

A molecular route to 1 nm thick carbon nanomembranes (CNMs) and graphene for functional applications

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Our group focuses its activities on the large-scale fabrication and applications of novel 2D carbon materials (graphene, carbon nanomembranes (CNMs) and their hybrid systems). We have developed an original and effective approach to fabricate CNMs and graphene from organic self-assembled monolayers (SAMs). This approach is based on the electron-radiation induced crosslinking of aromatic SAMs and their subsequent annealing. In this process, the SAM is converted into a graphene sheet with well-defined thickness and arbitrary dimensions. Sizes of the sheets are defined by the electron exposure that can be flexibly adjusted from a few nanometres to the macroscopic dimensions. Electric transport data and spectroscopy demonstrate that the conversion into graphene can gradually be adjusted via annealing temperature and it is accompanied by an insulator to metal transition. Thus by simple changing the annealing temperature such properties like electrical conductivity, electron mobility, ambipolar electric field effect as well as optical characteristics can be tuned. By the transfer procedure developed in our group, the fabricated CNM and graphene sheets can flexibly be placed onto arbitrary substrates, e.g., holey substrates where they form suspended membranes with extremely large lateral dimensions. The choice of molecular precursors can be used to tune the properties of CNMs and graphene, and to facilitate their direct preparation on semiconductor and insulator substrates. We are working on implementations of CNMs and graphene in field effect transistors, biosensors, transparent conductive coatings, nano-electro-mechanical systems (NEMS), separation technologies and high resolution electron microscopy (HRTEM).

References

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Figures

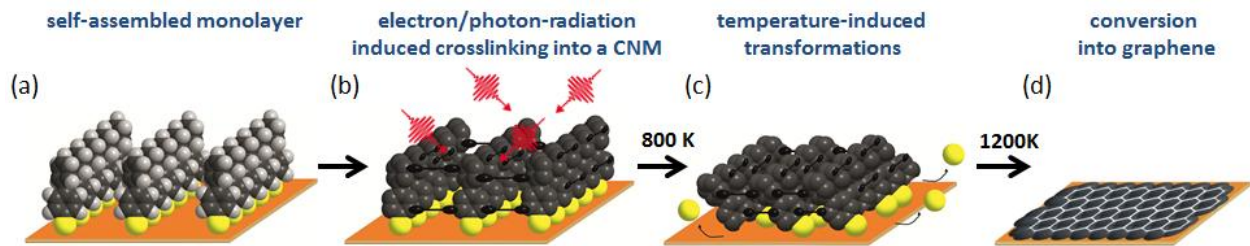


Fig. 1 Schematic representation of the fabrication of carbon nanomembranes (CNM) and graphene from self-assembled monolayers (SAM). (a) An aromatic SAM (here biphenylthiol) is formed on the target surface. (c) The SAM is cross-linked via electron/photon irradiation to form a 1 nm thick CNM. (c-d) Annealing at high temperatures converts the CNM into graphene [1, 7, 8-9].

