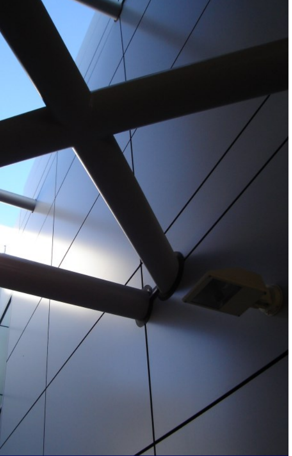

MECHANICAL ENGINEERING

The Department of Mechanical Engineering presents:

The Ph.D. Dissertation Defense of

Alex Dupuy

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Processing and Properties of High Performance Lead Free Electro-Optic Ceramics

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Dr. Javier Garay Chairperson

Electro-optic (EO) materials allow for the precise control of light using electrical signals, which has allowed for the advancement of an incredible array of photonic technologies such as laser systems and optical telecommunications. Most EO devices currently utilize single crystals, but high performance EO single crystals often have composition limitations since dopants can segregate and not all compositions can be grown using equilibrium restricted techniques. Bulk polycrystalline ceramic materials can potentially overcome such limitations and allow for the exploration of new EO systems. Due to the specific microstructures required for transparency, conventional processing techniques have difficulty in producing bulk polycrystalline EO ceramics. Reported here for the first time are the optical and EO properties of a new class of transparent lead free ceramic that outperforms EO materials in use today. This material is a barium titanate (BaTiO3) based solid solution, (1-x)Ba(Zr0.2Ti0.8)O3-x(Ba0.7 Ca0.3)TiO3 referred to here as BXT. The EO material was successfully processed using the Current Activated Pressure Assisted Densification (CAPAD) technique, commonly called Spark Plasma Sintering (SPS), which has been shown to be effective at consolidating optical materials. Using this technique along with a new powder synthesis method, it was possible to produce a transparent EO BXT ceramic with a highly dense and homogeneously reacted microstructure. Densified BXT shows a remarkable EO coefficient of 530 pm/V, which is superior not only to state of the art LiNbO3 crystals but also top-quality lead containing ferroelectric ceramics such as PLZT. This exceptional coefficient will allow for miniaturized EO systems with reduced operating voltages. The mechanisms behind the high EO performance in BXT were determined using additional EO and ferroelectric measurements. These measurements indicate that BXT undergoes a field induced structural evolution which heavily contributes to the EO effect. Along with efficient domain motion, this structural evolution includes a field induced phase change to a lower symmetry crystal structure. This work shows that lead free EO polycrystalline ceramics can have properties that are competitive or superior to state of the art EO materials. Due to its exceptional EO properties, BXT in particular has a promising future as an EO material.