Study of metal-insulator transitions of strongly correlated oxides for bolometric detection

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Strongly correlated oxides have been the subject of intense study for the last two decades. Many of these materials exhibit exciting and technically useful properties; examples include high temperature superconductivity, colossal magnetoresistance, ferromagnetism and ferroelectricity. Recently, perovskite ruthenates $(Sr,Ca)_{n+1}Ru_nO_{3n+1}$ have become a focus in this field, since they exhibit a rich variety of fascinating ordered ground states, such as spin-triplet superconductivity, itinerant magnetism, orbital ordering, Mott insulator, and a field-tuned electronic nematic phase. The close proximity of these exotic states testifies to the delicate balance among the charge, spin, lattice and orbital degrees of freedom in ruthenates, and provides a remarkable opportunity for observing novel quantum phenomena through controlling external stimuli and potential applications.

In this project, we will investigate the metal-insulator transitions in Ca-based ruthenates and explore their possible application in bolometric detection, which has important industrial and military applications. The responsivity and detectivity of a bolometer are sensitively dependent on the relative magnitude of the change in the resistance of a sensitive element, i.e., $(1/R)dR/dT$, which is known as the temperature coefficient of resistance (TCR). Current microbolometers are primarily based on amorphous silicon and vanadium oxides, with TCR vales in the range of 0.01 - 0.05 K^{-1}, which is relatively low, limiting their sensitivity. The other major problem is that the films of these materials are non-uniform and amorphous, leading to high $1/f$ noise. Therefore, it is imperative to find alternative materials to develop a new generation of bolometric detectors. Our preliminary studies show that perovskite calcium ruthenates are promising candidates. These compounds exhibit tunable metal-insulator (MI) transitions; the MI transition temperature T_{MI} can be tuned to room temperature through chemical substitution and their TCR is high near T_{MI} (~ 0.5 K^{-1}). The other advantage for ruthenates is that it allows for homogeneous epitaxial film growth, which is expected to reduce the $1/f$ noise by two orders of magnitude. Our specific goal is to prove the concept for a microbolometer with 10x improvement in detectivity and 100x improvement in $1/f$ noise from current state of the art devices.

The student will get research experience in single crystal growth of materials and low-temperature resistivity measurements.