



23rd International conference on Advanced Nanomaterials
15th International conference on Advanced Graphene Materials
15th International conference on Hydrogen Energy
13th International conference on Advanced Energy Materials
10th International conference on Advanced Magnetic and Spintronics Materials
9th International conference on Advanced Polymer Materials and Nanocomposites
10th International conference on Solar Energy Materials
8th International conference on Organic Light Emitting Diodes (OLED)

23-25 July 2025
University of Aveiro, Aveiro- Portugal

CERTIFICATE OF PARTICIPATION

This is to certify that

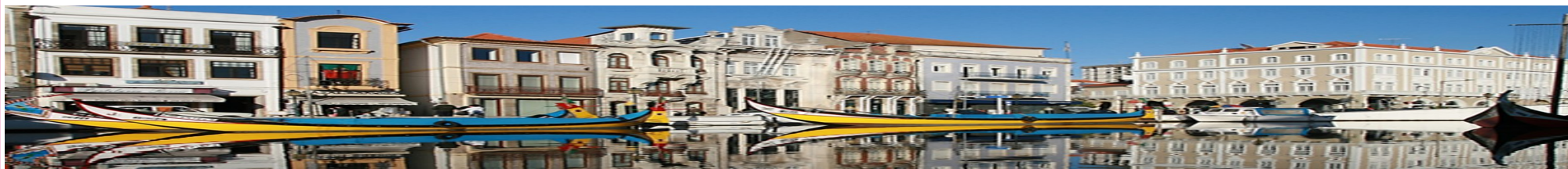
Mr. Luis Angel Arellanes-Mendoza, Universidad Tecnologica de la Mixteca, Mexico

has participated in ANM2025 conference and has presented the work

Porous and Conductive Al₂O₃-ZnO Ceramics Bonded and Foamed with Glycerol-Citrate Polyester for Photoelectrode Applications

in the session of SEM - Solar Energy Materials

Dr. Elby Titus (Conference Chair), 24 July 2025



Porous and Conductive Al₂O₃-ZnO Ceramics Bonded and Foamed with Glycerol

Citrate Polyester for Photoelectrode Applications

Luis Á. Arellanes-Mendoza^{*1}, Alexander N. Bondarchuk¹, Iván Corrales-Mendoza¹

¹Universidad Tecnológica de la Mixteca, México (luisarellanes32@gmail.com)



INTRODUCTION

Porous and conductive ceramics are widely used in various practical applications [1], such as high-surface-area electrode architectures, lightweight and conductive materials for electromagnetic interference shielding, and solar energy absorbers in heaters. Consequently, there is significant interest in developing these materials and exploring new fabrication methods. Herein, to the best of our knowledge, we report for the first time a simple and cost effective approach for fabricating porous ZnO-based ceramics using glycerol-citrate polyester as both a binder and a foaming agent.

EXPERIMENTAL

Porous and conductive Al₂O₃-ZnO ceramics were obtained from Al₂O₃ (2 mol%) and ZnO (98 mol%) powders, mixed with the Glycix polymer [2], and sintered at 1350 °C for 1 hour in air, followed by an additional heat treatment in vacuum (21.3 kPa) at 800°C for 1 hour. The Glycix polymer was synthesized by mixing citric acid and glycerol in a 50:50 molar ratio and in some cases modified with a corresponding percent of triethanolamine replacing a portion of glycerol percent. The oxide powders and Glycix were combined in a 55:45 weight ratio, pressed at 370 kPa, and heat-treated at 170 °C in air for 2 hours in a TERMOLINE 21100 tubular oven to induce polymerization and bind the powder particles. In some experiments, polymerization and foaming were carried out using an LG MH1449CR microwave operating at 1120 W for 60 s.

