Spintronics and photonics are new branches of material science that aim at the storage, manipulation, and transmission of information using electronic spin and photons as the basic unit of information, paralleling in many ways the traditional approaches that are based on conventional electronics: that is, the use of the electronic charge degree of freedom to process information. These approaches, in theory at least, hold enormous potential for the development of advanced data encryption, information computing, and energy transfer processes. In parallel to these advances, many interesting effects based on the reduced dimensionality of materials have been discovered over the last two decades or so, leading to the emergence of the new fields of nanotechnology and nanoscience.

Our group is interested in the study of new nanoscale inorganic materials that are relevant to energy and information storage and transfer applications. Our strategy is fundamentally interdisciplinary, and involves the development of materials synthesis and characterization methods, the use of a wide array of magneto-optical and electrochemical tools to understand the underlying physics that govern these novel materials, and the design of simple working devices to manipulate and optimize energy and information processes at the nanoscale.

In particular, we are interested in the study of magnetic semiconductors such as magnetite (Fe₃O₄), Ga₃Mn₅As, and rare-earth-based semiconductors (i.e., EuTe). In the bulk, these materials are known to exhibit many interesting effects such as giant Faraday rotation, optical second harmonic generation, interesting effects such as giant Faraday rotation, optical second harmonic generation, spin-photogalvanism, and light-induced magnetization, that are all connected to the ability to store and extract information and/or energy based on the electronic spin degree of freedom. One very compelling objective that illustrates the over-arching theme of our lab is the realization of a spin-light emitting diode (spin-LED) using chemically processed colloidal materials, as it epitomizes some of the different challenges we are interested in taking up:

- Synthesis of ferromagnetic nanomaterials for spin polarization;
- Coupling of these materials into conductive heterostructured films;
- Efficient transport of charge carrier through interfaces;
- Long-range spin-polarization of electrical current;
- High efficiency conversion of spin-polarized current into circularly-polarized emitted light.

Ultimately, our goal is to push forward the limits of our understanding of the physics of novel complex nanomaterials through careful chemical manipulation and detailed spectroscopic and magnetic investigations, which will open up new avenues for addressing current issues relevant with energy/information storage/transfer.

A schematic spin-LED: negative charge carriers’ spins are polarized following transport through a spin-polarized layer; these spin-polarized electrons then recombine with positive charge carriers, leading to the emission of circularly-polarized light.