Hybrid Inorganic/Organic Systems for Opto-Electronics

Collaborative Research Centre 951

HIOS

Colloquium Announcement

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"Hybrid Inorganic/Organic Systems for Opto-Electronics"

Tanja Weil

Synthesis of Macromolecules Department, Max Planck Institute for Polymer Research, Mainz

Nanodiamond-based Quantum Materials for Biomedicine

Sergey Sadofev

Department of Physics, Humboldt-Universität zu Berlin

Vacuum deposition of two-dimensional Van der Waals materials

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Collaborative Research Centre 951
Department of Physics
Humboldt-University of Berlin

Email: sfb951@physik.hu-berlin.de
Tel.: +49 30 2093 66374
www.physik.hu-berlin.de/sfb951

Partners

Nanodiamond-based Quantum Materials for Biomedicine

Tanja Weil

Synthesis of Macromolecules Department, Max Planck Institute for Polymer Research Mainz, Germany

Fluorescent nanodiamonds (FNDs) are emerging as promising quantum materials for biomedical applications and precision sensing due to their unique optical and magnetic properties.[1] They are obtained by implementing elemental defects into the carbon lattice, such as the nitrogen vacancy (N-V), giving unconditionally stable fluorescence without bleaching or blinking even after several months of continuous excitation. The emission wavelength of FNDs is not size-dependent and is tuneable from the visible to the near infrared region according to the elemental defects. In addition, the N-V center in FNDs serves as single-spin sensor[2] that locally detects various physical properties offering great potential for atomic resolution imaging under physiological conditions. The advent of diamond quantum sensing promises solving the longstanding goal of single molecule detection with atomic resolution under ambient conditions[1] There is currently no other nanomaterial that would offer such features.

There is an urgent need to prepare high quality N-V diamonds nanodiamonds in a controlled fashion to customize diamond sizes and lattice defects. We present the synthesis of nanodiamonds that paves the way to tailored quantum materials with precisely defined and positioned lattice defects. In addition, functionalization of nanodiamonds is crucial for various applications in biology and medicine. Nanodiamond surface coatings based on biopolymers[3-4] and proteins[2,5] will be discussed that provide the basis for quantum sensing and drug delivery in living biological environments. In addition, functionalization of N-V diamonds with proteins or DNA provides access to precisely assembled diamonds on DNA origami to access sophisticated quantum devices[4].

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Vacuum deposition of two-dimensional van der Waals materials

Sergey Sadofev

Department of Physics, Humboldt-Universität zu Berlin, Germany

Two-dimensional van der Waals materials, particularly, transition metal dichalcogenides (TMDs), have recently emerged as a novel class of optoelectronic materials. The direct bandgap and giant exciton binding energy of molybdenum and tungsten dichalcogenides thinned to a single stacking layer make TMDs very attractive for extremely thin multifunctional truly interface devices, allowing for straightforward integration with conjugated molecules within a framework of hybrid inorganic-organic systems. In this talk, we present our recent findings in the fabrication of TMDs by vacuum deposition using direct resistive heating and sublimation of metal elements (Mo, W, Ta), while the group VI elements (S, Se) are co-evaporated from standard Knudsen cells. This simple technique enables us for the reproducible preparation of continuous TMD films with the layer thickness variable in the range of 1-5 stacking units. The sample area is limited only by homogeneity of the molecular fluxes and temperature distribution across the wafer, providing direct access to the large area coatings compatible with device fabrication processes. The synthetized layers of MoS_2, WS_2, $MoSe_2$ and WSe_2 exhibit clear excitonic structure in optical spectra characteristic for these compounds. While our motivation here is to demonstrate a proof of concept, the technique is capable not only of the production of single layers, but also of controllable doping and fabrication of alloys and heterostructures, including metallic TaS_2 towards, e.g., plasmonic applications.