

Graphene-Based Composite Membranes for Hydrogen Barrier Applications

Georgia P. Tsouvaltz¹, Rashid. K. A. Al-Rub^{3,4}, Costas Galiotis^{1,2}, Georgios N. Karanikolos^{1,2*}

¹ Department of Chemical Engineering, University of Patras, Patras, GR 26504, Greece

² Foundation for Research and Technology Hellas, Institute of Chemical Engineering and High Temperature Chemical Processes, University of Patras, Patras, GR 26504, Greece

³ Department of Mechanical Engineering, Khalifa University of Science and Technology, P.O. Box 2533, Abu Dhabi, UAE

⁴ Advanced Digital & Additive Manufacturing Group, Khalifa University of Science and Technology, P.O. Box 127788, Abu Dhabi, UAE

*karanikolos@chemeng.upatras.gr

Hydrogen is considered as an environmentally friendly and sustainable energy carrier making it a promising candidate to replace non-renewable fossil fuels such as coal, crude oil, and natural gas [1]. Despite its environmental friendliness and energy potential, hydrogen is still not used at scale as the main fuelling source owing to storage, transportation, and distribution challenges [2]. Its tendency to permeate polymers, including current commercial plastic pipes, and its high corrosivity towards metal storage tanks hinders its utilization [3,4]. To address this issue, this work focuses on developing cost-efficient and applicable materials for safe hydrogen transportation. The main material of choice is high-density polyethylene (HDPE), a material widely used in the pipelines industry for its durability, high crystallinity and low permeability [5,6]. In this work, graphene-based nanomaterials are used as fillers, as they possess high hydrogen barrier potential owing to the carbon lattice that does not allow hydrogen molecules to pass through due to its compact hexagonal structure, and their two-dimensional morphology and high aspect ratio that, upon proper dispersion, can provide a tortuous path resulting in reduced permeability and promote polymer crystallinity [7,8]. The composite membranes are created on a lab scale and are then mechanically tested to verify the inclusion of the graphene does not compromise the integrity of the polymer and to show its reinforcing effect. Additionally, the composite membranes are analysed thermally and mechanically to estimate the material's crystallinity and evaluate graphene's contribution to the composite thermal and mechanical stability.

References

- [1] Varghese, A. M., Reddy, K. S. K. & Karanikolos, G. N., *Ind Eng Chem Res* 61 (2022), 6200–6213.
- [2] Kapsi, M., Veziri, C. M., Pilatos, G., Karanikolos, G. N. & Romanos, G. E., *Int J Hydrogen Energy* 47 (2022) 36850–36872.
- [3] Yuan, S. et al., *Int J Hydrogen Energy* 91 (2024) 555–573.
- [4] Ahmad, S. et al., *J Energy Storage* 101 (2024) 113733.
- [5] Fujiwara, H. et al., *Int J Hydrogen Energy* 46 (2021) 11832–11848.
- [6] Khalid, H. U., Che Ismail, M., Nosbi, N. & Ab Aziz, M. Y. H. Bin, 2020 Second International Sustainability and Resilience Conference: Technology and Innovation in Building Designs (51154) (2020). 1–5.
- [7] Alkrunz, M. et al., *Int J Hydrogen Energy* 85 (2024) 794–803.
- [8] Liu, M. et al., *Compos Sci Technol* 249 (2024) 110483.

Figures

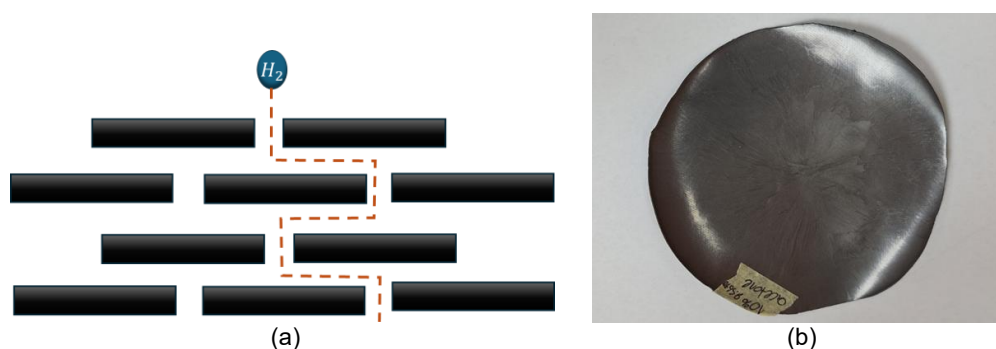


Figure 1: a) Hydrogen's tortuous path inside the composite membrane due to the existence on high aspect ratio Nanofillers, b) Prepared graphene-doped HDPE membrane