H2O: Heterostructures of 2D Materials and Organic Semiconductor Nanolayers

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Abstract

This project will integrate 2D materials with newly developed nanolayers of organic semiconductors to create van der Waals heterostructures for applications in electronic and optoelectronic systems. Progress in nanotechnology brings enormous interest in two-dimensional (2D) organic and inorganic materials having a huge market potential in electronics. In addition to novel properties of individual crystals, by stacking them on top of each other, it is also possible to create van der Waals heterostructures (vdWh) which hold promise for novel devices with designed properties. Here we propose the integration of nanolayers of organic semiconductors (OSC) together with inorganic 2D materials, which could contribute significantly to technological advancement by exploiting the properties of both materials. However, for practical application of vdWhs, large-scale preparation of heterostructures without compromising their crystallinity and interface quality is required. So far, the primary challenge lies in the difficulty of preparation of high quality ultra-thin OSC layers on top of 2D crystals over a large area. To address these challenges, this project will utilize novel methods to fabricate vdWh with 2D materials while retaining their structural integrity and high interface quality. We will develop 2D nanolayers (down to few monolayers) of OSC which will be mechanically stable and transferable by cross-linking and layer-transfer methods. Specifically, we will produce p–n junctions of OSC and atomically thin CVD grown transition metal di-chalcogenides (TMDC), such as semiconducting MoS2 and WSe2, in a lateral and vertical configuration for demonstration of devices such as rectifying diodes, photdetectors, light emitters and photovoltaic solar cells.The p-n junction devices will be integrated to other 2D materials for development of all-2D vdWhs for improvement in device characteristics. The CVD graphene will be used as contact materials to OSC and TMDC, where the interface resistance can be controlled with gate voltage by tuning the Schottky barrier. Furthermore, we will integrate the recently developed carbon nanomembranes (CNM) as dielectrics in the vdWh devices.We will utilize our cutting-edge expertise in growth, nanofabrication, spectroscopic, optical and electrical transport methods to understand the vdWh heterointerfaces and to develop novel electronic and optoelectronic devices. For basic understanding of vdWhs we plan to use our experience in (synchrotron based) photoemission spectroscopy for characterization of electronic structure, electrical transport measurements for understanding the charge transport properties, optical characterization by photocurrent and solar cell characterization, and photocurrent spectroscopy measurements. These vdWh devices will allow us to exploit the advantages offered by both 2D materials and OSC: excellent electronic and optoelectronic properties, flexibility, large area and low-cost production, atomically flat interfaces, excellent gate control over the junction and a great potential for scalability.

Consortium

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