

The successes of electronic and optoelectronic technologies have required *perfection*, as exemplified by single crystal silicon with remarkably low defect densities. However, this requirement cannot be met by emerging semiconductors from molecular, hybrid, or nanocrystalline materials where room-temperature and solution synthesis/processing conditions inevitably result in a high density of defects that are detrimental to their performance. Overcoming such a seemingly insurmountable barrier may lead to true breakthroughs in future applications of designer semiconductors.

Defects affect charge transport mainly through the ubiquitous Coulomb potential, e.g., in the Shockley-Read-Hall recombination in which a mobile electron (hole) is attracted to and recombines with an immobile hole (electron) on a trap site. If the Coulomb potential is screened on time scales relevant to charge carrier transport and recombination, the detrimental effects of defects can be much reduced. This is possible because semiconductors from molecular, hybrid, or nanocrystalline building blocks are intrinsically “soft” and easily polarizable, thus, allowing dynamic screening. The idea of protecting charge carriers via efficient screening of the Coulomb potential is rooted in large polaron physics or solvation chemistry. Recent discoveries by the PI on hybrid organic-inorganic lead halide perovskites have provided the first evidences of screening in turning intrinsically defective materials into defect tolerant semiconductors.

The objective of the proposed research is to explore dynamic screening as a design principle to turn *imperfection* to *perfection*. Using model systems of hybrid perovskites, interfaces of 2D transition metal dichalcogenides (TMDCs) to liquid-like dielectrics, conducting metal organic frameworks (MOFs), and phonon-glass electron-crystals, the PI will establish dynamic screening as a design principle for defect tolerance using ultrafast spectroscopies, in conjunction with transport measurements. The long term objective is to provide a scientific foundation to accelerate progress towards the era of ubiquitous and large-scale electronics/optoelectronics for future DOD technologies and for the society.