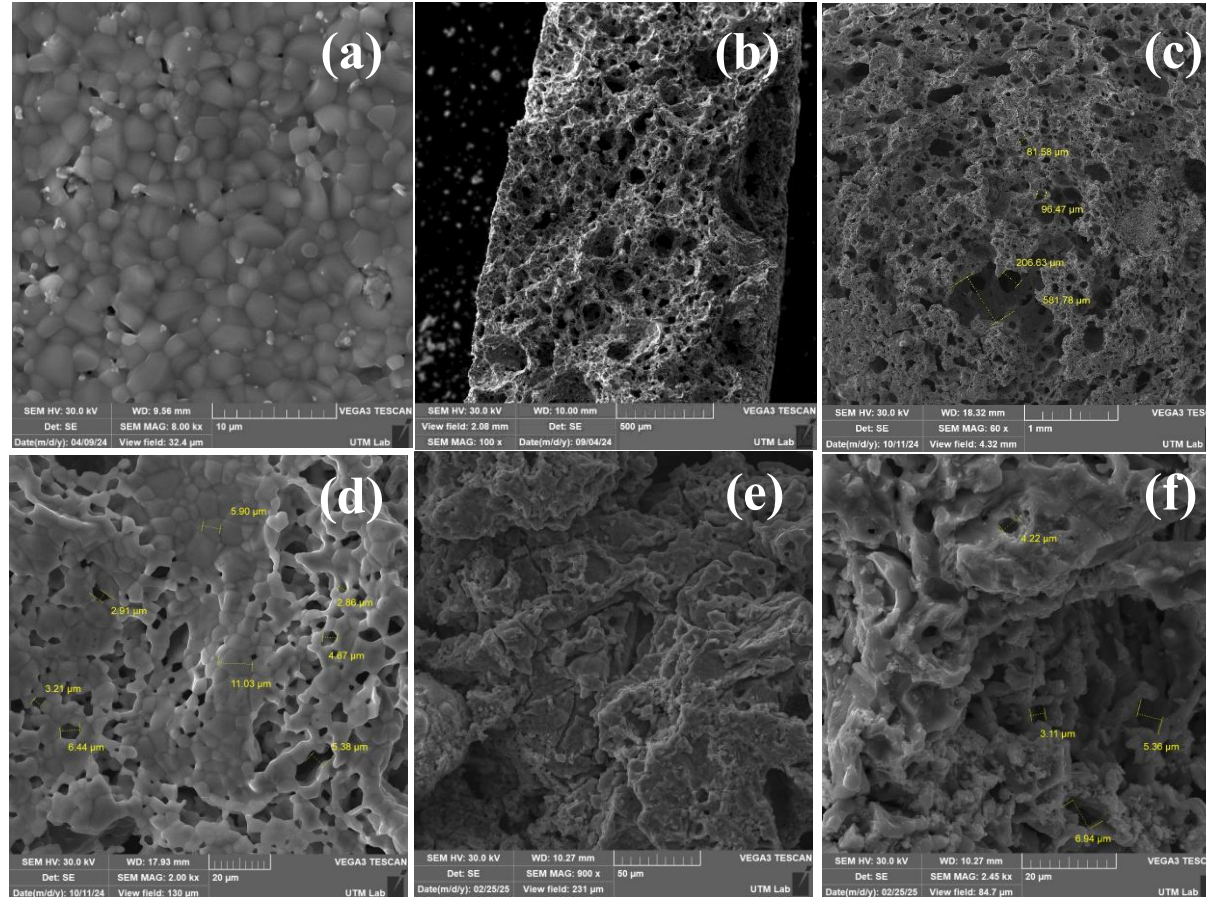


Fig. 1. SEM micrographs of Al₂O₃-ZnO ceramics prepared from (a) precursors compressed at 150 MPa without the Glycix polymer and (b–e) with Glycix, compressed at 370 kPa. Polymerization and foaming were performed using a microwave (b–d) and a tubular oven (e–f). A cross-section of the sample is shown in (b), while its surface is displayed in (c, d).

REFERENCES

1. Y. Chen et al., *aterials Science and Engineering*, 143 (2021)
2. A.H. Alberts et. al, *Faraday Discuss.* 202, 111 (2017).
3. A.N. Bondarchuk et al. *Solar Energy Materials and Solar Cells*, 221 (2021).

