Molecular engineering of graphene, carbon nanomembranes and their heterostructures for nanotechnology applications

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Abstract
Bottom-up approaches via molecular self-assembly have high potential to facilitate the use of carbon-based free-standing two-dimensional (2D) in nanotechnology. In this talk it will be demonstrated how self-assembled monolayers (SAMs) of aromatic molecules can be employed to this end. By electron or photon irradiation these organic monolayers are converted into dielectric carbon nanomembranes (CNMs) with a thickness of one molecule. CNMs possess their structural integrity and similar to graphene or BN sheets can be separated from their original substrates and transferred onto various other substrates, fabricated as suspended sheets or stacked into multilayer films with precise control over their thickness and atomically sharp boundaries. By annealing CNMs in vacuum or at atmospheric pressure they are converted into graphene. This approach makes possible both scalable production of high-electronic-quality graphene and CNMs as well as direct writing of their nanostructures on various technologically relevant substrates. Layer-by-layer assembly of the CNM/graphene heterostructures opens many doors to the engineering of novel materials for optics, electronics, biofunctional coatings and nanosensors. Physical and chemical properties of these materials, obtained by state-of-the-art spectroscopy, microscopy, electric and magneto-transport measurements, their nanopatterning and functional applications will be presented. Implementation of CNM/graphene heterostructures in novel field-effect devices aiming to improve electronic performance of the integrated graphene sheets (electric-field gating, environmental stability, mobility of the charge carriers) will be shown.

References

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Figures

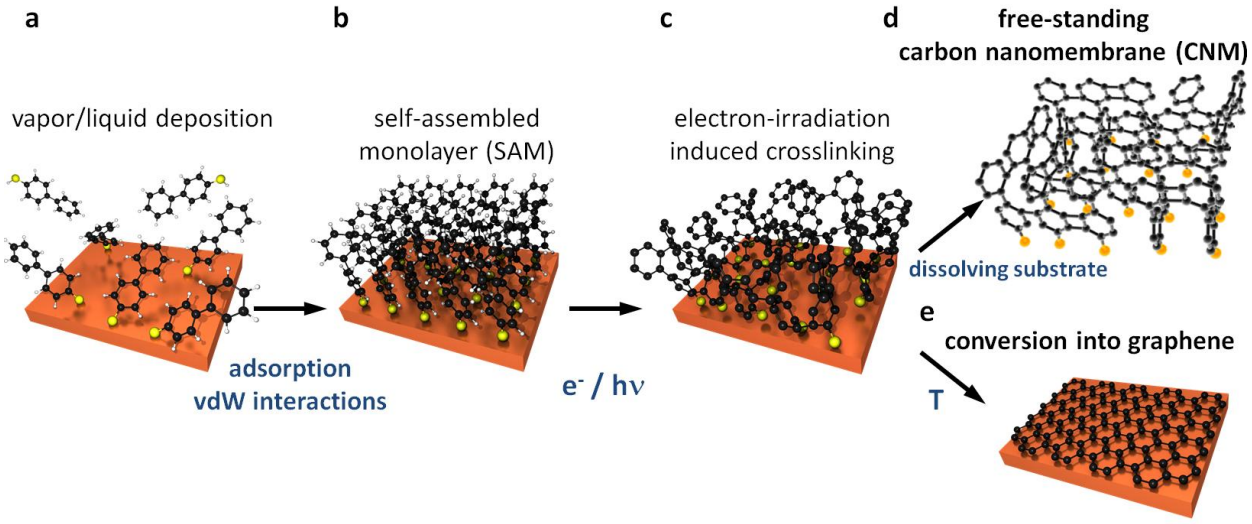

Fig. 1 Schematic of the fabrication route to carbon nanomembranes (CNMs) and graphene from aromatic self-assembled monolayers (SAMs): **a**, Deposition of molecules on a substrate; here, vapor deposition of biphenyl-thiols (BPT). **b**, Formation of a SAM. **c**, Electron/photon-irradiation-induced crosslinking of the BPT SAM into a carbon nanomembrane (CNM). **d**, Formation of a free-standing CNM by dissolving the substrate. **e**, Conversion of a CNM into graphene by annealing [1-4, 8].

