

**Carbon Capture, Utilisation and Storage:
Opportunities, challenges and pathways to Net Zero**

Thematic workshop - 17th September 2026 - Faculty of Civil and Industrial Engineering,
Sapienza University of Rome

Gas Separation membranes for CCS applications

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Carbon capture and storage and utilization (CCUS) is considered as essential, to reduce the impact of industrial processes on global warming [1]. To that aim however the development of highly efficient and scalable CO₂ separation technologies is requested [2]. Among the alternative approaches, membrane-based gas separation technologies are attracting increasing attention due to their operational simplicity, modular design, compact footprint, and potential for lower energy consumption compared with conventional separation processes [3,4]. However, conventional polymeric membranes are typically limited by the well-known permeability–selectivity trade-off described by Robeson [5]. To overcome this limitation different approaches are possible and, at UNIBO, two alternative solutions have been particularly studied referring the use of facilitated transport and Layer by Layer (LbL) deposited membranes. [6,7]

Molecular sieving LbL membranes have been obtained alternating nanometric layers of positive charged poly diallyl dimethyl ammonium chloride (PDAA) and negative charged graphene oxide (GO) sheets, [8] obtaining permeance in the order of 20 GPU and H₂ selectivities to CO₂ and CH₄ in the order of 30 and 1000 respectively. Surprisingly, excellent selectivity for hydrogen was observed even after one single deposition cycle, with a LbL membrane c.a. 4 nm thick showing as well the highest permeances. Such unexpected combination of selectivity/permeance was attributed to the formation of a peculiar interpenetrated structure with GO sheets spaced approximately 1.1 nm apart and intercalated by polymer chains, which self-assemble forming intercalated selective layers even after a single deposition cycle. Facilitated transport membranes on the other hand have been studied by considering use of Nanocellulose as a support for the addition of different types of carriers; namely L-Arginine and 1-ethyl-3-methylimidazolium acetate ([EMIM][Ac]) ionic liquid [9,10]. Nanocellulose of endowed with different surface charges were considered to understand the most efficient support for the promotion of facilitated transport.

In general, high surface charge carboxymethylated nanocellulose (CMC-NFC) ensured optimal permeation results which also significantly improved with increasing of carrier content. CMC-NFC membranes with 50 wt% IL loading, showed CO₂ permeability at 75°C higher than 180 Barrer at 85% RH, CO₂/N₂ selectivity in the order of 70. Same nanocellulose added with 40% L-Arginine, on the other hand, showed CO₂ permeability of about 200 Barrer and CO₂/N₂ selectivity higher than 200 when tested at 50°C and 90%RH.

Both size selective and facilitated transport membranes showed permselectivities close or above the Robeson's upper bound thus confirming their high potential for CO₂ capture applications.

Keywords: *Carbon Capture, facilitated transport, Layer by Layer deposition.*

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