At temperatures above 150°C, citric acid gradually underwent decarboxylation to form itaconic acid releasing CO₂ and water vapor¹, which acted as foaming agents. Before sintering at 1350°C, the samples were slowly heated in air at a rate of 1°C/min to 550°C to remove the polymer. The iron oxide coating was prepared by chemical vapor deposition as described in [3]. The sample was then treated at 800 °C for 1 h in air, followed by heat treatment at 350 °C in vacuum (21.3 kPa) for 30 min.

RESULTS AND DISCUSSION

Figure 1 presents sintered Al₂O₃-ZnO ceramics prepared with and without the Glycix polymer. As observed, the polymer functions as a foaming agent, generating pores within the ceramic structure. As a result, the material prepared with this polymer in a microwave has a density of 3.58 g/cm³, whereas the ceramics without it have a density of 5.39 g/cm³, approximately 1.5 times higher. After heat treatment in vacuum, their electrical conductivity reaches 543.6 S/m and 234.6 S/m for ceramics prepared with and without polymer addition, respectively. The higher conductivity of the materials prepared with Glycix is attributed to its binding effect, which enhances particle connectivity during sintering.

RESULTS AND DISCUSSION (continued):

The grain and pore sizes in the ceramics depend on the sintering conditions and can also be modified by the applied pressure during powder compaction or by the addition of triethanolamine to the polymer.

