THE WILLIAM E. BOEING DEPARTMENT OF
AERONAUTICS & ASTRONAUTICS

... welcomes ...

CHRISTOPHER S. LYNCH

UNIVERSITY OF CALIFORNIA LOS ANGELES

Mechanical properties, reliability, and failure in ferroelectric materials

Linear piezoelectricity describes the mechanical behavior as a perfectly linear stress-strain curve that can be shifted along the strain axis by application of an electric field. In reality, ferroelectric materials are heterogeneous and display stress-strain behavior that is non-linear and hysteretic. The source of the non-linearity and hysteresis is non 180-degree domain wall motion and phase transformations. This discussion begins with a review of the effects of domain wall motion and phase transformations in ferroelectric materials with perovskite structure, and the effects on mechanical properties. Examples will be presented that explain the observed stress-strain behavior in commonly available ferroelectric materials that include various compositions of lead zirconate titanate (PZT) and PMN-PT based single crystals and how this behavior is affected by electric field.

Ferroelectric materials are used in a broad range of applications from acoustic imaging to high power sonar, from micron scale actuation to macro-scale morphing. Reliability is not an issue for low cycle, low stress, and low electric field applications; but considerations of reliability in device design become increasingly important when the ferroelectric materials are used in high field applications. Reliability is compromised by tensile stress. Tensile stress arises any time the ferroelectric material is clamped and the applied electric field drives it to contract. This can occur where a piezoelectric actuator is mounted against a rigid structure, or within the ferroelectric material in regions where the electric field is not homogeneous such as near the edges of electrodes. A number of examples will be presented that result in field inhomogeneities including interdigitated electrodes, partial electrodes in multilayers, and surfaces with patterned electrodes to control shape. A first approximation of stress concentrations can be obtained using a linear piezoelectric finite element analysis. The limitations of this approach will be discussed. More details can be obtained using material models with hysteresis, but these take programming and are not generally commercially available. Mechanical failure ends the life of the device. In many cases mechanical failure can be avoided by properly pre-loading the ferroelectric material in compression, but there are times when this simply is not possible. An overview of the fracture mechanics approach to understanding fracture will be presented. This will be followed by several approaches that have led to improved actuator reliability through the use of pre-stress.

WILLIAM E. BOEING
DEPARTMENT OF AERONAUTICS & ASTRONAUTICS
UNIVERSITY *of* WASHINGTON

Monday, May 15, 2017 @ 4:00pm
Johnson Hall. Rm 102 | UW Seattle

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THE WILLIAM E. BOEING DEPARTMENT OF
AERONAUTICS & ASTRONAUTICS

... Distinguished Guest Speaker ...

CHRISTOPHER S. LYNCH
UNIVERSITY OF CALIFORNIA LOS ANGELES

Professor and Chair,
Mechanical and Aerospace Engineering

Prof. Lynch performed his MS, PhD, and Post Doctoral work at UC Santa Barbara. He joined the Woodruff School of Mechanical Engineering at Georgia Tech in 1995 and the Department of Mechanical and Aerospace Engineering at UCLA in 2007 where he served as director of the #1 ranked MS Online program and currently serves as the MAE department chair.

His research has focused on characterization, applications, and modeling of ferroelectric and magnetostrictive materials. He has contributed to the development of constitutive models based on internal state variables, on micromechanics, and on the phase field approach; and to improved material reliability through his contributions to experimental and analytical field coupled fracture mechanics. His experimental data and related modeling work have been implemented in codes that his research group uses in the design and development of ferroelectric-based devices. His recent work has focused on magnetoelectric coupling at the nanoscale. He leads the modeling thrust of the NSF TANMS NERC and leads the UCLA portion of an AF Center of Excellence. He has published over 150 journal articles and conference papers in these areas.

Prof. Lynch has served as chair of the ASME aerospace division. He founded the conference on smart materials and adaptive structures, ASME SMASIS, and served as the general chair of the annual SPIE Smart Structures conference for 2014-2015. He has been honored with receipt of the NSF CAREER award, the ONR Young Investigator award, an ASEE educator award, as Fellow of ASME, Fellow of SPIE, the ASME Smart Structures Prize, the SPIE Smart Materials and Structures Lifetime Achievement Award, several teaching awards, and is the editor-in-chief of the journal Smart Materials and Structures.

The William E. Boeing Chair's Distinguished Seminar Series brings scholars of national and international reputation who have made an impact in the field of aerospace engineering and beyond. This seminar series will cover a diversity of topics of current interest to those in academia, industry and the general public. It is our hope that these monthly seminars will encourage an exchange of ideas and bring aerospace engineering and science to the forefront.

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