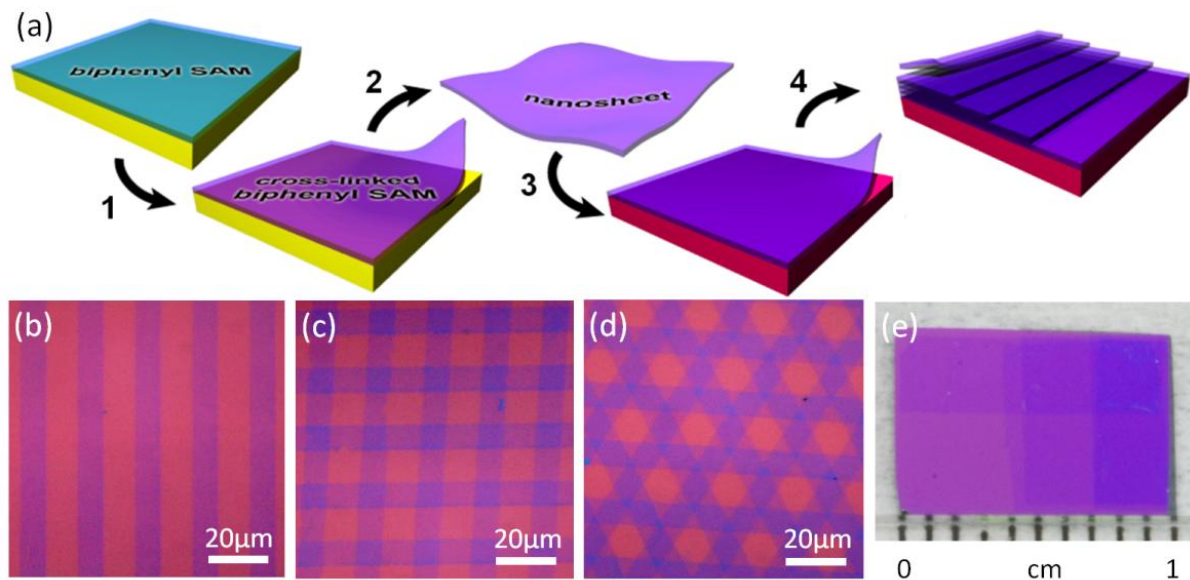


Fig. 2. Engineering and lithography of individual CNMs, graphene sheets and their hybrid stacks. (a) Scheme of the fabrication of monolayer and multilayer structures from ~ 1 nm thick CNMs. (1)-(2) Formation and e-beam crosslinking of a SAM; (3) transfer to an arbitrary surface; (4) assembly of multilayers by repeating this process. (b)-(d) Line patterns fabricated on SiO_2/Si substrates by transfer, photolithography and plasma etching. Carbonic nanolayers are bluishshifted with respect to the substrate. (e) Stacks of 1 to 5 layers on a SiO_2/Si substrate [2, 4, 6-7].

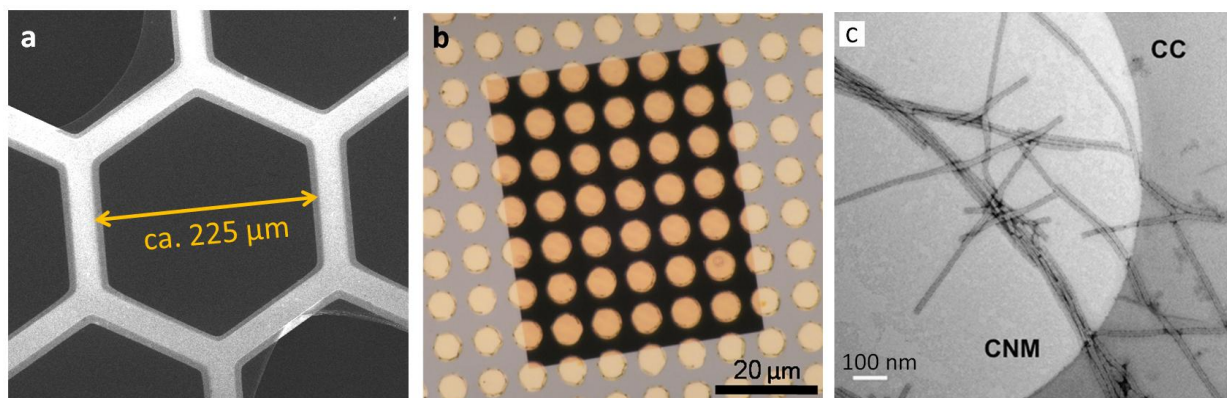


Fig. 3. Free-standing 1 nm thick CNMs. (a) A scanning electron microscope image of a CNM suspended on a metal grid. (b) An optical microscope image of a pattern of 30 nm thick Au dots on a suspended CNM. Such nanomembranes are of high potential for applications in NEMS and HRTEM. (c) Energy filtered TEM of tobacco mosaic virus (TMV) on a CNM; zero-loss image. Due to extreme thinness of the CNM, the biological imaging is possible [3, 8].