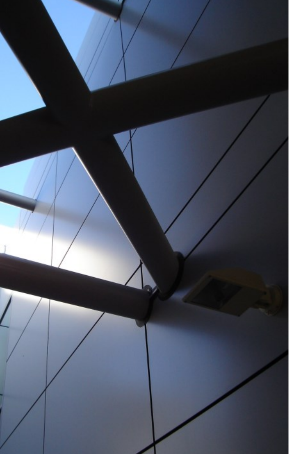

MECHANICAL ENGINEERING

The Department of Mechanical Engineering presents:

The Ph.D. Dissertation Defense of

Elias Penilla

Monday, August 15, 2016, 4:10PM
Bourns Hall A265

Synthesis, Consolidation, and Processing of Bulk Polycrystalline Transparent YAG, Ruby, and Over-Equilibrium Rare-Earth Doped Alumina for Photonic Applications

Doctor of Philosophy, Graduate Program in Mechanical Engineering
University of California, Riverside, August 2016
Dr. Javier Garay Chairperson

The past decade has seen significant advances in the development and improvements to high-energy laser technologies, with improvements coming from all directions, i.e. pumping technology, cavity design, cooling methods, and improved gain media quality, etc. Regardless, the continued development of high-energy lasers and the supporting technologies remains intense. From a materials development perspective, the need for gain media with superior optical, thermal, and mechanical properties is alluring because improvements in the materials properties often translate directly to increases in device performance. Advances in powder processing and sintering/consolidation techniques, in the past two decades have produced polycrystalline ceramics with the requisite densities, transparencies, and photoluminescence properties to be viable laser gain materials. In fact, the performance of some cubic (optically isotropic) ceramics now rival and even surpass their single-crystal counterparts. In the first portion of this dissertation Current Activated Pressure Assisted Densification (CAPAD) is implemented to process and consolidate transparent bulk polycrystalline YAG and Ce:YAG ceramics via a simultaneous solid-state synthesis and densification route. The simultaneous reaction/densification during CAPAD processing results in improved densification rates and with reaction kinetics that are about 2 orders of magnitude higher when compared to traditional solid-state reaction pressureless sintering and that the higher reaction kinetics occurring during CAPAD result at much lower temperatures, (~600°C) compared to conventional reaction sintering. In the second portion of this dissertation, the increased consolidation and reaction kinetics are leveraged to develop transparent bulk polycrystalline Cr:Al_2O_3 (ruby) and rare-earth (RE), RE:Al_2O_3 into viable laser gain materials. The advantages of Al_2O_3 as an optical gain media over state of the art gain materials such as YAG and laser glasses are significant; it has higher thermal conductivity, chemical inertness and higher mechanical toughness, all attributes that could lead to more stable, more powerful lasers. Despite these promising attributes, producing RE:Al_2O_3 ceramics with suitable functional properties for laser applications has steep processing challenges. RE:Al_2O_3 cannot be made using traditional equilibrium methods because the equilibrium solubility limits of REs in the Al_2O_3 is on the order of 10-3 to 10-4 %, not high enough to produce lasing (~10-1 %, required). In addition, Al_2O_3 is birefringent which can cause severe scattering in ceramics. These obstacles are mitigated through careful powder and CAPAD processing`in order to produce ceramics with fine grain sizes that mitigate scattering and with rare-earth dopant concentrations as high as 0.5 at.% (RE:Al), orders of magnitude higher than previously reported. Results are presented that prove for the first time that bulk polycrystalline RE:Al_2O_3 is a viable laser gain media. A common theme of this work will be the interplay between material processing, the resultant material properties, and the development of optical devices using bulk polycrystalline transparent ceramics.