Colloquium Announcement
of the Collaborative Research Centre 951
“Hybrid Inorganic/Organic Systems for Opto-Electronics”

Andras Kis
Electrical Engineering Institute and Institute of Materials Science and Engineering,
École Polytechnique Fédérale de Lausanne, Switzerland

Excitonic devices based on
2D semiconductor heterostructures

Sylke Blumstengel
Institut für Physik, Institut für Chemie, IRIS Adlershof,
Humboldt-Universität zu Berlin, Germany

Exciton and charge transfer
at 2D van-der-Waals interfaces

Time: Thursday, 28.01.2021, 13:30
Place: The colloquium takes place online (ZOOM)
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Password: 951951
Excitonic devices based on 2D semiconductor heterostructures

Andras Kis1,2

1Electrical Engineering Institute, École Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland
2Institute of Materials Science and Engineering, École Polytechnique Fédérale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland

The discovery of graphene marked the start of research in 2D electronic materials which was expanded in new directions with MoS2 and other layered semiconducting materials. They have a wide range of interesting fundamental properties and potential applications. New opportunities are enabled by the band structure of transition metal dichalcogenides (TMDCs) in which we could harness the valley degree of freedom for valleytronics and next-generation photonics. Long-lived interlayer excitons in van der Waals heterostructures based on TMDCs have recently emerged as a promising platform for this, allowing control over exciton diffusion length, energy and polarization. I will show here how by using MoS2/WSe2 van der Waals heterostructures, we can realize excitonic transistors with switching action, confinement and control over diffusion length at room temperature in a reconfigurable potential landscape. On the other hand, the weak interlayer interaction and small lattice mismatch in MoSe2/WSe2 heterostructures results in brightening of forbidden optical transitions, allowing us to resolve two separate interlayer transitions with opposite helicities and meV-scale linewidths. These have opposite helicities under circularly polarized excitation, either preserving or reversing the polarization of incoming light. By using externally applied electrical fields, we can control their relative intensities and polarization by different regions in the moiré pattern, characterized by different local symmetries and optical selection rules. Our more advanced excitonic devices now also offer the way to manipulate the motion of valley (spin) polarized excitons.

References
Functionalization of monolayer (ML) transition metal dichalcogenides (TMDC) with conjugated organic molecules provides a route to improve and expand the functionality of TMDC MLs in optoelectronic and photonic devices. The molecular layer can, for example, enhance, control, and spectrally tune the absorption and emission of light if properly designed. Decisive is the coupling of electronic excitations across the heterointerface. We have studied organic molecule/TMDC interfaces in various configurations by a combination of optical and photoemission spectroscopy. At interfaces with a type-II energy level alignment we observe fast excited state charge transfer. This process has been employed to enhance and spectrally expand the photoresponse of a MoS$_2$-based hybrid photodetector. On the other hand, at interfaces with a type-I energy level alignment, ground and excited state charge transfer are ruled out. Instead, transfer of electron–hole pairs, i.e., excitons from the molecular layer to the TMDC is observed with a rate much faster than the radiative and nonradiative recombination rate of the donor material. This process results in an enhancement of the PL yield of the MoS$_2$ ML.