Fabrication of laterally structured graphene/carbon nanomembrane hybrids — Andreas Winter1, Stefan Wundrack2, Rainer Stosch2, and Andrej Turchanin1

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Laterally structured free-standing micro- and nanostructures of single-layer graphene (SLG) embedded into dielectric sheets with a thickness comparable to graphene are of great interest for applications in electronic or optoelectronic devices. However, their fabrication is not a trivial task at present. Here, we demonstrate how such hybrids can be engineered using electron-irradiation-induced crosslinking of graphene micro-/nanostructures with carbon nanomembranes (CNMs). CNMs are a dielectric 2D carbon material with the thickness of about 1 nm consisting of cross-linked randomly oriented benzene rings. We show scalable production of well-defined laterally patterned CNM-SLG hybrids of various architectures and characterize their structural, chemical and electronic quality by complementary spectroscopic and microscopic techniques including helium ion microscopy and Raman spectroscopy. Application areas of the generated hybrids will be discussed.

Non-destructive chemical functionalization of single-layer graphene for electronic applications — Mirosław Woszczyński1, Miriam Grotthe1, Andreas Winter2, Annika Willunat3, Stefan Wundrack2, Rainer Stosch2, Franz Ahlers, Thomas Weimann4, and Andrej Turchanin1

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Chemical functionalization of single-layer graphene (SLG) is of key importance for implementations of functional electronic or optoelectronic devices such as, e.g., field effect transistor (FET) based nanosensors. However, the electronic quality of graphene typically degrades after the functionalization with presently employed methods, significantly restricting the application areas. Here, we present a route to non-destructive chemical functionalization of graphene via engineering of carbon nanomembrane (CNM)/SLG hybrids. We employ SLG, grown by methane CVD on Cu foils, and amino-terminated 1 nm thick CNMs, to fabricate hybrid CNM/SLG FETs on oxidized silicon wafers. Structural, chemical and electronic properties of these devices are characterized by Raman spectroscopy, X-ray photoelectron spectroscopy and electrical transport measurements. We unambiguously show that the chemically high electronic quality of pristine SLG is preserved in the amino-functionalized hybrids opening broad avenues for their use in graphene-based FETs.

Etching Nanoscale tunnels into graphite—a new route to produce suspended graphene — Maya Lukas1, Velimir Meded2, Aravind Vajayaraghavan1, Li Song3,4, Pulickel M. Ajayan3, Karin Fink3, Wolfgang Wenzel4, and Ralph Krupke1,5

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Catalytic hydrogenation of graphite, although known since the 1970s, has recently attracted renewed attention, as a route for nanopatterning of graphene and to produce graphene nano-ribbons. These reports show that metallic nanoparticles etch surface layers of graphene or graphene anisotropically along the crystallographic zigzag <11-20> or armchair <110> directions.

We report the sub-surface etching of highly oriented pyrolytic graphite (HOPG) by Ni nanoparticles, to form a network of tunnels, as seen by SEM and STM. The layers on top of tunnels which are only a few layers below the surface bend inward, while their local density of states remains fundamentally unchanged. Our work opens a new route to produce suspended graphene for the study of fundamental mechanical and electronic properties. M. Lukas, V. Meded et al., Nat. Commun. accepted for publication.
thanks to a low diffusion barrier of fullerenes on graphene. Nevertheless, cohesion is a decisive factor in the collective motion, cohesion among the fullerenes is weaker than adhesion to the surface. Moving on the graphene. Surprisingly, according to the theory, the complex theoretical calculations of several adsorption configurations, the determined orientation of fullerenes is independently confirmed by each, is critically evaluated by a comparison of STM measurements of the fullerenes in the islands, which occupy 4x4 graphene unit cells.

Regular islands of fullerenes were found. The particular orientation of the graphene surface due to its small atomic lattice. We show that metallic tips, which have been characterized prior to the measurement, cannot truthfully image the graphene surface due to their large, non-spherical electron density [1]. Calculations predict that the metal tip atom strongly interacts with the graphene surface [2]. Carbon oxide front atom identification (COFI) [2] shows that contact of a clean metal tip with graphene can lead to graphene fluxes attaching to the tip apex. This results in blurred images and multi-valley force versus distance curves. As a solution we use a metal tip, functionalized with an inert carbon monoxide molecule as suggested by Gross et al. [3]. The closed-shell nature of the CO drastically reduces the attraction between tip and graphene. Additionally, the small size of the CO allows truthful imaging of the graphene surface.


Role of substrate-molecular interactions in arrangement and collective motion of fullerene islands on graphene — Martin Svec¹, Pablo Meringo², Yannick Daffo³, César González³, Enrique Abad³, Pavel Jelinek¹, and Jose-Angel Martin-Gago⁵

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Fullerenes interacting with graphene are a model system, that should be entirely driven by van der Waals (vdW) interactions. We concentrate on the interactions occurring between fullerenes and the single-layer graphene grown on SiC(0001) [1]. By using a VT-STM at 40K, regular islands of fullerenes were found. The particular orientation of the fullerenes in the islands, which occupy 4x4 graphene unit cells each, is critically evaluated by a comparison of STM measurements to extensive STM simulations with realistic fullerene-terminated tips. The determined orientation of fullerenes is independently confirmed by complex theoretical calculations of several adsorption configurations, taking into account the vdW interaction between the constituents of this system. Furthermore, islands of fullerenes were found collectively moving on the graphene. Surprisingly, according to the theory, the cohesion among the fullerenes is weaker than adhesion to the surface. Nevertheless, cohesion is a decisive factor in the collective motion, thanks to a low diffusion barrier of fullerenes on graphene.