Controlling excitons in 2D semiconductor heterostructures

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Two dimensional (2D) semiconductors, such as $MoSe_2$ and WSe_2, host tightly bound excitons (electron-hole pairs) that interact strongly with light. These monolayer semiconductors can be stacked together to realize heterostructures that exhibit new excitonic effects. In this presentation, I will discuss the optical response of two different 2D semiconductor heterostructures. First, I will review the progress towards understanding interlayer excitons (IXs) in $MoSe_2$ -WSe_2 heterobilayers. These IXs host a rich moiré physics associated with the spatially modulated interactions between layers. I will discuss our recent discoveries related to exciton transport in structures that have a hBN separator between the $MoSe_2$ and WSe_2 layers. IXs also possess a large permanent dipole moment that allows for their energy to be tuned with an out-of-plane electric field. By nano-patterning a gate on top of the $MoSe_2$-WSe_2 heterostructure, we have demonstrated quantum dot-like potentials (Figure 1a-b), which have potential applications toward realizing deterministic single photon emitters [1,2]. Using the same architecture, we have demonstrated high speed IX currents based on “slide” like quasi-one dimensional channels (Figure 1c-d), which have applications to excitonic circuitry [3].

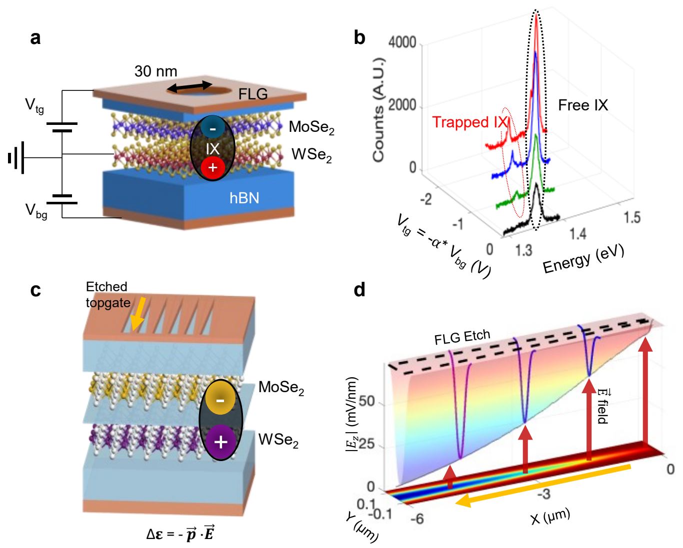

Figure 1: (a) Depiction of a $MoSe_2$-WSe_2 heterostructure with a nanopatterned top gate. (b) Photoluminescence spectra as a function of applied top and bottom gate voltage (Vtg, Vbg). The spatial modulation of the out-of-plane electric field (due to the hole) results in a trapped IXs under the nanopatterned hole shown in b. (c) Depiction of the IX ramp device consisting of nanopatterned long, skinny isosceles triangles in the top bilayer graphene gate. (d) A COMSOL simulation of the out-of-plane electric field shows a ramp/slide energy potential for IXs that is used for high speed IX transport.

References

[1] D.N. Shanks et al., Nano Letters **21,** 13 (2021)

[2] D.N. Shanks et al., Phys. Rev. B **106,** 16 (2022)

[3] D.N. Shanks et al., Nano Letters **22,** 16 (2022)

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