Development of graphene-based membranes for environmental and energy applications: design rules and framework for sustainable development

Carmen Rial, Elena Pagalday, Hugo Salazar, Senentxu Lanceros-Mendez
BCMaterials, Basque Center for Materials, Applications, and Nanostructures
carmen.rial@bcmaterials.net

Multifunctional hybrid materials are a key driving force for the development of a wide variety of applications. In particular, active and multifunctional materials are being increasingly implemented in water remediation and energy generation and storage systems. Those apparently unrelated application areas often rely on advanced membrane technology for the degradation, separation and/or removal of contaminants, in the former case, and for the development of catalytic platforms and storage membranes, in the latter. The successful development of the specific applications relies both in the ability tailor the functional response of the membrane, though the proper selection of matrix and active fillers, as well as on the fabrication technologies for obtaining a suitable membrane microstuctructure.

Hybrid membranes based on a polymer matrix with embedded graphene or graphene related materials, processable from solution and/or by additive manufacturing technologies, is an area of increasing interest due to improved sustainability, tailorability of materials properties and simple integration into functional applications.

Graphene related materials (GRM) are particularly interesting as functional fillers in membrane technology based on their extraordinary surface area, nanosized pores, and mechanical and chemical stability, as well as by the tailorability of its functional properties. Therefore, extensive research is being conducted to identify novel methods and design strategies. However, several problems are related to lab scale and industrial scale, or the long-term stability of graphene-based membranes in different systems. Moreover, other important aspect are the selection of the GRM type and their production method [1], which will determine the effectiveness of the membrane. In the context of circular economy, the aspect of sustainability production of GRM have gained considerable attention. Large scale of high quality GRM using eco-friendly methods is a critical step towards more sustainability production. However, the production of GRM requires substantial amounts of energy, which usually is from fossil fuels, and chemical solvents that can generate greenhouse gas emissions and environmental pollution [2]. In this regard, for practical applications all these considerations should be improved.

Motivated by all the above, the objective of this study in the GIANCE project was to develop hybrid membranes based on graphene and graphene related materials for environmental remediation, water desalination and hydrogen generation and storage. The main strategies and membranes designs, relevant results and challenges in the development of those membranes will be presented. The common ground for the different application areas in terms of membrane development will be highlighted as well as the specificities leading to successful applications.

Further, as the scalability of the production of graphene still possess some difficulties in terms of sustainability, a comprehensive study of the production process of different GRM types will be provided, as a guide for a more sustainable GRM production.

References

[1] VS Nanjundappa et al., Applied Surface Science Advances, 14 (2023)100386
[2] D. Beloin-Saint-Pierre, One Earth, 5 (2022) 1324