Ballistic Excitons and Surface Functionalization in a Superatomic Semiconductor

Roy, Delor, Nuckolls and Berkelbach, Columbia University

The transport of energy and information in semiconductors is limited by scattering between electronic carriers and lattice phonons, resulting in diffusive and lossy transport that curtails all semiconductor technologies. Using $Re_6Se_8Cl_2$, a van der Waals (vdW) superatomic semiconductor, IRG2 PIs have demonstrated the formation of acoustic exciton-polarons, an electronic quasiparticle shielded from phonon scattering (Fig. 1a). Polaron transport in $Re_6Se_8Cl_2$ is directly image at room temperature (Fig. 1a), revealing quasi-ballistic, wavelike propagation sustained for nanoseconds and several microns. Shielded polaron transport leads to electronic energy propagation orders of magnitude greater than in other vdW semiconductors (Fig. 1b,c), exceeding even silicon over nanoseconds. We propose that, counterintuitively, quasi-flat electronic bands and strong exciton–acoustic phonon coupling are together responsible for the remarkable transport properties of $Re_6Se_8Cl_2$, establishing a new path to ballistic room-temperature semiconductors. This work, recently accepted for publication in *Science,* is a major step in the long and active search for room-temperature ballistic semiconductors, which could power next-generation technologies such as lossless transistors operating over three orders of magnitude faster than current electronics.

Using $Re_6Se_8Cl_2$ as a superatomic pegboard, the IRG2 team have also developed robust and general method to functionalize 2D superatomic sheets with high precision and controllable densities. Fig. 1d shows the covalent attachment of 2,2'-bipyridine (bipy) ligands to exfoliated $Re_6Se_8Cl_2$ sheets through radical-based Cl substitution. These ligands can bind molecular Co catalysts, and with no optimization, the resulting surface-tethered complexes catalyze the oxidation of water with no release or decomposition of the Co complex.

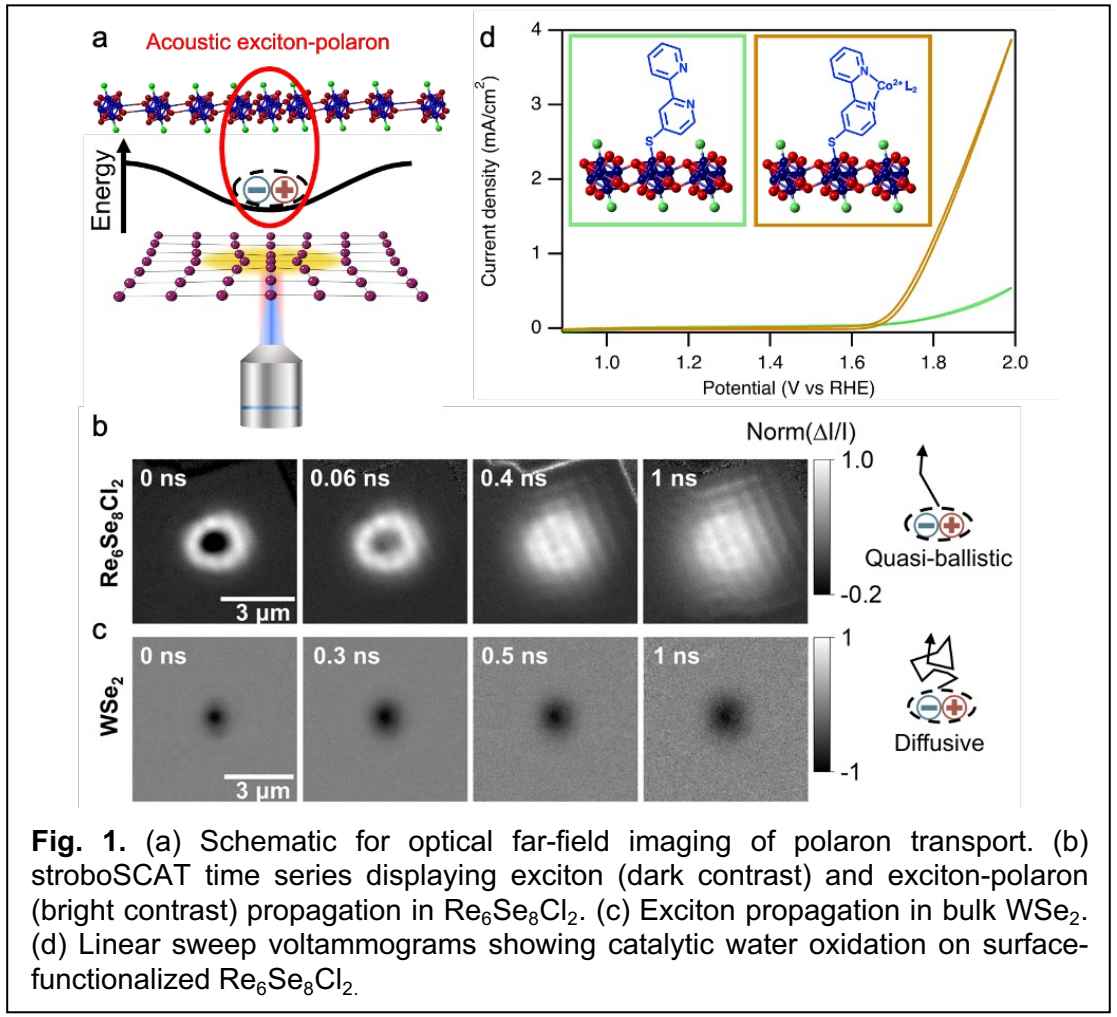

Fig. 1. (a) Schematic for optical far-field imaging of polaron transport. (b) stroboSCAT time series displaying exciton (dark contrast) and exciton-polaron (bright contrast) propagation in $Re_6Se_8Cl_2$. (c) Exciton propagation in bulk WSe_2. (d) Linear sweep voltammograms showing catalytic water oxidation on surface-functionalized $Re_6Se_8Cl_2$.

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