Processing and Microstructural Engineering of Ceramics for Advanced Functional Applications

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Ceramics are a unique class of materials that operate in a variety of environments that range from underwater acoustic transducers to refractory systems for space re-entry vehicles. In all applications, ceramics must be carefully processed in a way that maximizes the microstructural material characteristics required for improved performance. In this work, process development of $PbTiO_3$-based oxide and SiC/Si_3N_4 non-oxide ceramics is demonstrated as it relates to the fabrication of ceramic materials for piezoelectrics and high-temperature refractory materials, respectively. Microstructural engineering of textured piezo-ceramics fabricated by the templated grain growth (TGG) approach is discussed and the process for controlling grain size to tailor mechanical and electromechanical properties is demonstrated. Limitations and existing challenges to grain size control are also discussed and highlighted. A compositional selection strategy is also employed that enables tailoring of piezoelectrics for actuators as well as sensors. For refractory ceramics, SiC and Si_3N_4 ceramic tape processing and thermal processing are discussed. Si_3N_4 phase stability was shown to be thermodynamically limited by the partial pressure of nitrogen during high temperature sintering. SiC ceramics were sintering process is discussed and prototype bulk SiC leading-edge designs are showcased.