Engineering Excitons in 2D Lateral Heterostructures for Reconfigurable Optoelectronics

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Two-dimensional (2D) transition metal dichalcogenides (TMDs) have enabled the exploration of exotic quantum phenomena with promising applications.[1] Among various architectures, lateral heterostructures (LHS) offer a unique solid-state platform for engineering the confinement and transport of carriers and excitons across 1D junctions.[1] We report CVD-grown multi-junction 2D lateral heterostructures[2] with diode-like rectification and gate-tunable electroluminescence. Temperature-dependent photoluminescence reveals exciton, trion, and quantum emitter dynamics governed by defects and interfacial charge modulation.[3] We further demonstrate multimodal excitonic transistor behavior in bilayer LHS FETs, enabling reconfigurable trion-to-exciton conversion.[4] By tuning bias and excitation energy, we access a regime of polarity-reversible photoconductivity, making these devices ideal for multifunctional optoelectronic systems. Recent moiré-engineering efforts through vertical stacking of LHS (MoS_2–WS_2 and $MoSe_2$–WSe_2) have unlocked quadruple moiré pockets with twist-angle (θ) control from 0° to 60°, allowing programmable modulation of excitons and phonons.[5] Our findings showcase the promises of 2D LHS as a tunable platform for spectral photodetection, exciton-based logic, and on-chip quantum photonic circuits.

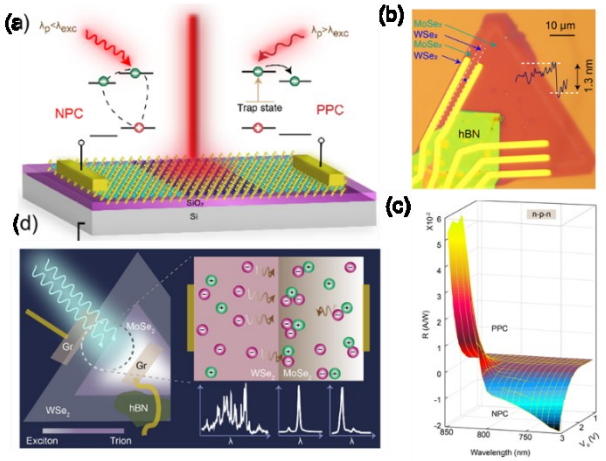

Figure (a) Trion-Engineered Multimodal Photo-Transistors in 2D bilayer $MoSe_2$–WSe_2 Lateral Heterostructures, and (b) corresponding device. Variation of responsivity (R) with the tunable incident wavelength and applied source-to-drain bias (V_d) for the n-p-n device. The z-axis represents the sign and magnitude of R between negative and positive photoresponse.[4] (d) Precise electrical tuning of exciton complexes, their transfer across interfaces, and quantum emitters in 2D Lateral Heterostructure.[3]

[1] S. Chakraborty *et al. npj 2D Materials and Applications* 9, 94 (2025)
[2] P. K. Sahoo et al., *Nature,* 553, 63–67 **(**2018)
[3] B. Kundu *et al. Nano Lett. 24, 14615–14624* (2024).
[4] B. Kundu *et al. Advanced Functional Materials, e17486* (2025)
[5] S. Chakraborty et al., *Advanced Materials e20008* (2025)