Enhancing Electrochemical Sensor Performance: Studies of Electrodes Tailored with ZnO/ZnFe2O4 Nanoparticles

Your abstract submission has been received

Click here **to print this page now.**

You have submitted the following abstract to 245th ECS Meeting (May 26 - 30, 2024). Receipt of this notice does not guarantee that your submission was complete, free of errors, or accepted for presentation.

Enhancing Electrochemical Sensor Performance: Studies of Electrodes Tailored with $ZnO/ZnFe_2O_4$ Nanoparticles

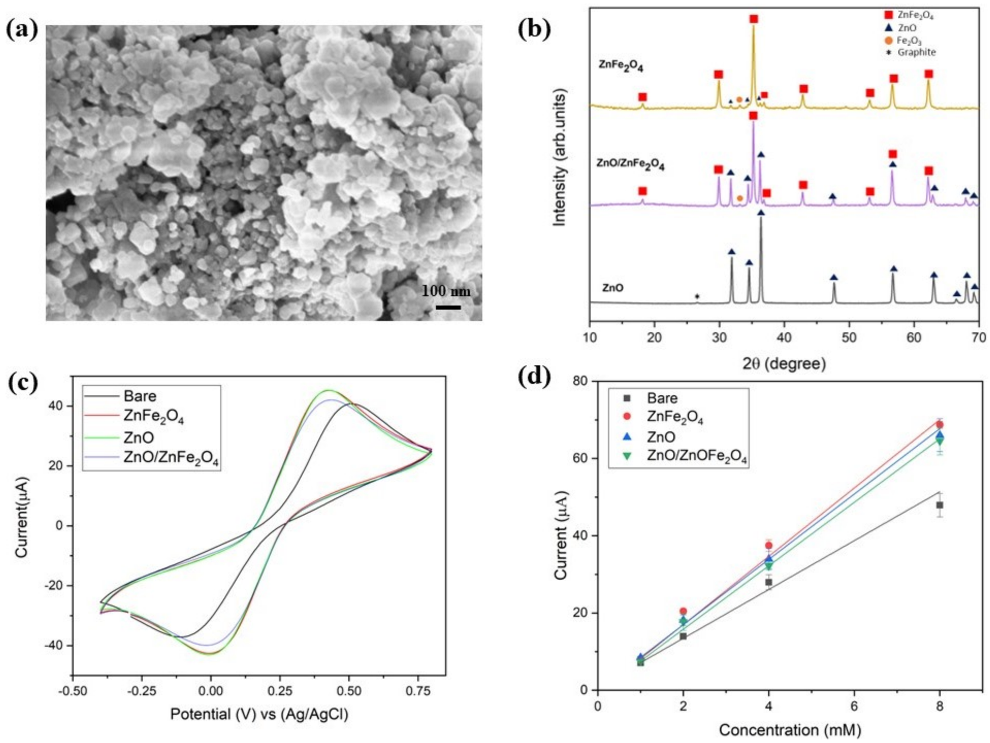
M. Madagalam (Politecnico di Torino), M. Bartoli (Fondazione Istituto Italiano di Tecnologia), C. Fernandes (KU Leuven), M. Rosito, E. Padovano (Politecnico di Torino), I. Taurino (KU Leuven), S. Carrara (EPFL), and A. Tagliaferro (Politecnico di Torino)

Abstract Text:
Spinel metal oxides possess excellent magnetic, electrical, and optical properties. They take AB_2O_4 (face centered cubic) form with oxygen anions providing tetrahedral (Td) and octahedral (Oh) sites for A^{+2} and B^{+3} cations. Spinel can have a normal, inverse, or mixed form based on the occupancy of different cations in Td and Oh sites. The peculiarity of the spinel crystal structure is that its composition can be easily modified without affecting the crystal structure based on the type of cation. The type of cation in the composition defines if the spinel has a normal or inverse form [1]. Based on these premises, we have already synthesized $Zn_xNi_{1-x}Fe_2O_4$ (x =0, 0.2, 0.4, 0.6, 0.8, 1) nanomaterials achieving a clear gradual transition from inverse (x=0) to normal (x=1) spinel. Synthesized nanomaterials were employed as mediators in electron transfer between the screen-printed carbon working electrode and paracetamol to understand the effect of chemical composition and crystal structure on the electron transfer at the electrochemical interface [1]. Normal spinel $ZnFe_2O_4$ was found to be the best nanomaterial in terms of sensitivity and kinetic rate constant. In further works, with the aim to understand the effect of ionic radii on sensitivity and electron transfer rate constant in electrochemical sensing of paracetamol, we have focused on the normal spinel structure and modified the composition by varying the concentration of Fe^{3+} with Cr^{3+} and Bi^{3+} [2,3]. This study also proved that the normal spinel $ZnFe_2O_4$ has the highest sensitivity and electron transfer rate constant towards paracetamol sensing.

