PhD Thesis

"Control of the Excitonic Properties in Transition Metal Dichalcogenides based Structures"

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In recent years, atomically thin transition metal dichalcogenides (TMDs) have emerged as promising semiconducting materials. Their unique properties stem from their electronic band structure emerging from the broken inversion symmetry and strong spin-orbit coupling, as well the presence of strongly bound excitons. This endows them with additional degrees of freedom for charge carriers and excitons, which are promising for both studies of fundamental physical phenomena and applications in opto-electronic devices. Van der Waals nature of the interlayer bonding of TMDs and other emerging layered materials allows for fabrication of complex multi-layered structures, which add additional complexity and opportunity for achieving desired opto-electronic properties. Despite intense research, many mysteries regarding the fundamental physical phenomena governing properties of such structures remain to be solved.

The ongoing need for investigation of the intriguing characteristics of TMDs motivated the realization of this thesis. Here I present studies of several TMD-based structures, the focus of which was the possibility of controlling the excitonic properties via both intrinsic and extrinsic factors.

In monolayer MoS_2 deposited on a patterned substrate I demonstrate the unexpected effect of anisotropic strain on the fine structure and polarization properties of the charged exciton state.

In monolayer WSe_2 I show the importance of the Dexter-like coupling mechanism on the valley polarization and that it can be used for broad tunability of the degree of valley polarization by the choice of excitation energy.

In WSe_2/2D-perovskite heterostructure I reveal the successful spin injection from TMD into the 2D-perovskite and the formation of an interlayer exciton state, whose properties are closely related to those of the constituent WSe_2 monolayer.

Finally I explore the excitonic landscape of a natural bilayer of $MoSe_2$ and the tunability of the excitonic states via application of electric field, which revealed formation of new excitonic states and their complex interactions.

Overall, the results presented in this thesis constitute an important step towards understanding of fundamental properties of TMDs and TMD-based structures.