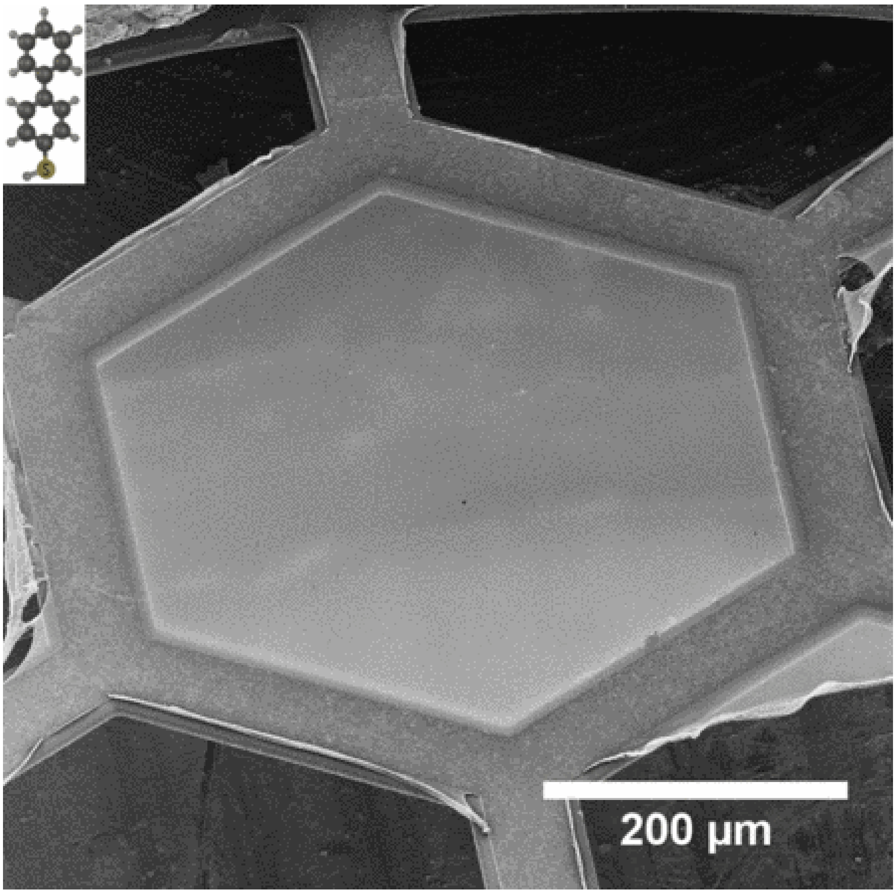
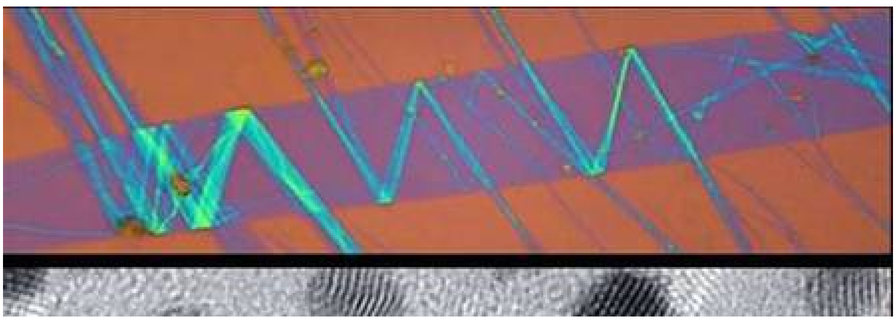
Carbon Nano Membranes (CNMs)

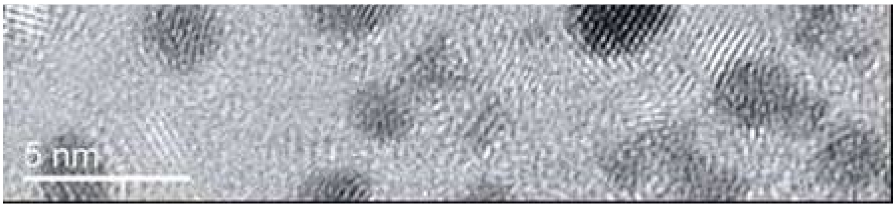


Helium Ion Micrograph of a CNM on copper grid.

