Nano-scale, atomic-thickness plasma processing of functional 2D materials

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Highlight statement: Low-temperature non-equilibrium plasma processes are effective in theproduction and processing of two-dimensional functional inorganic and organic materialsincluding MoS2 for optoelectronic applications and vertically oriented graphenes with preciselytuned water repellence/capture for energy storage and water purification applications.

The first case study is related to inorganic 2D materials and introduces plasma-enabled soft, selective, high-throughput and uniform large-area, atomic-layer-precision plasma etching of MoS_2,without damaging the remaining layers or substrate.[1] This is achieved by using SF_6 + N_2 plasmas with low-energy (<0.4 eV) electrons, which minimizes ion-related damage. The etching process removes the same numbers of MoS_2 layers from the areas even with very different initial number of layers. The process conditions that allow to achieve a monolayer MoS_2 are introduced. The Raman and photoluminescence spectra are layer-number dependent and controllable. The plasma etching is scalable and relies on the reactive chemistry commonly used in semiconductor micromanufacturing processes and is potentially generic and extendable to other flat two-dimensional materials.

The second case study is related to organic 2D materials and is focused on sub-micrometer graphene microwell structures which are used to precisely control of liquid-solid interactions within sub-micrometer spaces and improve liquid penetration into tiny gaps.[2] This approach is inspired by the micro-textures of dry-climate Australian natural plants and allows to control the transition from the hydrophobic to superhydrophilic states. The plasma enables precise nanoscale texturing of the graphene microwells with graphene 'nano-winglets' which can change the tilt under different liquid evaporation conditions. This makes it possible to purify water by capturing gold nanoparticles and to improve the performance of supercapacitor electrodes. These results contribute to the advancement of the future sustainable nanotechnologies[3] for energy and water purification, critical aspects of the sustainable future environments. Fruitful collaborative work with the groups of Profs. S. Xiao and Z. Bo and contributions of all coauthors involved is gratefully acknowledged.

1. S. Xiao et al., *Scientific Reports* 6, 19945 (2015), DOI: 10.1038/srep19945
2. Z. Bo et al., *Bio-inspired tuneable sub-microfluidics* (submitted)
3. K. Bazaka, M. V. Jacob, K. Ostrikov, *Chem. Rev.* 116 (1), 163-214 (2016).