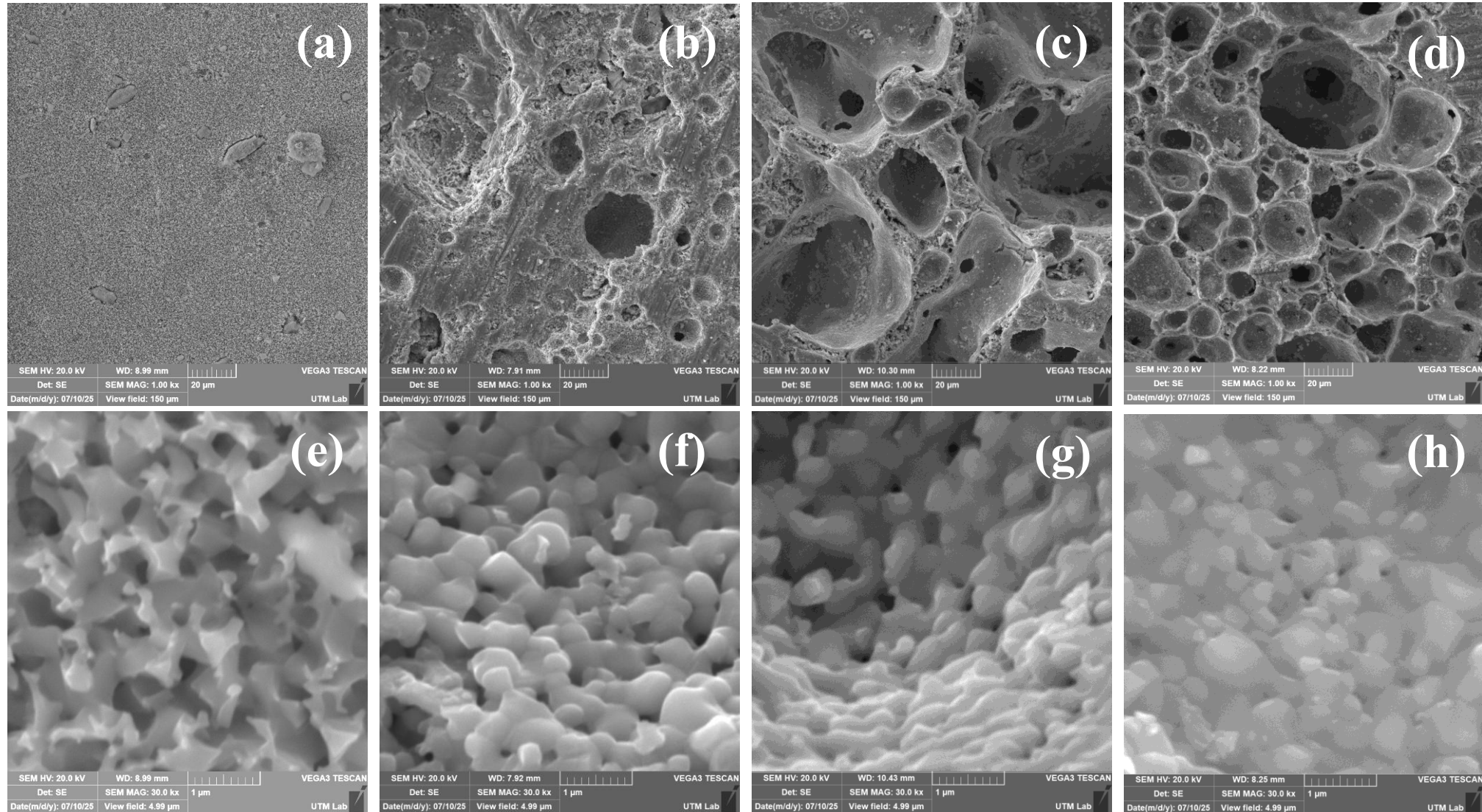
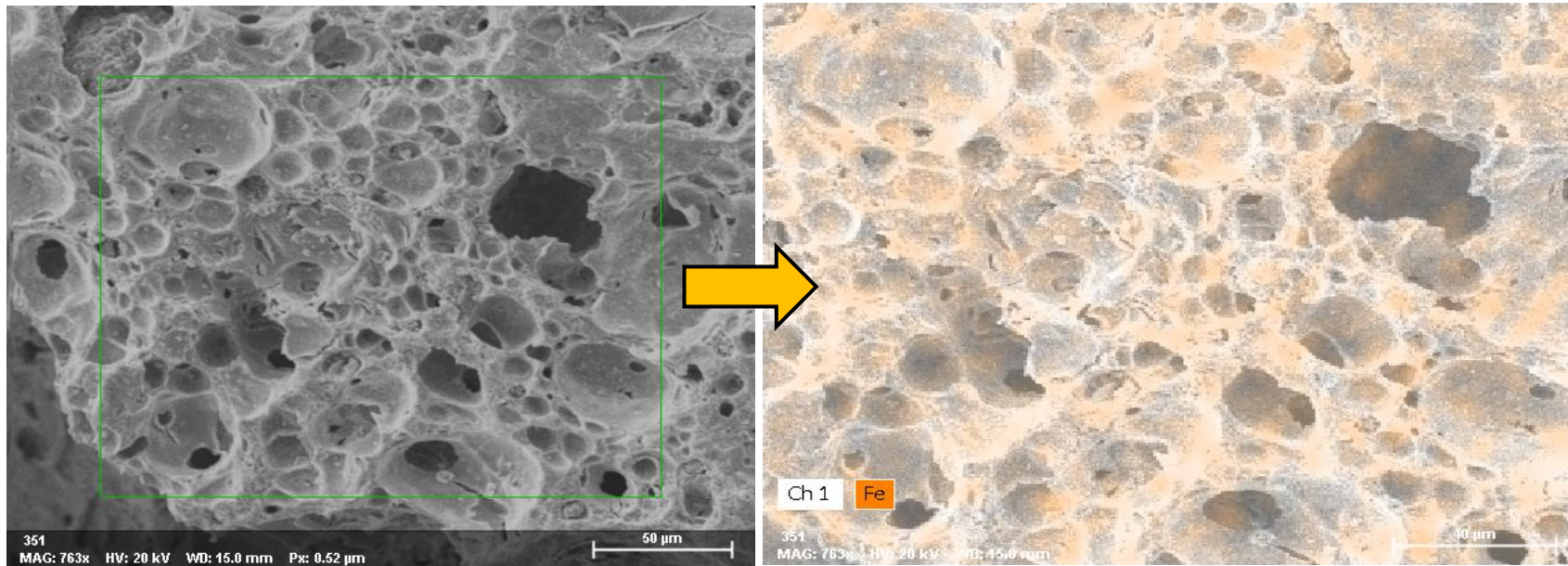