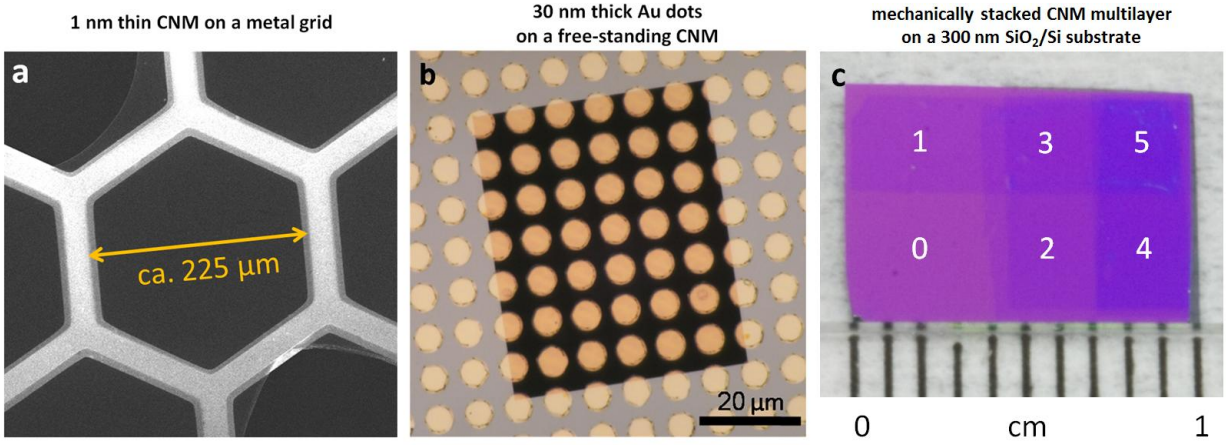

Fig. 2 Free-standing CNMs and CNM stacks. a, SEM image of the 1 nm thin free-standing BPT-based CNM on a metal grid. **b**, Optical image of the free-standing CNM with an evaporated metal pattern. **c**, Optical image of the mechanically stacked CNMs on a SiO_2/Si wafer (1 to 5 layers) [3, 5, 7-8]

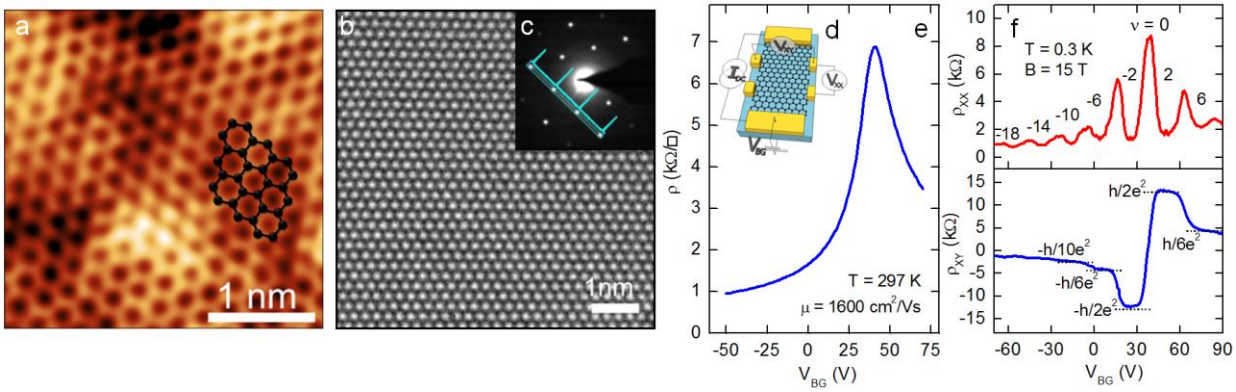

Fig. 3 Single-layer graphene (SLG) formed by conversion of biphenyl-thiol SAMs on Cu. a, HR STM image on Cu(111). **b**, HRTEM image and diffraction pattern (**c**) of a free-standing SLG produced from the BPT SAM on a Cu foil and (**d-f**) its electric and electro-magnetic transport properties [1].