Atomic-level structure controls energy transfer in 2-D material heterojunctions

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Heterojunctions formed from two-dimensional materials are promising structures for tailoring applications including photocatalysis and chemical reactivity, opto-electronics, molecular sensing, and nonlinear transduction, among others. Because 2-D materials consist of only a few atomic layers or unit cells in the out-of-plane direction, atomic level structure can dictate in-plane lattice properties that persist in micron-to-millimeter terraces. I will demonstrate that angstrom-scale lattice parameters determine both the nonlinear optical response and energy dissipation rates in heterojunctions consisting of 2-D metals and their alloys. In particular, I will show that introducing disorder in the lateral rotation of metal atoms at step edges results in accelerated bulk electron-phonon scattering rates for group III metals. This result is exciting, because similar structural control over energy dissipation rates is not observed for 3-D and bulk metals. Hence, the 2-D heterojunction may provide opportunities for achieving structural control over interfacial energy transfer that are not possible for other materials. In a related example, I will describe how molecular dopants affect inter-layer electron transfer in few-layer transition metal dichalcogenides (TMDs). I will show that TMD n-doping by polyoxometalates leads to efficient nonlinear excitation and accelerated inter-layer energy transfer. Taken together, these results provide specific examples of how atomic level structure can be leveraged to control inter-layer energy transfer in multi-component materials.

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