DREXEL UNIVERSITY
Materials Science and Engineering
College of Engineering

Fall Seminar Series

Nanoscale Susceptibilities in Ferroelectric Thin Films: Insights from Multidimensional Spectroscopy and Machine Learning

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Large susceptibilities in ferroelectrics depends on our ability to drive reconfiguration of the ferroic order parameter with externally-applied stimuli. Consequently, there is interest in understanding how ferroelectric order, at multiple length scales, responds under applied fields; and what this means for macroscopic properties. In recent years, in operando (e.g., piezoresponse force microscopy (PFM), transmission electron microscopy, etc.) capable of probing stimuli-driven changes in ferroelectric order at the appropriate length and time scales have become available. These approaches, however, have led to an orders-of-magnitude increase in the volume, variety, veracity, and velocity of the experimentally-generated data; rendering conventional analysis approaches untenable. Here, using multidimensional PFM spectroscopies we show how machine learning can bring physically-important phenomena concealed within "big" multichannel hyperspectral data into focus for interpretation. Specifically, we highlight how specially designed deep-learning neural networks which can consider the inherent temporal dependence in the collected data can be applied to glean new insights regarding how nanoscale, 3d domain geometry can be exploited to enhance piezoelectric responses and electromechanical energy conversion. Furthermore, the methodology developed paves the way for spectroscopic techniques wherein the conventional scientific methods of designing targeted experiments aimed at a specific hypothesis are supplanted by approaches which collect all seemingly relevant data, which can then be automatically interpreted to identify a hypothesis for empirical testing.

Joshua C. Agar, PhD is an assistant professor in the Department of Materials Science and Engineering at Lehigh University. His research interests center around advanced complex oxide thin-film deposition, custom multidimensional and multifrequency electromechanical scanning probe spectroscopies, and machine and deep learning. Joshua earned a BS from the University of Illinois at Urbana-Champaign, an MS from the Georgia Institute of Technology and a PhD from the University of Illinois at Urbana Champaign, all in the field of materials science and engineering. Joshua was a postdoctoral fellow at the University of California-Berkeley. His work has been published and highlighted in a range of high impact journals across scientific disciplines including: *Nature Materials, Advanced Materials, ACS Nano, Physical Review Letters*, etc.