In this work, we will present the synergic effect that can be obtained by interfacing $ZnFe_2O_4$ with ZnO nanomaterials by tuning the band gap of the heterogeneous structure. The aim is to understand the effect of band gap on sensitivity and electron transfer rate constant in electrochemical sensing. $ZnFe_2O_4$, ZnO, and $ZnO/ZnFe_2O_4$ nanomaterials are synthesized by a simple, single step auto combustion technique using the respective metal nitrates as precursors. Nanomaterial morphology and particles size are investigated by scanning electron microscopy. X-ray diffraction technique is employed to analyze the crystal structure and identify different phases in the newly synthesized materials. Then, commercially available screen-printed carbon electrodes with carbon working electrode and carbon counter electrodes are used for the electrochemical measurements in combination with an external double junction Ag/AgCl as a reference electrode. The synthesized nanomaterials are mixed with 1-butanol and a 5 μL solution is used to modify the surface of the carbon working electrode to mediate the redox reactions between the carbon surface and the molecule of interest. Primarily the sensors are characterized using cyclic voltammetry with ferri/ferrocyanide redox couple as a probe molecule. Improvement in sensitivity is observed for $ZnFe_2O_4$ (8.85 ± 0.50 μA/mM), ZnO (8.50 ± 0.30 μA/mM), and $ZnO/ZnFe_2O_4$ (8.22 ± 0.16 μA/mM) sensors compared to the bare carbon one (6.30 ± 0.40 μA/mM). By performing cyclic voltammetry at different scan rates (v) from 25 to 125 mV/s, a good linearity of redox currents with respect to $v^{0.5}$ is observed and redox peak positions are varying linearly with ln(v). Peak-to-peak separation (ΔE_p) is reduced for $ZnO/ZnFe_2O_4$ sensors compared to the carbon one. All these results suggest a faster electron transfer at the interface when the modified electrodes are used. Laviron model is employed to calculate the electron transfer rate coefficient and constant. The rate constant for $ZnFe_2O_4$ (41.8 ± 2.6 ms^{-1}), ZnO (46.0 ± 4.0 ms^{-1}), and $ZnO/ZnFe_2O_4$ (33.1 ± 4.5 ms^{-1}) sensors is 3 to 5 times higher as compared to the bare carbon one (9.97 ± 0.78 ms^{-1}). We are currently studying the potential application of $ZnO/ZnFe_2O_4$ nanomaterials in electrochemical sensing of small molecules relevant in biomedical field (dissolved oxygen, pH) and pharmaceutical drugs (paracetamol) to assess the potential for their use in different clinical settings.

References:

1. M.Madagalam et al., “Unraveling the effect of chemical and structural composition of $Zn_xNi_{1-x}Fe_2O_4$ on the electron transfer at the electrochemical interface,” *Small Struct*. 2023, 2300163.
2. M.Madagalam et al., “$ZnM_xFe_{2-x}O_4$ (M=Cr, Bi) Nanoparticles-modified electrochemical sensors: Effect on sensitivity and first-order kinetic rate constant,” *2023 IEEE BioSensors Conference (BioSensors)*, London, United Kingdom, 2023, pp. 1-4, doi: 10.1109/BioSensors58001.2023.10280910.
3. M. Madagalam et al., "ZnCr2-xFexO4 Nanoparticles-Modified Electrochemical Sensors: A Comparative Study," *2023 IEEE SENSORS*, Vienna, Austria, 2023, pp. 01-04, doi: 10.1109/SENSORS56945.2023.10325135.



(a) SEM image of $ZnO/ZnFe_2O_4$ nanomaterial, **(b)** XRD patterns of ZnO, $ZnFe_2O_4$, and $ZnO/ZnFe_2O_4$ nanomaterials, **(c)** Cyclic voltammograms of different sensors with 4mM Ferri/Ferrocyanide in 0.1M PBS at pH 7.4 (v = 100 mV/s), and **(d)** Calibration of different sensors to determine the sensitivity of the sensors.

Symposium Selection:
L05 - Electrochemistry at the Nanoscale 2

Submitter's E-mail Address:
mallikarjun.madagalam@polito.it

Preferred Presentation Format:
Oral

Comments to Organizers:
This paper is part of a doctoral student work.

First Corresponding Author

Mr. Mallikarjun Madagalam
Affiliation(s): Politecnico di Torino
Address:
Corso Duca degli Abruzzi 24
Turin, 10129
Italy
Phone Number: +393512359076
E-mail Address: mallikarjun.madagalam@polito.it

Second Author

Dr. Mattia Bartoli

Affiliation(s): Fondazione Istituto Italiano di Tecnologia
Phone Number:
E-mail Address: mattia.bartoli@iit.it

Third Author

Ms. Catarina Fernandes
Affiliation(s): KU Leuven
Phone Number:
E-mail Address: catarina.fernandes@kuleuven.be

Fourth Author

Mr. Michele Rosito
Affiliation(s): Politecnico di Torino
Phone Number:
E-mail Address: michele.rosito@polito.it

Fifth Author

Elisa Padovano
Affiliation(s): Politecnico di Torino
Phone Number:
E-mail Address: elisa.padovano@polito.it

Sixth Author

Irene Taurino
Affiliation(s): KU Leuven
Phone Number:
E-mail Address: irene.taurino@kuleuven.be

Seventh Author

Sandro Carrara
Affiliation(s): EPFL
Phone Number:
E-mail Address: sandro.carrara@epfl.ch

Eighth Author

Alberto Tagliaferro
Affiliation(s): Politecnico di Torino
Phone Number:
E-mail Address: alberto.tagliaferro@polito.it

If necessary, you can make changes to your abstract between now and the deadline of Friday, December 15 2023

To review or revise your submission prior to the deadline, click on the link below; you may need to log in again with your ECS credentials.

https://ecs.confex.com/ecs/245/gateway.cgi

Any changes that you make will be reflected instantly. You DO NOT need to go through all of the submission steps in order to change one thing. If you want to change the title, for example, just click "Title" in the abstract control panel and submit the new title.

When you have completed your submission, you may close this browser window.

Tell us what you think of the abstract submittal

Home Page