Low dimensional systems

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We study objects like **zero dimensional endofullerene** molecules and **two dimensional (2D) boron nitride** layers in view of their functionality as nano-materials. Single molecule magnetism is the focus in the fullerene research, where we apply bulk sensitive x-ray absorption and a sub-Kelvin superconducting quantum interference device for the investigation of the materials that are obtained from collaborations with synthesis groups. In the 2D materials activity we aim to grow highest quality boron nitride on substrates up to the four inch wafer scale with chemical vapour deposition and subsequent exfoliation. For this purposes we use a dedicated clean room, optical microscopy, transmission electron microscopy and surface science tools such as low energy electron diffraction, photoemission and scanning tunneling microscopy.

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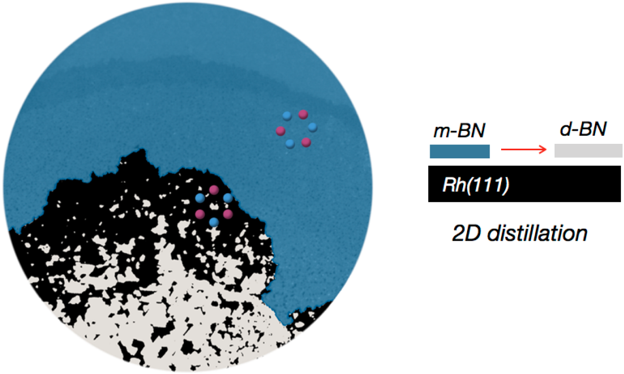
Surface distillation of hexagonal boron nitride

Production of high-quality two-dimensional (2D) materials is critical to the full exploitation of their single layer properties and combination in hybrids. With respect to 2D electronic device performance hexagonal boron nitride (*h*-BN) is foreseen to become the key packaging material since it is atomically thin, impermeable, flat, transparent and chemically inert. Surface distillation is a new scheme to produce *h*-BN that is superior to material from chemical vapor deposition (CVD). Single layer CVD *h*-BN is delaminated from Rh(111) and transferred back to a clean Rh(111) surface. The twisting angle between BN and the new substrate yields metastable moiré structures (*m*-BN). Annealing above 1000 K leads to 2D distillation, i.e., catalyst-assisted BN sublimation from the edges of the transferred layer and subsequent condensation into superior quality *d*-BN. It is a low-cost way of high-quality 2D material production remote from CVD instrumentation [1]. The project is a collaboration with the Hong Kong University of Sci-



Illustrated frame from a movie of the 2D distillation process. Left: Colored LEEM image with a field of view of 23 μm at a process temperature of 910°C. The blue regions are covered with misaligned single layer boron nitride m-BN that has been back-transferred onto the Rh(111) substrate. The m-BN sublimates onto the Rh(111) substrate (black) where boron (pink) and nitrogen (light-blue) diffuse to the light grey regions where they condense into highly ordered d-BN, which is aligned to the substrate. The driving force for surface distillation is the lower chemical potential of d-BN. Right: Corresponding sketch of the 2D distillation process. (LEEM image Zichun Miao, HKUST).

ence and Technology (HKUST) where low energy electron microscopy (LEEM) experiments on our samples were performed (see Figure) and the UZH department of chemistry. The results lead to a joint UZH/HKUST patent application "A method for on-surface synthesis of a hexagonal boron nitride monolayer" that protects the production of single layer *h*-BN with high lattice quality. The method of surface distillation does not directly involve the use of precursor molecules from the gas phase, but the transfer of a single layer *h*-BN on a catalyst surface where this *h*-BN can be cleaned by mild thermal annealing leading to *m*-BN and further distilled to *d*-BN.

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Highlighted Publications:

1. High-Quality Hexagonal Boron Nitride from 2D Distillation
   H. Cun *et al.*, ACS Nano **15** 1351 (2020)

2. Gadolinium as an accelerator for reaching thermal equilibrium and its influence on the ground state of $Dy_2GdN@C_{80}$ single-molecule magnets
   A. Kostanyan *et al.*, Phys. Rev. B **103** 014404 (2021)

3. Sub-Kelvin hysteresis of the dilanthanide single-molecule magnet $Tb_2ScN@C_{80}$
   A. Kostanyan *et al.*, Phys. Rev. B **101** 134429 (2020)