Aktuelle Fragen
der Nanophysik

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Characterization of TMDs monolayers and their heterostructures

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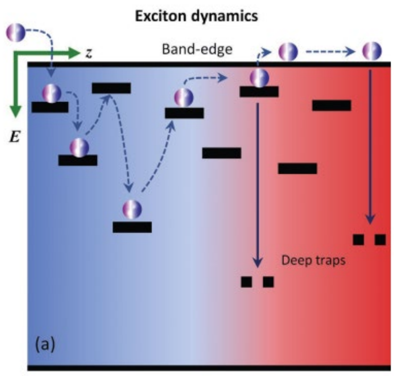
Transition metal dichalcogenides have emerged as a highly promising material for optoelectronics and quantum technology, owing to their exceptional optical and electronic properties, which can be tailored through various methods. Alloying semiconductors is often employed to tailor the material properties required for device applications. However, the cost of this tunability is the additional disorder introduced by alloying. To elucidate the characteristics of disorder potential in ternary alloys of atomically thin transition-metal dichalcogenides (TMDs), such as $Mo_xW_{1-x}Se_2$, we have conducted measurements of exciton photoluminescence across a broad temperature range spanning from 10 to 200 K. In contrast to binary materials like $MoSe_2$ and WSe_2, the ternary system exhibits a non-monotonic temperature-dependence in the luminescence Stokes shift and linewidth. This behavior strongly suggests the presence of a disorder potential that creates localized states for excitons and influences the exciton dynamics responsible for the observed non-monotonic temperature dependence.[1]

On the same hand, we have developed a platform based on binary–ternary heterobilayer of $Mo_{0.5}W_{0.5}Se_2$ with $MoSe_2$ and WSe_2 to fine-tune the interlayer exciton emission. These interlayer emission energies are above those reported for $MoSe_2/WSe_2$ (≃1.30–1.45 eV). Consequently, binary–ternary heterostructure systems offer an extended energy range and tailored emission energies not accessible with the binary counterparts. Moreover, even though $Mo_{0.5}W_{0.5}Se_2$ and $MoSe_2$ have almost similar optical gaps, their band offsets are different, resulting in charge transfer between the monolayers following the optical excitation.[2]

From a different perspective, we employed far-field imaging techniques to study the emission pattern of interlayer excitons in TMDs heterostructure systems within the measurable light cone. This allowed us to investigate the radiation profile of various excitonic features from such heterostructure system.[3]



[1] H. Masenda *et al.*, "Energy Scaling of Compositional Disorder in Ternary Transition-Metal Dichalcogenide Monolayers," *Adv. Electron. Mater.*, p. 2100196, 2021, doi: 10.1002/aelm.202100196.

[2] M. A. Aly, E. O. Enakerakpor, M. Koch, and H. Masenda, "Tuning Interlayer Exciton Emission with TMD Alloys in van der Waals Heterobilayers of Moo.5Wo.5Se2 and Its Binary Counterparts," *Nanomater. 2023, Vol. 13, Page 2769*, vol. 13, no. 20, p. 2769, Oct. 2023, doi: 10.3390/NANO13202769.

[3] M. A. Aly *et al.*, "Radiative pattern of intralayer and interlayer excitons in two-dimensional WS2/WSe2 heterostructure," *Sci. Rep.*, vol. 12, no. 1, pp. 1–7, Apr. 2022, doi: 10.1038/s41598-022-10851-3.