

Original Research

SYNERGISTIC INTERACTION BETWEEN Sb AND RARE-EARTH OXIDES IN
SnO₂ ELECTROCATALYSTS

DOI: 10.5937/EcoTER26452S

Katarina Stojanović^{1,a*}, Marija Simić^{1,b}, Danka Aćimović^{1,c}, Branislava Savić Rosić^{1,d},
Marija Ječmenica Dučić^{1,e}, Danijela Maksin^{1,f}, Tanja Brdarić^{1,g}

¹University of Belgrade, Vinča Institute of Nuclear Sciences-National Institute of the Republic of
Serbia, Mike Petrovića Alasa 12-14, 11000 Belgrade, SERBIA

^a <https://orcid.org/0009-0003-3467-9875> ^b <https://orcid.org/0000-0001-9518-7709>

^c <https://orcid.org/0000-0001-7506-9684> ^d <https://orcid.org/0000-0002-4632-7960>

^e <https://orcid.org/0000-0002-6437-519X> ^f <https://orcid.org/0000-0003-4842-1122>

^g <https://orcid.org/0000-0003-2547-7123>

Abstract

The synergistic interaction between Sb doping and rare-earth oxide modification of SnO₂ electrodes was investigated toward the oxygen evolution reaction (OER) using linear sweep voltammetry (LSV). Sb doping significantly improved electrode performance, increasing current density and reducing the onset potential to ~1.60 V vs SHE. The addition of rare-earth oxides further modulated the activity in a composition-dependent manner. Gd₂O₃ and Eu₂O₃ exhibited a positive synergistic effect, maintaining high conductivity while enhancing surface reactivity, whereas Sm₂O₃ showed a similar contribution. In contrast, Y₂O₃ disrupted the synergy, leading to electrode deactivation. The results demonstrate that optimal OER performance arises from the balance between bulk conductivity (Sb effect) and surface catalytic properties (rare-earth effect).

Keywords: SnO₂-Sb electrode, rare-earth oxides, LSV.

INTRODUCTION

Electrochemical oxidation processes, particularly the oxygen evolution reaction (OER), play a crucial role in environmental remediation and wastewater treatment. Tin dioxide (SnO₂)-based electrodes are widely studied due to their chemical stability and high oxygen overpotential [1]. However, their relatively low electrical conductivity limits their catalytic efficiency.

Doping with antimony (Sb) is a well-established strategy to enhance electrical conductivity and improve electrochemical performance. In recent years, additional surface modification using rare-earth oxides has attracted attention due to their ability to alter surface defect chemistry, oxygen mobility, and catalytic activity [2].

* katarina.stojanovic@vin.bg.ac.rs

A key challenge is achieving a balance between electrical conductivity and surface catalytic activity. Sb doping is known to improve the bulk conductivity of SnO₂, while rare-earth oxides can modify surface properties such as defect density and oxygen mobility.

However, the synergistic interaction between Sb doping and rare-earth oxide modification of SnO₂ electrodes toward to the electrical conductivity and OER remains insufficiently understood. Therefore, this study systematically investigates the influence of Eu₂O₃, Gd₂O₃, Sm₂O₃, and Y₂O₃ on the electrochemical performance of Sb-doped SnO₂ electrodes, with particular emphasis on whether rare-earth oxide incorporation enhances or disrupts the overall electrocatalytic activity.

MATERIALS AND METHODS

SnO₂-based electrodes doped with Sb and modified with rare-earth oxides (Eu₂O₃, Gd₂O₃, Sm₂O₃, Y₂O₃) were synthesized according to procedures by Zhi [3] and Xin *et al.* [4]. Electrochemical measurements were performed using linear sweep voltammetry (LSV) in an Na₂SO₄ (0.1M, pH 4) as electrolyte.

The potential was scanned from −0.5 to 3.5 V vs Ag/AgCl at a constant scan rate (10mV/s). All potentials were converted to the standard hydrogen electrode (SHE) scale.

RESULTS AND DISCUSSION

The LSV curves (Figure 1a) clearly demonstrate that OER activity is governed by a synergistic interplay between Sb doping and rare-earth oxide modification.

The undoped SnO₂ electrode shows poor performance, confirming that both conductivity and catalytic activity are limited in the absence of modification. Introduction of Sb significantly enhances performance by improving charge transport, resulting in a lower onset potential (~1.60 V vs SHE) and a substantial increase in current density (Figure 1b).

The addition of rare-earth oxides further modulates this behavior, revealing distinct synergistic and antagonistic effects:

Gd₂O₃ and Eu₂O₃ preserve the high conductivity induced by Sb while enhancing surface catalytic properties, resulting in a positive synergistic effect. This is reflected in high current densities (~15 mA cm^{−2}) and relatively low OER onset potentials (Figure 1b, c).

Also, Sm₂O₃ exhibits a similar synergistic interaction, leading to moderate activity (~12 mA cm^{−2}), suggesting partial improvement of surface properties without fully optimizing the interface.

Y₂O₃, in contrast, disrupts the synergy between conductivity and catalytic activity. As shown in Figure 1, this sample exhibits negligible current response, indicating that Y₂O₃ likely blocks active sites or introduces an insulating effect that counteracts the benefits of Sb doping.

The overall trend (Figure 1): SnO₂–Sb > Gd₂O₃ > Eu₂O₃ ≈ Sm₂O₃ >> SnO₂ > Y₂O₃, confirms that the best performance is achieved when bulk conductivity (Sb effect) and surface reactivity (rare-earth effect) act in synergy.

