Mechanism and New Applications of Large and Persistent Photoconductivity

Large and persistent photoconductivity (LPPC) in semiconductors is due to the trapping of photo-generated minority carriers at crystal defects. Theory suggests that anion vacancies in II-VI semiconductors are responsible for LPPC due to negative-\(U\) behavior, whereby two minority carriers become kinetically trapped by lattice relaxation following photo-excitation \([1-2]\). By performing a detailed analysis of photoconductivity in CdS, we provide experimental support for this negative-\(U\) model of LPPC \([3]\). We also show that LPPC is correlated with sulfur deficiency. We use this understanding to vary the photoconductivity of CdS films over nine orders of magnitude, and vary the LPPC characteristic decay time from seconds to 10,000 seconds, by controlling the activities of Cd\(^{2+}\) and S\(^{2-}\) ions during chemical bath deposition. We suggest a screening method to identify other materials with long-lived, non-equilibrium, photo-excited states based on the results of ground-state calculations of atomic rearrangements following defect redox reactions, with a conceptual connection to polarons and organic dyes.

We apply our knowledge of defect physics in CdS to propose and design a new type of semiconductor device – the donor level switch (DLS), which operates by switching individual defects between deep-donor and shallow-donor states. We study DLS behavior by making two-terminal devices using hole injection layers to control the charge state of sulfur vacancies. We also apply our knowledge to study the influence of LPPC on the performance of CIGS thin-film solar cells.

If time allows we will also cover recent results from our group on infrared optical properties and phase-change functionality in transition metal di-chalcogenides (TMDs), and early results on growth and the opto-electronic performance of sulfide perovskite semiconductors.