Solid Oxide Fuel Cells are energy conversion devices that convert chemical energy of a fuel directly into electrical energy. They are known for being fuel-flexible, have minimal harmful emissions, ideal for combined heat and power applications, highly energy-efficient when combined with gas or steam turbines. The current challenges facing the widespread adoption these fuel cells include cost reduction, long-term testing of fully integrated systems, improving the fuel cell stack and system performance, and studies related to reliability, robustness and durability. The goal of this dissertation is to further the understanding of the mechanical properties and crystal structure of materials used in the cathode and electrolyte of solid oxide fuel cells, as well as to report on the development of a supplementary educational tool that could be used in course related to fuel cells. The first part of the dissertation relates to the study of LaCoO3 based perovskites that are used as cathode material in solid oxide fuel cells and in other energy-related applications. In-situ neutron diffraction of LaCoO3 perovskite during uniaxial compression was carried out to study crystal structure evolution and texture development. In this study, LaCoO3 was subjected to two cycles of uniaxial loading and unloading with the maximum stress value being 700-900 MPa. The in-situ neutron diffraction revealed the dynamic crystallographic changes occurring which is responsible for the non-linear ferroelastic deformation and the appearance of hysteresis in LaCoO3. At the end of the first cycle, irreversible strain was observed even after the load was removed, which is caused by non-recoverable domain reorientation and texture development. At the end of the second cycle, however, no irreversible strain was observed as domain reorientation seemed fully recovered. Elastic constants were calculated and Young's modulus was estimated for LaCoO3 single crystals oriented along different crystallographic directions. The high temperature mechanical behavior study of LaCoO3 based perovskites is also of prime importance as solid oxide fuel cells operate at high temperatures. Incidentally, it was observed that as opposed to the behavior of most materials, LaCoO3 exhibits stiffening between 700 oC to 900 oC, with the Young's modulus going from a value of ~76 GPa at room temperature to ~120 GPa at 900 oC. In-situ neutron diffraction, XRD and Raman spectroscopy were used to study structural changes occurring in the material as it was heated. The results from these experiments will be discussed. The next portion of the dissertation will focus on electrolytes. Numerical simulation was carried out in order to predict the non-linear load-stress relationship and estimation of biaxial flexure strength in layered electrolytes, during ring-on-ring mechanical testing. Finally, the development of an interactive and inter-connected educational software is presented that could serve as a supplementary tool to teach fuel cell related topics.
The public is welcome to attend.