Investigation of capacitive and photocatalytic properties of FTO-ERGO/TiO_2/Al nanocomposites for energy applications

Ebru TURGUT HİM[1], Zeynep Selin BAŞARAN YILMAZ [1] and Ümit DEMİR [1]

[1]Department of Chemistry, Faculty of Sciences, Gebze Technical University, Gebze/Kocaeli, Turkey 41400

Photocatalysts have been studied in many application areas in recent years due to their high activities, stabilities, and low toxicities. Especially, the discovery of the use of titanium dioxide (TiO_2), a semiconductor, as a photocatalyst in water splitting has attracted great interest for the effective utilization of solar energy. Titanium dioxide, due to its suitable band edge positions, high chemical stability, high optical absorption, and photocorrosion resistance, as well as its low cost, is widely used in photocatalytic material studies. However, TiO_2 has disadvantages such as rapid recombination of photo-generated charge carriers and its ability to be active in only a small part of the solar spectrum, the UV region, due to its wide bandgap. Therefore, improvements can be made by doping metal oxides like TiO_2 with metals or non-metals. It is believed that the doping ions narrow the wide bandgap of TiO_2, increasing its photoactivity in the visible region, while also improving charge transfer at the interface and reducing recombination rates. Literature shows that TiO_2 composite structures doped with graphene and reduced graphene oxide exhibit higher photoactivity compared to graphene-free structures. Additionally, it is known that doping TiO_2 with metals such as lithium, sodium, potassium, magnesium, and aluminum increases the electron transfer rate and enhances the photocatalytic effect.

TiO_2 is also widely used in supercapacitor applications. Supercapacitors are widely used in portable electronics and electrochemical energy storage as they have higher energy density, fast charge-discharge capacities, long cycle stability and higher power density than electrostatic capacitors and batteries. But, TiO_2 has high band gap energy and low electrical conductivity that limit its performance. To overcome these limitations, researchers have focused on incorporating carbon-based materials, particularly graphene, into TiO_2 nanocomposite structures. Graphene is highly abundant and possesses excellent electrical conductivity and chemical stability. It has been observed that the electrical conductivity of TiO_2 can be improved by introducing metals capable of creating donor or acceptor states within the band gap, thereby increasing the concentration of charge carriers [1]. In this study, the addition of aluminum under optimized conditions to the FTO-ERGO/TiO_2 nanocomposite structure is expected to result in a well-structured surface with enhanced charge storage capabilities.

In this study, FTO-ERGO/TiO_2 nanocomposite structures are obtained by the electrochemical reduction of graphene, which is an environmentally friendly method that does not involve toxic chemicals [2], and followed by electrochemical doping of the surface with aluminum, as seen in figure 1. TiO_2 decorated with electrochemically reduced graphene oxide forms three-dimensional, well-structured surfaces that enhance the scattering and interaction of photons on the surface. This increases the conductivity of the surface and reduces the probability of recombination.

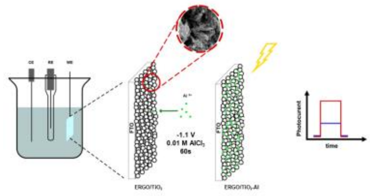

Figure 1. The schematic representation of production of FTO-ERGO/TiO_2/Al nanocomposite electrodes.

The nanocomposites were characterized in terms of their composition, morphology, and structure using Scanning Electron Microscopy (SEM), X-ray Diffraction Spectroscopy (XRD), and X-ray Photoelectron Spectroscopy (XPS). To assess their electrochemical properties, cyclic voltammetry (CV), linear sweep voltammetry (LSV), and chronoamperometry techniques were employed for electrochemical analysis. Photoelectrochemical responses under illumination were obtained without the application of an external potential, and as a result, doping parameters were determined under optimum conditions. According to the photoelectrochemical responses, the FTO-ERGO/TiO_2/Al nanocomposite structure, which exhibited the highest photoactivity, generated a current of 316 $\mu A/cm^2$ compared to the undoped structure. The optimized nanocomposite structure was utilized in the photocatalytic degradation of methylene blue. A decrease in the absorption peak intensity at the characteristic wavelength of 665 nm, which corresponds to the characteristic absorbance of the dye, was confirmed by UV Spectrometry during the photocatalytic degradation.

References

[1] Wu, L., Cao, S., Ying, Z., Huang, W., Xu, D., Zhu, X., & Song, Y. Journal of The Electrochemical Society, 166(16), A3889–A3895 (2019)

[2] E. Temur, M. Eryiğit, H. Öztürk Doğan, E. Çepni, & Ü. Demir, Applied Surface Science, 581(2021).

Res.Asst.Ebru TURGUT HİM is with the Department of Chemistry in Gebze Technical University. Having graduated from Yildiz Technical University in 2021. Started her master's degree at Gebze Technical University in 2021. Her research interest covers electrochemical synthesis, photocatalytic degredation of pollutants.

Presentating author: Ebru TURGUT HİM, e-mail: e.turgut2022@gtu.edu.tr tel:5315253306