Enhanced visible light photoactivity of Magnesium-doped TiO_2/ERGO nanocomposite electrodes for efficient photoelectrochemical water splitting

Ekin AKYÜREK[1], Ebru TURGUT HİM[1] and Ümit DEMİR[1]
[1]Department of Chemistry, Faculty of Sciences, Gebze Technical University, Gebze/Kocaeli, Turkey 41400

Titanium dioxide (TiO_2) is a stable semiconductor photocatalyst that absorbs photons when exposed to ultraviolet (UV) light and produces electrons (e^-) and holes (h^+) that can participate in chemical reactions. TiO_2 is a vital semiconductor material in photoelectrochemical (PEC) water splitting, enabling the conversion of sunlight into clean and renewable hydrogen fuel. However, due to its high band gap energy of TiO_2 (3.2 eV), reducing the band gap energy by doping TiO_2 with narrow band gap materials has attracted great research interest in recent years. When TiO_2 interacts with light to form an e^- and a h^+, they quickly recombine instead of producing a chemical reaction or electric current, producing a photon or heat, limiting the efficiency of photocatalysts. To overcome this limitation, TiO_2 is doped with different metals and nonmetals [1]. This doping provides additional energy states in the band gap of TiO_2 that can trap electrons or holes and prevent recombination.

In this study, TiO_2 and reduced graphene oxide (ERGO) nanocomposite electrodes on fluorine doped tin oxide (FTO) transparent conductive glass were synthesized in one step by an economical and environmentally friendly electrochemical method that we improved earlier [2]. Then, these electrodes were converted into TiO_2/ERGO nanocomposite structures doped with Mg with Ti^{3+} defects and O cavities in the structure by electrochemical reduction in an electrolyte containing alkaline earth (Mg^{2+}) metal cations without using high temperature, toxic reducing agents or high pressure hydrogen. It is thought that doped Mg^{2+} ions narrow the wide band gap of TiO_2 and increase its photoactivity in the visible region, as well as improve charge transfer at the interface and decrease the recombination rate. Characterization of the obtained samples in terms of composition, structure and morphology was performed using X-ray Diffraction Spectroscopy (XRD), Scanning Electron Microscopy (SEM) (Figure 1), X-ray Photoelectron Spectroscopy (XPS) and Energy Dispersion Spectroscopy (EDS). Electrochemical analyzes were performed with cyclic voltammetry (CV), linear sweep voltammetry (LSV) and chronoamperometry. The activity and photoelectrochemical efficiency increases in the visible region of doped TiO_2/ERGO structures were determined by photocurrent density, and UV-VIS. Doped TiO_2/ERGO-FTO electrodes, which have high activity in the visible region, will be used for photoelectrochemical water splitting without applied any bias voltage (Figure 2).

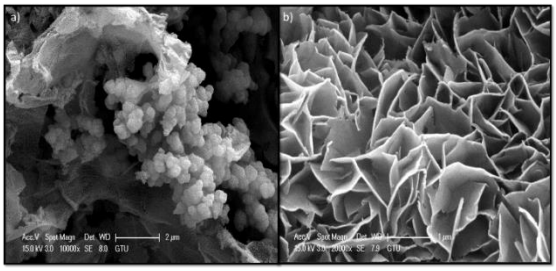


Figure 1. SEM images of TiO_2/ERGO (a) and Mg-TiO_2/ERGO (b) electrodes

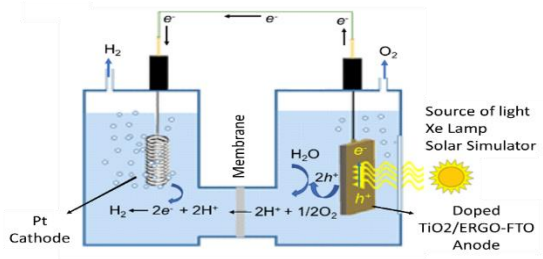


Figure 2. Mechanism for H_2 production from external potential application of TiO_2/ERGO-FTO electrodes

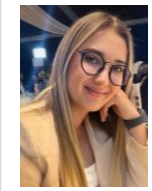
Acknowledgments

This research is supported by TUBITAK (The Scientific and Technological Research Council of Turkey) with project number 122Z028, which the authors gratefully acknowledge

References

[1] Temur, E., Eryiğit, M., Öztürk Doğan, H., Çepni, E. & Demir, Ü. Electrochemical fabrication and reductive doping of electrochemically reduced graphene oxide decorated with TiO2 electrode with highly enhanced photoresponse under visible light. Appl. Surf. Sci. 581, (2022).

[2] Doğan, H. Ö., Ekinci, D. & Demir, Ü. Atomic scale imaging and spectroscopic characterization of electrochemically reduced graphene oxide. *Surf. Sci.* 611, 54–59 (2013).



Ekin Akyürek is with Department of Chemistry, Gebze Technical University. Having graduated from Department of Metallurgical and Materials Engineering Manisa Celal Bayar University in 2021, Ekin Akyürek started her M.SC in 2022 from Gebze Technical University. Her research interest covers electrodeposition of metal oxide/graphene nanocomposite, photoelectrochemical sensors and dye sensitized solar cells.

Ekin AKYÜREK, e-mail: e.akyurek2022@gtu.edu.tr tel: 0531 964 19 98