Carbon Nano Membranes (CNMs) are similar to plastic foils, but only ~1 nanometer thick. CNMs are made by radiation induced cross-linking of surface bound organic molecules. CNMs can be chemically and biologically functionalized as well as transformed into graphene, thus providing a 2D-platform for applications.

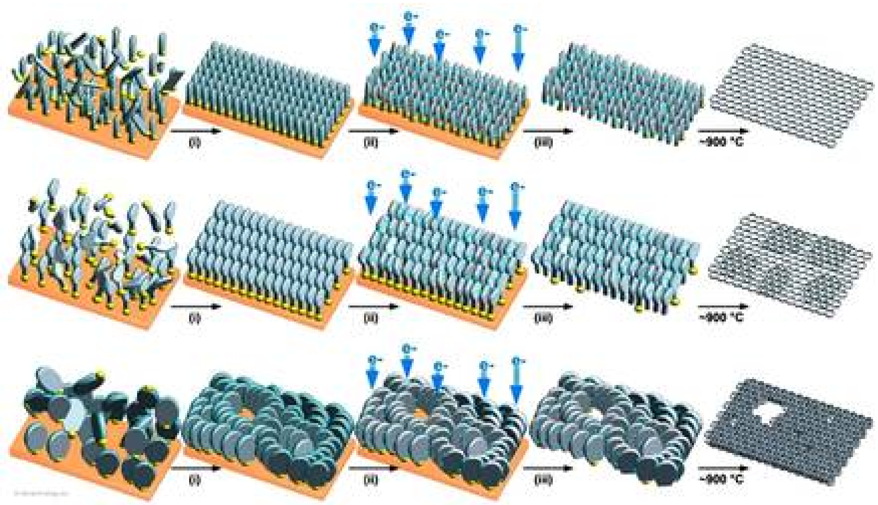
From Monolayers to Nanomembranes
The starting point of CNM fabrication is a self-assembled monolayer (SAM) of aromatic molecules which are linked to a surface via a functional group. When the so-assembled molecules are exposed to radiation, one obtains a ~1 nm thick mechanically stable film of cross-linked carbon. The Gölzhäuser group is working with partners in Europe, the US and Japan on the characterization of these materials for electrical, optical and mechanical purposes, and towards applications of CNMs into new products.





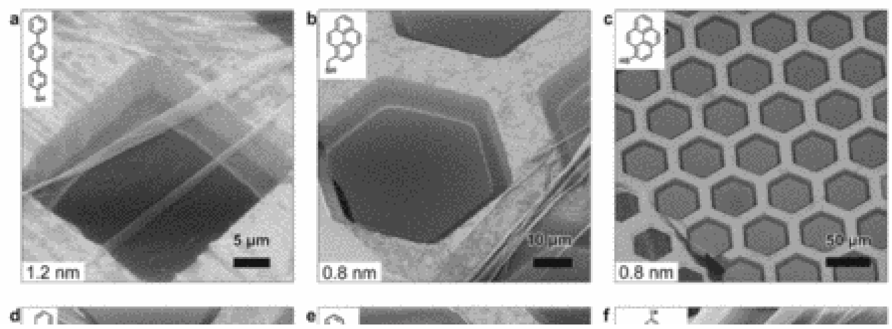
CNM onto oxidized silicon, due to the interference contrast, the CNM is visible with the naked eye. It can be seen folding their colors. Bottom: Transmission electron micrograph of a CNM decorated with small gold particles.

