3D Printing Nanoporous Nanocomposite Membranes

Hari Kalathil Balakrishnan, Laura Carvalho, Robel Tekle, Hassan Arafat, Ludovic F. Dumée
Khalifa University, Research & Innovation Center for Graphene and 2D Materials (RIC-2D), Abu Dhabi, United Arab Emirates
harikrishnan.balakrishnan@ku.ac.ae

The incorporation of nanoporosity into 3D-printed materials presents a promising opportunity to overcome the limitations of traditional fabrication methods in membrane technology [1]. However, current advancements in 3D printing face challenges in directly producing scalable macro materials with the necessary nanoporosity. To address this, we propose a novel strategy that combines ultraviolet (UV)-based 3D printing with polymer monolith chemistry [2] [3]. This enables the fabrication of membrane and separation materials with customizable geometries, controlled porosities, and integrated modular features. This approach not only streamlines the fabrication process but also allows for the integration of two-dimensional (2D) materials as well as nanosheets paving the way for the development of functional membranes with photocatalytic and electrocatalytic properties. Titanium dioxide (TiO_2) was chosen for its non-toxic properties in the development of membranes with superior photoactive/photocatalytic properties, increased permeability, and reduced fouling tendencies. [4] . Simultaneously, graphene nanosheets with higher mechanical properties, enhanced ionic and proton conductivity, and electrocatalytic properties, along with antifouling properties, were used to develop electrocatalytic membranes [5]. The current strategy facilitates the development of catalytic membranes with pore features ranging from ~ 10 nm to several hundred nm. Conventional phase inversion techniques are limited in terms of the maximum 2D material loading (~ 5-10 wt%) due to rheological, mechanical, and uniform distribution challenges caused by agglomeration [6]. In contrast, the proposed technique and the wide range resin chemistries enable much higher nanosheet and nanomaterials loading, up to 30 wt% and higher, with enhanced dispersion and uniform distribution through layer-by-layer control. Furthermore, the process allows for the creation of highly customized membranes with precise deposition of 2D materials in a highly automated and reproducible manner.

References

[1] H. K. Balakrishnan, E. H. Doeven, A. Merenda, L. F. Dumée, R. M. Guijt, *Anal. Chim. Acta* **2021**, 1185, 338796.
[2] H. K. Balakrishnan, L. F. Dumée, A. Merenda, C. Aubry, D. Yuan, E. H. Doeven, R. M. Guijt, *Small Structures* **2023**, 4, 2200314.
[3] H. Kalathil Balakrishnan, S. M. Lee, L. F. Dumée, E. H. Doeven, R. Alexander, D. Yuan, R. M. Guijt, *Nanoscale* **2023**, 15, 10371.
[4] S. Riaz, S. J. Park, *Journal of Industrial and Engineering Chemistry* **2020**, 84, 23.
[5] M. Pedrosa, J. L. Figueiredo, A. M. T. Silva, *Journal of Environmental Chemical Engineering* **2021**, 9, 104930.
[6] M. Khraisheh, S. Elhenawy, F. AlMomani, M. Al-Ghouti, M. K. Hassan, B. H. Hameed, *Membranes (Basel)* **2021**, 11.

Figure 1: 3D-printed graphene-based membranes with various sizes. SEM image confirms the porous nature of the 3D-printed membrane.