Fig. 2. SEM micrographs of Al_2O_3 - ZnO ceramics prepared from: (a, e) precursors compressed at 150 MPa without the Glycix polymer; and precursors compressed at 370 kPa with the following additives: (b, f) Glycix; (c, g) Glycix with 10% triethanolamine; and (d, h) Glycix with 20% triethanolamine. Polymerization and foaming were performed using microwave irradiation.

RESULTS AND DISCUSSION (continued):



The conductive and porous Al_2O_3 -ZnO ceramics were coated with a thin iron oxide layer approximately several tens of nanometres thick, and the resulting structures were tested as photoelectrodes.

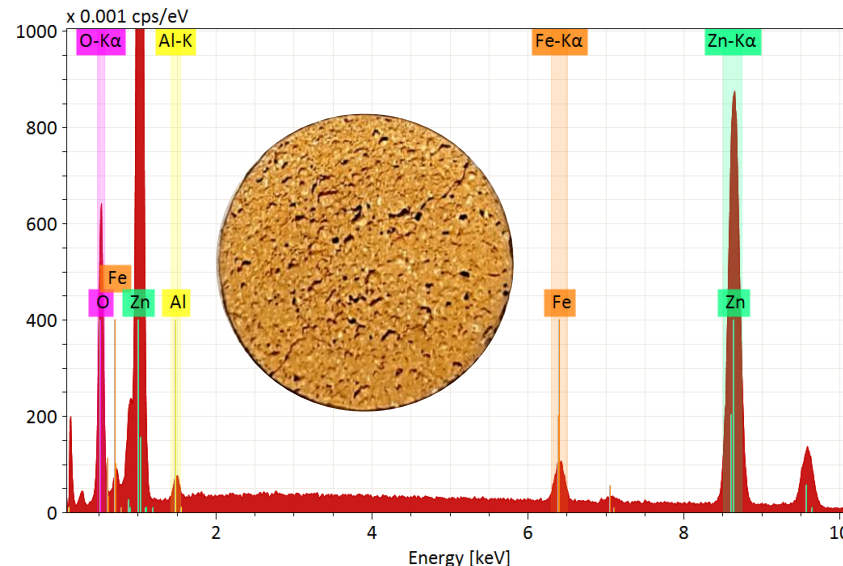
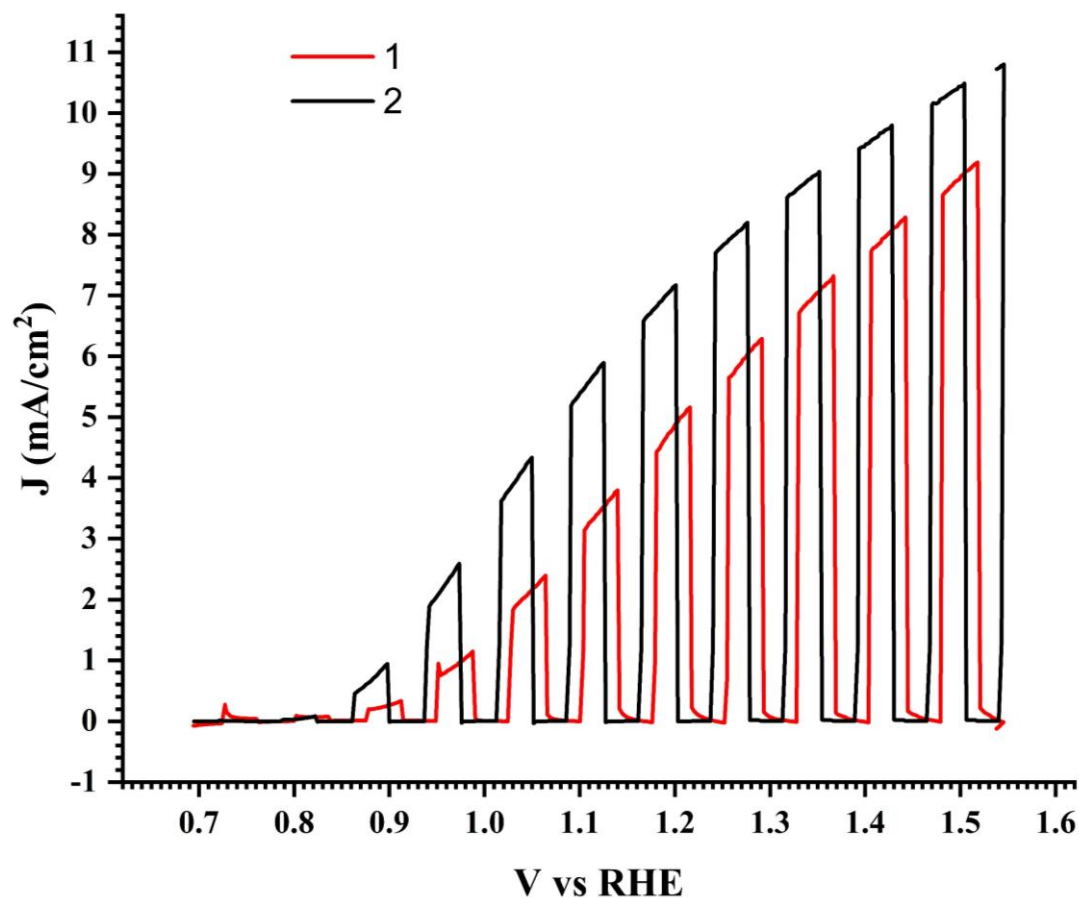


