Synthesis and nanomechanical assessment of ultrathin carbon nanomembranes targeted for permeation applications

Marinos Dimitropoulos[1, 2], George Trakakis[2], Nikolaus Meyerbröker[3], Christos Pavlou[1, 2], Raphael Gehra[3], Polina Angelova[3], Albert Schnieders[3], Christos Kostaras[1, 2], Costas Galiotis[1, 2] and Konstantinos Dassios[1, 2, *]

[1] Department of Chemical Engineering, University of Patras, Patras, Greece

[2] Institute of Chemical Engineering Sciences, Foundation for Research and Technology Hellas, Patras, Greece

[3] CNM Technologies GmbH, Morgenbreede 1, 33615 Bielefeld, Germany

*kdassios@upatras.gr

Carbon nanomembranes (CNMs) are a type of two-dimensional material created by using low-energy electron irradiation to cross-link self-assembled monolayers (SAMs) of aromatic precursor molecules [1]. The thickness and porosity of CNMs can be adjusted according on the precursor molecules and the preparation circumstances, from which they also inherit their terminal functionality [2]. This tunability renders them the ideal candidates for permeation applications such as water separation. Pressure-driven membrane processes rely a great deal on the mechanical integrity of the material, as these carry the mechanical loads generated by the flow of liquids. The membranes may be subjected to substantial physical compression at high working pressures, which can diminish or even destroy their performance [3]. In order to guarantee the structural stability of the membrane during operation, the goal of this work was to investigate and analyze the mechanical properties of CNMs and their substrates. Unlike macro-materials, measuring the mechanical characteristics of nanometer-thick membranes is a daunting task. For that reason, Atomic force microscopy (AFM) was used to measure the membranes' inherent mechanical properties as they were suspended over patterned substrates but also supported on atomically flat substrates. CNMs were tested with Quantitative nanomechanical mapping, nanoindentation and fatigue experiments which highlighted the ability of the membranes to withstand flow related mechanical loads.

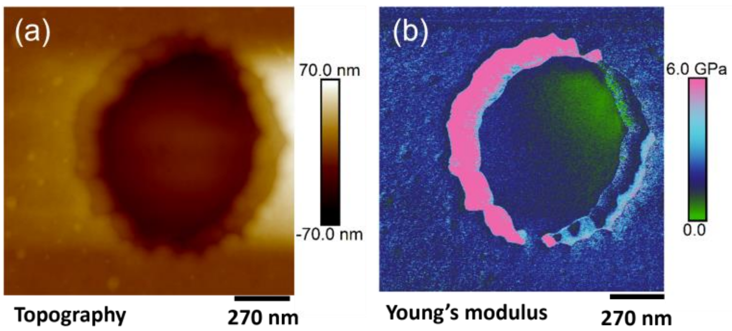

Figure: (a) Topography and (b) Young's modulus mapping of a suspended CNM.

[1]. Turchanin, A. and A. Golzhauser, *Carbon nanomembranes from self-assembled monolayers: Functional surfaces without bulk.* Progress in Surface Science, 2012. **87**(5-8): p. 108-162.

[2]. Angelova, P., et al., *A Universal Scheme to Convert Aromatic Molecular Monolayers into Functional Carbon Nanomembranes.* Acs Nano, 2013. **7**(8): p. 6489-6497.

[3]. Dimitropoulos, M., et al., *Nanomechanics of Ultrathin Carbon Nanomembranes.* Nanomaterials, 2023. **13**(2).