8 film thicknesses. The results for a 10-cycle ZIF-8 layer (~1600 nm) are shown below. Figure 1a shows the interference fringes of the reflectivity spectra, in which the red shift caused by increasing the ethanol concentration can also be observed. The monitored dynamic shift of the spectrum's dip localized between blue lines under the first 8 min of ethanol exposure can be observed in Figure 1b, which shifts the fringes by up to 60 nm for concentrations over 40%, which is similar to the reported data [1] and larger than recorded other optical techniques [3]. Overall, ZIF-8 appears to be an advanced sensing material for room-temperature ethanol sensors. Our current focus is on studying the sensitivity of ZIF-8 to various volatile compounds and discussing its detection limits, considering its practical applications.



(**a**) (**b**)

Figure 1. (**a**) Interference fringes' red shift (arrow) for increasing ethanol/water concentrations (volume percentage in water). (**b**) Comparison of the monitored dynamic interference peak shift in an 8 min time frame. The figure inset shows the interference peak shift at t = 5 min for the different concentrations.

Author Contributions: Conceptualization, M.M.-S.; methodology, and investigation, S.N., I.F.-G., N.J., A.E.-M. and M.M.-S.; software, M.M.-S.; validation, A.E.-M. and M.M.-S.; writing—original draft preparation, A.E.-M.; writing— review and editing, M.M.-S. and A.R.-R.; visualization, M.M.-S.; supervision, project administration, funding acquisition, M.M.-S. and A.R.-R. All authors have read and agreed to the published version of the manuscript.

Funding: This research received funding from the Spanish Agencia Estatal de Investigación (AEI), through project PID2019-107697RB-C41/AEI/10.13039/501100011033, and from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 801342 (Tecniospring INDUSTRY) and the Government of Catalonia's Agency for Business Competitiveness (ACCIÓ).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding authors.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Lu, G.; Hupp, J.T. Metal-organic frameworks as sensors: A ZIF-8 based Fabry-Pérot device as a selective sensor for chemical vapors and gases. *J. Am. Chem. Soc.* **2010**, *132*, 7832–7833. [CrossRef]
2. Keppler, N.C.; Hindricks, K.D.J.; Behrens, P. Large refractive index changes in ZIF-8 thin films of optical quality. *RSC Adv.* **2022**, *12*, 5807–5815. [CrossRef] [PubMed]
3. Hromadka, J.; Tokay, B.; Correia, R.; Morgan, S.P.; Korposh, S. Highly sensitive volatile organic compounds vapour measurements using a long period grating optical fibre sensor coated with metal organic framework ZIF-8. *Sens. Actuators B Chem.* **2018**, *260*, 685–692. [CrossRef]