Hybrid Inorganic/Organic Systems for Opto-Electronics

Collaborative Research Centre 951

Colloquium Announcement

of the Collaborative Research Centre 951
"Hybrid Inorganic/Organic Systems for Opto-Electronics"

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2D inorganic and organic materials and their hybrids for implementation in electronic and photonic devices

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A theoretical approach to interfacial charge and energy transfer: atomically thin semiconductors functionalized with graphene, metal nanoparticles and dye molecules

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2D inorganic and organic materials and their hybrids for implementation in electronic and photonic devices

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Two-dimensional (2D) inorganic and organic materials and their vertical and lateral heterostructures exhibit a manifold of novel physical phenomena as well as open broad avenues for their implementation in electronic and photonic devices. In this talk I will give an overview of our recent progress on the synthesis, characterization and applications of these materials with a particular emphasis on their structure-property relationships and engineering on novel 2D material-based inorganic-inorganic and inorganic-organic hybrids. The examples will include demonstration of the scalable high-quality chemical vapor deposition (CVD) synthesis of monolayers (MLs) of transition metal dichalcogenides (TMDs) [1-3], rise of the giant persistent photoconductivity in TMD MLs due to variation of the intrinsic defect density [4], study of the interlayer excitons in the stacked van der Waals (vdW) bilayers of the CVD grown MoS_2 [5], CVD growth of monolayer $MoSe_2$-WSe_2 lateral heterostructures and their implementation in various electronic and optoelectronic devices [6], assembly and characterization of van der Waals heterostructures of organic and inorganic 2D materials for photonic and electronic applications [7-8].

[1] A. George et al., Controlled growth of transition metal dichalcogenides monolayers using Knudsen-type cells for the precursors *J. Phys. Mater.* 2 (**2019**) 016001.

[2] G. Q. Ngo, A. George et al., Scalable functionalization of optical fibers using atomically thin semiconductors. *Adv. Mater.* 32 (**2020**) 2003826.

[3] S. Shree et al., High optical quality of MoS_2 monolayers grown by chemical vapor deposition. *2D Mater.* 7 (**2020**) 015011.

[4] A. George, M. Fistul et al., Giant persistent photoconductivity in monolayer MoS_2 field-effect transistors. *npj 2D Mater. Appl.* 5 (**2021**) 15.

[5] I. Paradeisanos et al., Controlling interlayer excitons in MoS_2 layers grown by chemical vapor deposition. *Nat. Commun.* 11 (**2020**) 2391.

[6] E. Najafidehaghani, Z. Gan et al., One-dimensional *p-n* junction electronic and optoelectronic devices from transition metal dichalcogenide lateral heterostructures grown by one-pot chemical vapor deposition synthesis. *Adv. Funct. Mater.* (**2021**) in press.

[7] Z. Tang et al., Optically triggered control of the charge carrier density in chemically functionalized graphene field effect transistors. *Chem. Eur. J.* 26 (**2020**) 6473.

[8] Y. D. Sırmacı et al., Plasmonic metasurfaces situated on ultrathin carbon nanomembranes. *ACS Photonics* 7 (**2020**) 1060.

A theoretical approach to interfacial charge and energy transfer: atomically thin semiconductors functionalized with graphene, metal nanoparticles and dye molecules

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Atomically thin semiconductors constitute a remarkable playground for exciton physics in two dimensions. This involves optically accessible (bright) as well as spin- and momentum-forbidden (dark) excitonic states including intravalley and intervalley excitations. Here, we present applications of a many-body theory to charge-, Dexter- or Förster-type transfer processes at interfaces of atomically thin semiconductors functionalized with graphen, metal nanoparticles and dye molecules.

In particular, as a new process, we also introduce exciton-plasmon conversion from WSe_2-excitons to graphen-plasmons. Our results are compared to experimental results in the CRC, AG Ernstorfer and AG Bolotin.