Coatings utilizing the piezospectroscopic (PS) effect could enable on the fly stress sensing for structural health monitoring applications. While the PS effect has been historically utilized in several applications, here the photo-luminescent material, \( \beta-Al_2O_3 \), is distributed in nanoparticle form within a matrix to create a stress sensing coating. Parallel to developing PS coatings for stress sensing, the multi-scale mechanics associated with the observed PS response of nanocomposites and their coatings has been applied to give material property measurements, providing an understanding of particle reinforced composite behavior.

Understanding the nanoparticle-coating-substrate mechanics is essential to interpreting the spectral shifts for stress sensing of structures. In the past, methods to experimentally measure the mechanics of these embedded nano-inclusions have been limited, and much of the design of these composites depend on computational modeling and bulk response from mechanical testing. The PS properties allow for embedded inclusion mechanics to be revisited with unique experimental setups that probe the particles state of stress under applied load to the composite. These experimental investigations of particle mechanics will be compared to the Eshelby theory and its derivative theories in addition to the nanocomposite coating mechanics. This work discovers that simple nanoparticle load transfer theories are adequate for predicting PS properties in an intermediate volume fraction range.

With fundamentals of PS nanocomposites established, the approach was applied to selected experiments to prove its validity. In general it was observed that the elastic modulus values calculated from the PS response were similar than observed from macroscale strain measurements such as a strain gage. When damage models were applied to monitor the elastic modulus during loading, it was observed that the rate of decay for the elastic modulus was much higher for the PS measurements than for the strain gage.

A novel experiment including high resolution PS maps with secondary strain maps with digital image correlation is reviewed on an open hole tension, composite coupon. The two complementary measurements allow for a unique PS response for every location around the hole with a spatial resolution of 400 micron. Progression of intermediate damage mechanisms was observed before digital image correlation indicated them. Using the PS nanocomposite model, elastic modulus values were calculated. By introducing an elastic degradation model with some plastic deformation allows for estimation of material properties during the progression of failure.

This work was part of a continuing effort to understand the mechanics of a stress sensing PS coating. The mechanics were then applied to various experimental data that provided elastic property calculations with high resolution. The significance is in the experimental capture of stress transfer in particulate composites. These findings pave the way for the development of high resolution stress-sensing coatings.
The public is welcome to attend.