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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Excitonic devices based on 2D semiconductor heterostructures

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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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Excitonic devices based on 2D semiconductor heterostructures

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The discovery of graphene marked the start of research in 2D electronic materials which was expanded in new directions with MoS_2 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 MoS_2/WSe_2 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 $MoSe_2/WSe_2$ 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

[1] A. Ciarrocchi, D. Unuchek, A. Avsar, K. Watanabe, T. Taniguchi, A. Kis. Nature Photonics 13, 131–136 (2019).

[2] D. Unuchek, A. Ciarrocchi, A. Avsar, K. Watanabe, T. Taniguchi, A. Kis. Room-Temperature Electrical Control of Exciton Flux in a van Der Waals Heterostructure. Nature 560, 340–344 (2018).

[3] D. Unuchek, A. Ciarrocchi, A. Avsar, Z. Sun, K. Watanabe, T. Taniguchi, A. Kis. Valley-Polarized Exciton Currents in a van Der Waals Heterostructure. Nature Nanotechnology 14, 1104–1109 (2019).

Exciton and charge transfer at 2D van der Waals interfaces

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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.