Fig. 3. Elemental mapping and EDS data recorded on the surface of Al_2O_3 -ZnO ceramics with iron oxide coating. The inset shows a photograph of the ceramics with the hematite coating.

RESULTS AND DISCUSSION (continued):

Figure 4 shows the cyclic voltammetry plots recorded for hematite photoelectrodes formed on different $\text{Al}_2\text{O}_3\text{-ZnO}$ ceramic substrates, prepared with (curve 1) and without (curve 2) the polymer. As seen from these preliminary results, a photocurrent density of approximately 7.6 mA/cm^2 at 1.23 V vs. RHE was observed for the photoelectrode formed on ceramics without polymer. In contrast, the substrate prepared with Glycix yielded a photocurrent of approximately 5.2 mA/cm^2 under the same conditions. The lower photocurrent observed in the more porous photoelectrode may be attributed to its complex 3D surface morphology, which hinders the formation of a uniform hematite coating during horizontal chemical vapor deposition, as supported by the EDS data shown in **Figure 3**.



Measurements were performed under chopped blue LED illumination (455 nm , 198 mW/cm^2 ; Thorlabs M455L2) in a 0.1 M NaOH electrolyte. SEM micrographs of the corresponding $\text{Al}_2\text{O}_3\text{-ZnO}$ substrates are presented in Figure 2(a, e) and Figure 2(c, g).

CONCLUSION

Highly conductive and porous Al_2O_3 -ZnO ceramics were successfully fabricated using the Glycix polymer as both a binder and a foaming agent and subsequently applied as host substrates for iron oxide photoelectrodes. The simplicity and versatility of this fabrication method, combined with the wide availability of Glycix components, make it a promising approach for the large-scale production of porous electroceramics.

Iron oxide photoelectrodes grown on the Al_2O_3 -ZnO ceramic substrates exhibit promising potential for photoelectrochemical applications, including solar-driven water splitting and water treatment.

ACKNOWLEDGMENTS

A.N.B. acknowledges the financial support of this study provided by CONACYT (Mexico), A1-S-20353.



Many thanks!

