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1. Voltage-controlled magnetostructural phase transformations in thin films: Each year more data is stored digitally on hard disks than was written in all prior human history, making increased data storage a pressing problem. The challenge in developing new materials and techniques to store data lies in writing the data; as the bits become smaller, the anisotropy must increase in order to maintain non-volatility. In increasing the anisotropy, the field required to switch the magnetic state also must increase, making it extremely difficult if not impossible to write the bits. Ideally the magnetic anisotropy of a single material could be electrically switched between soft magnetic behavior with weak magnetic anisotropy and hard magnetic behavior with uniaxial magnetic anisotropy; this switching would enable both bit writing (soft magnet) and non-volatile storage (hard magnet). The aim of this research project is to demonstrate exactly this result, i.e. that the magnetic anisotropy of a single material can be switched between these states using an electric field.

2. Magnetic nanostructures as contrast agents for ultra low-field magnetic resonance imaging: Ultra-low field MRI offers portability and decreased costs, however contrast agents, which have been widely used to improve the image quality in conventional MRI, are not yet optimized for ultra-low field magnetic resonance imaging. This project will focus on designing and fabricating nanostructures (using top-down techniques) that can be magnetized in the absence of a significantly large field.

3. Materials with large spin Hall effect (SHE): The SHE phenomena can be utilized to switch the magnetization of a ferromagnetic thin film using a spin current generated in a non-magnetic layer, making it attractive for magnetoelectronic applications. This project will identify and study materials likely to exhibit a large spin Hall effect such as Weyl semimetals (TaAs, NbAs, etc.). Devices for the measurement of this effect will be fabricated using top-down techniques from single crystals of these materials.