

# COMPARATIVE STUDY OF TITANIA SUBSTRATE WETTABILITY TO PROMOTE MXENE ADHESION FOR WATER SPLITTING APPLICATION

M. Sajid<sup>1</sup>, P. Gaigalas<sup>1</sup>, O. Gogotsi<sup>2</sup>, V. Klimas<sup>1</sup>, S. Ramanavicius<sup>1</sup>

<sup>1</sup>State Research Institute Center for Physical Sciences and Technology, Department of Electrochemical Material Science, Sauletekio av. 3, LT-10257 Vilnius, Lithuania

<sup>2</sup>Materials Research Center, Krzhizhanovskogo street, 3, 03680, Kyiv, Ukraine  
[mohd.sajid@ftmc.lt](mailto:mohd.sajid@ftmc.lt)

Renewable energy is widely recognized as the foundation of a sustainable and technologically advanced future. Among various clean energy modalities, hydrogen (H<sub>2</sub>) is regarded as a promising next-generation fuel owing to its high energy density and the absence of carbon emissions upon utilization[1]. Given the abundance of water on Earth, it is considered an ideal large-scale hydrogen reservoir. Nevertheless, the realization of efficient and economically viable water splitting continues to constitute a central challenge in contemporary energy research[2], [3]. Although excellent performance in the hydrogen evolution and oxygen evolution reactions is exhibited by noble-metal-based electrocatalysts, practical implementation has been significantly constrained by their high cost. Consequently, emphasis has been placed on advanced materials and innovative engineering strategies to enable cost-effective and scalable hydrogen production. Two-dimensional (2D) materials have been identified as exceptional candidates for electrochemical water splitting, with MXenes recognized as among the most promising and rapidly expanding members of the 2D materials family[3], [4]. The development of hybrid electrodes that integrate conventional substrates with advanced nanomaterials is still regarded as challenging. The performance of electrochemical electrodes is governed by multiple interdependent factors, including structural integrity, long-term cycling stability, surface wettability to promote efficient water interaction, and robust adhesion between the catalytically active material and the underlying substrate[3], [4], [5], [6]. In this work, biocompatible and low-cost titania (TiO<sub>2</sub>) was selected as the substrate, and a facile, solution-processed methodology was demonstrated to fabricate MXene-modified Ti electrodes with enhanced interfacial adhesion. To systematically improve the wettability and adhesion of MXene on titania, four distinct surface-modification strategies were implemented - anodization, plasma treatment, HF etching, and HF-HNO<sub>3</sub> surface activation, along with a multimodal surface-engineering approach. Through these treatments, the TiO<sub>2</sub> surface chemistry and morphology were optimized to strengthen MXene anchoring. Furthermore, the resulting Ti-MXene hybrid electrodes were comprehensively evaluated for applicability in electrochemical water splitting, and it was demonstrated that engineered interfacial properties contribute to enhanced electrode performance.

**Keywords:** Surface Functionalization, MXene, Adhesion, Water Splitting

- 
- [1] M. Sheng, X. Bin, Y. Yang, Z. Chen, and W. Que, 'A Green and Fluorine-Free Fabrication of 3D Self-Supporting MXene by Combining Anodic Electrochemical In Situ Etching with Cathodic Electrophoretic Deposition for Electrocatalytic Hydrogen Evolution', *Adv. Mater. Technol.*, vol. 9, no. 3, Feb. 2024, doi: 10.1002/admt.202301694.
- [2] M. Wang et al., 'A triple increase in global river basins with water scarcity due to future pollution', *Nat. Commun.*, vol. 15, no. 1, p. 880, Feb. 2024, doi: 10.1038/s41467-024-44947-3.
- [3] E. Y. Kim, J. H. Park, and G. Y. Han, 'Design of TiO<sub>2</sub> nanotube array-based water-splitting reactor for hydrogen generation', *J. Power Sources*, vol. 184, no. 1, pp. 284-287, Sep. 2008, doi: 10.1016/j.jpowsour.2008.05.059.
- [4] S. Ramanavicius and A. Jagminas, 'Synthesis, Characterisation, and Applications of TiO and Other Black Titania Nanostructures Species (Review)', *Crystals (Basel)*, vol. 14, no. 7, p. 647, Jul. 2024, doi: 10.3390/cryst14070647.
- [5] R. V. Lakshmi, P. Bera, and C. Anandan, 'Surface treatment and its effect on the electrochemical behavior of Ti-15Mo-3Nb-3Al alloy', *RSC Adv.*, vol. 6, no. 43, pp. 36345-36355, 2016, doi: 10.1039/C6RA00934D.
- [6] T. Zhang et al., 'Activating Titanium Metal with H<sub>2</sub> Plasma for the Hydrogen Evolution Reaction', *ACS Appl. Mater. Interfaces*, vol. 13, no. 21, pp. 24682-24691, Jun. 2021, doi: 10.1021/acsami.1c02646.