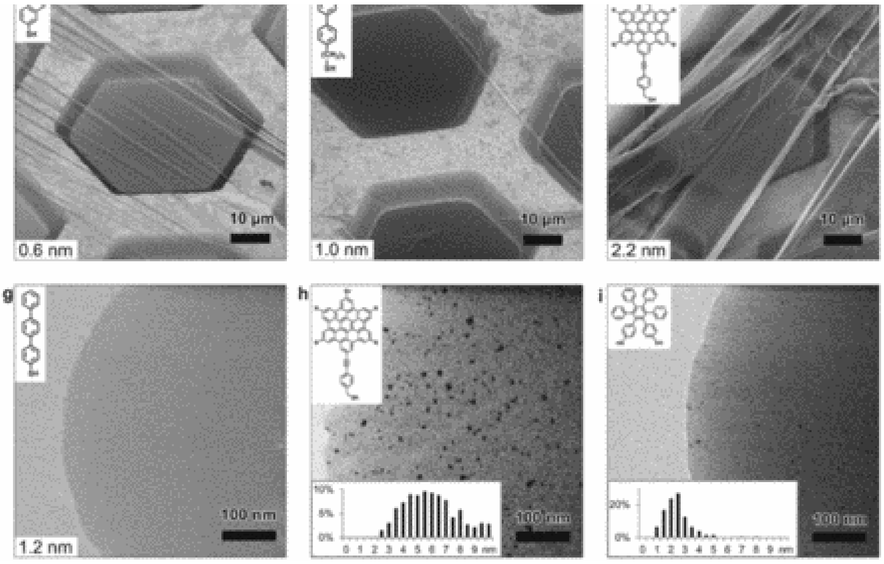
CNM forms in three steps. Lead compounds are bi- or terphenyls, which adsorb on a surface via a functional group. The SAMs are bombarded with electrons or extreme ultraviolet photons. This breaks intramolecular bonds and adjacent molecules form cross-links. A special method -developed in Bielefeld- allows CNMs to be transferred from one surface onto another, including materials and objects on which otherwise no SAMs form, such as grids for transmission electron microscopy. The transfer technique also allows the integration of CNMs into silicon chips or micro-structured surfaces.



CNMs from different precurser molecules.

CNMs have significant potential for technological applications. CNM based products include support membranes for electron microscopy of nanometer scale objects, where the support structure is often thicker than the actual nano-object, which results in a poor image quality. The CNMs, however, are thinner than most nano-objects, which improves the image contrast significantly. In addition to the thickness, the chemical functionalities of the two sides of the CNM can be tailored by the choice of suitable molecules. By selecting the irradiation parameters, the degree of cross-linking and thus the elasticity of the CNM can be tuned. In summary, CNMs are a new class of materials with interesting properties that lead to innovative products in many fields.

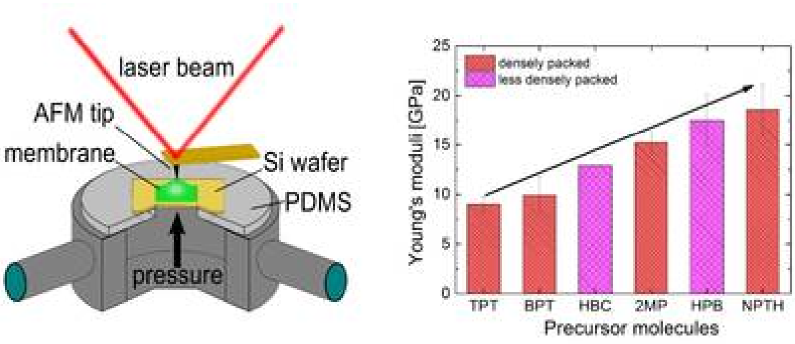




Tailoring the thickness of carbon nanomembranes by molecular design.

Mechanics of CNMs

To study the elastic and viscoelastic behaviors of freestanding CNMs, we developed a method -AFM bulge test- that uses an atomic force microscope to measure the displacement of a membrane bulging due to a pressure difference. Depending on the type of precursor molecules, Young's modulus of CNMs can be tailored within the range of 10 to 20 GPa, which is about 50- to 100-fold smaller than that of graphene monolayer (~1 TPa), but slightly higher than the upper bound of polymeric membranes. A correlation between the rigidity of the precursor molecules and the macroscopic mechanical stiffness of CNMs is thus revealed. Our setup is capable of determining a strain rate as low as $10^{-8}s^{-1}$, and the creep rates of CNMs are in a range of 10^{-6} s^{-1} at RT. The Creep behavior of CNMs appears to be stress-dependent and thermally activated, which can partially recover in the absence of an external load.



Schematics of AFM bulge test and Young' s moduli of CNMs prepared from different precursor molecules.