CARBON NANOMEMBRANES: 2D MATERIALS FOR NANOFLUIDIC SEPARATION TECHNOLOGY

Armin Gölzhäuser

Physics of Supramolecular Systems and Surfaces, Bielefeld University, 33615 Bielefeld, Germany
E-mail: ag@uni-bielefeld.de

Clean water is a global challenge, and membrane filtration is a key technology to achieve it. There are growing research efforts to explore the use of 2D carbon materials as nanoconduits for molecular transport and separation. Radiation induced chemistry plays a prominent role in these activities as the electron induced modification of molecular surfaces layers is an important step in the fabrication of nanomembranes. Here, we report on the fabrication and application of carbon nanomembranes (CNMs) [1]. CNMs are two-dimensional membranes (thickness ~1 nm) made by electron-induced cross-linking of aromatic self-assembled monolayers (SAMs). CNMs made from terphenylthiol (TPT) possess sub-nm pores of a density of ~10^{18} m^{-2}, which corresponds to *one sub-nm channel per square nanometer* [2]. TPT CNMs let water molecules rapidly pass through, while they efficiently hinder the translocation of ions. TPT CNMs have been utilized as forward osmosis membranes. Their membrane resistance reaches ~10^4 $\Omega \cdot cm^2$ in 1 M Cl^- solutions, comparable to lipid bilayers [3]. To investigate molecular transport through the tortuous sub-nm pores of CNMs, we studied the permeation of gases and vapors of different sizes (D_2O, He, N_2, O_2, CO_2, $CHCl_3$, C_7H_8 und C_6H_{14}), as well as of binary mixtures of water with the above molecules. In all mixtures the water permeation was much higher than the permeation of the other molecules, resulting in a high selectivity of the CNM. To explain this behavior, models of adsorption-controlled permeation (ACP), and water-assisted permeation are introduced. These describe the kinetics of the permeation process, starting from a molecule that is adsorbing on the membrane surface, diffusing over the surface until it encounters a pore and that is then translocating through the sub-nm pore [4]. We also found an Anti-Arrhenius behavior during the passage of gaseous molecules through CNMs [5]

[1] A. Turchanin and A. Gölzhäuser: Carbon Nanomembranes, *Adv. Mater*. **2016,** 28, 6075.
[2] Y. Yang, P. Dementyev, N. Biere, D. Emmrich, P. Stohmann, R. Korzetz, X. Zhang, A. Beyer, S. Koch, D. Anselmetti, A. Gölzhäuser, *ACS Nano* **2018**, *12*, 4695.
[3] Y. Yang, R. Hillmann, Y. Qi, R. Korzetz, N. Biere, D. Emmrich, M. Westphal, B. Büker, A. Hütten, A. Beyer, D. Anselmetti, A. Gölzhäuser, *Adv. Mater.* **2020,** 1907850.
[4] P. Dementyev, T. Wilke, D. Naberezhnyi, D. Emmrich, A. Gölzhäuser, *Phys. Chem. Chem. Phys.* **2019**, 21, 1547
[5] P. Dementyev, A. Gölzhäuser, *Physical Chemistry Chemical Physics* **2024**, 26, 6949.