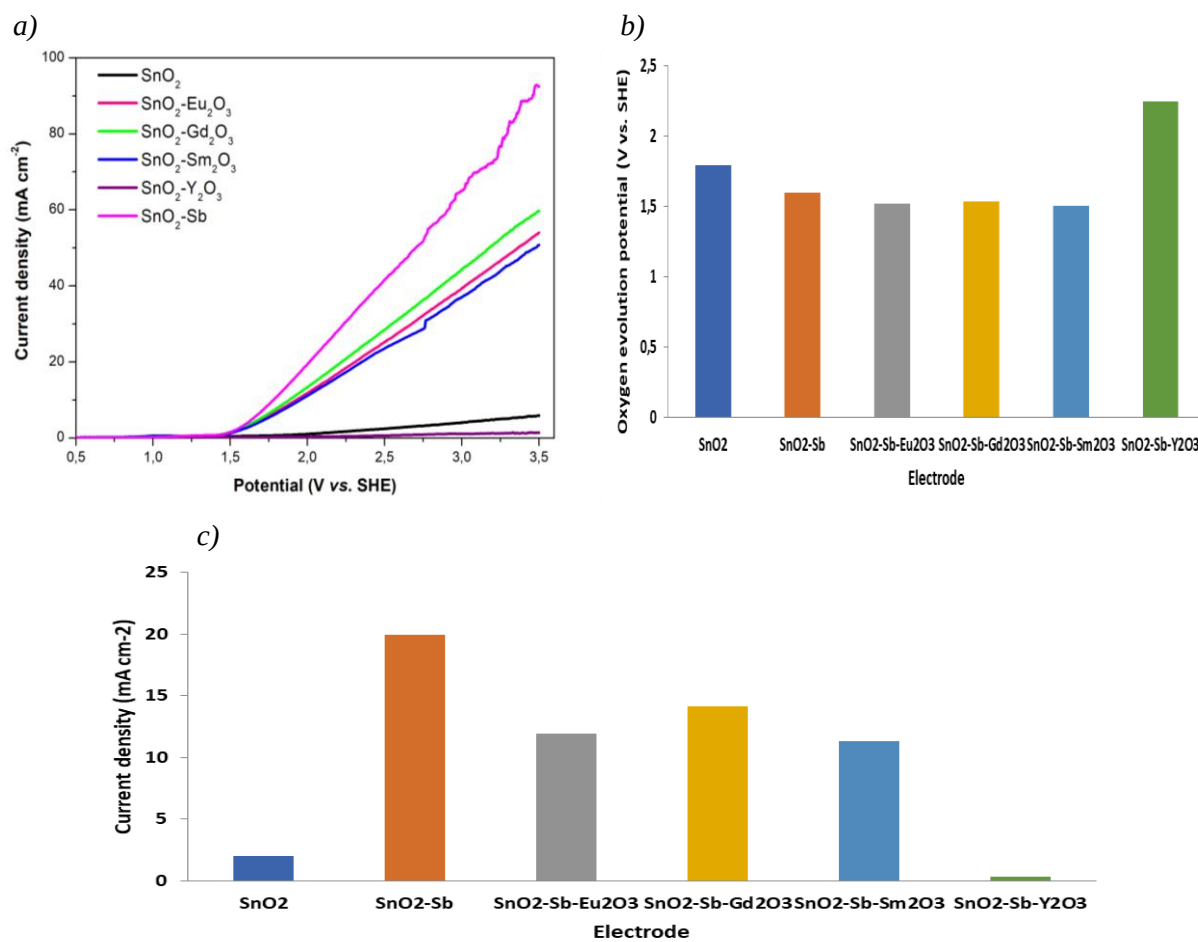


Figure 1 a) LSV curves of SnO₂-based electrodes (SnO₂, SnO₂-Sb, and rare-earth modified electrodes) recorded in Na₂SO₄ (0.1M) electrolyte pH 4; b) OER potential bar chart; and c) current (at 2.0 V) bar chart. Potentials are presented vs SHE

CONCLUSION

The results demonstrate that OER activity on SnO₂ electrodes is not determined by a single modification but by the synergy between Sb doping and rare-earth oxides. While Sb ensures efficient charge transport, rare-earth oxides tune surface catalytic properties. Gd₂O₃, Eu₂O₃ and Sm₂O₃ exhibit a beneficial synergistic effect, whereas Y₂O₃ disrupts this balance, leading to deactivation. These findings highlight the importance of simultaneously optimizing bulk and surface properties in the design of efficient electrocatalysts.

ACKNOWLEDGEMENT

The authors are grateful to the Ministry of Science, Technological Development and Innovation of the Republic of Serbia for financial support according to the contract with registration No. 451-03-33/2026-03/ 200017.

REFERENCES

- [1] Simić, M., Savić, B., Ognjanović, M., *et al.* J. Water Process Eng. 2023, 51, 103416.
- [2] Brdarić, T., Aćimović, D., Stojanović, K., *et al.* Sustainability 2024, 16, 3982.

- [3] Zhi, D., Qin, J., Zhou, H., *et al.* J. Appl. Electrochem. 2017, 47, 1313–1322.
- [4] Xin, Y., Wang, Z., Qi, Y., *et al.* J. Alloys Compd. 2010, 507, 105–111.