Materials Data Science: Understanding Degradation and Lifetime

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Abstract

Lifetime prediction of long-lived materials is a key area to develop materials data science which requires an understanding of the key degradation mechanisms in relation to the stressors (i.e., UV irradiance, water, temperature, mechanical stress) and the applied stressor level. Predicting the durability and mitigating materials degradation has failed under traditional materials reliability, which has been incapable of addressing many of these challenges in a wide array of applications. Materials reliability has thus far been focused on pass/fail criteria for materials generally under accelerated exposures. When a material fails in-use conditions, the necessary data to investigate the failure is often missing since detailed evaluations of multiple samples were not performed over the course of the materials exposures. Materials reliability requires a population of materials large enough to accurately quantify the noise and the information in the data (from simulations or experiments) and multiple evaluations of those materials through their lifetime to enable data-driven modeling. These approaches must be transferable across research, industry, and standard organizations; therefore, FAIR (Findable, Accessable, Interoperable, Reusable) principles for reproducible data handling and modeling need to be a key component of materials data science.

In PV modules, backsheets are used for electrical insulation while providing environmental protection to the PV module. As the backsheet degrades, the PV module becomes a safety concern and increases the potential for module performance loss. Optimizing the backsheet is important to reduce cost while still maintaining the safety performance. In order to reach the 2030 DOE SunShot goal of $0.03/kWh, the PV module power degradation rates need to be lowered to the 0.2%/year goal to increase the lifetime of PV modules installed in any of the highly diverse climates zones. Being able to accurately predict performance of solar modules over their 20 to 30 year product warranty or lifetime is typically done using traditional reliability approaches such as pass/fail testing and materials qualification, yet this has failed and has led to large-scale failures such as polyamide backsheets. However, this reliability and durability problem extends to many materials in a wide variety of value chains. In order to model these complex systems, I have developed a degradation pathway network modeling (netSEM) methodology which is based on structural equation modeling (SEM). This modeling methodology builds a systems of equations that relates stressors with degradation mechanisms to overall performance response which results in <Stressor|Mechanism|Response> (<S|M|R>) models. netSEM enables the mapping of stressors, mechanisms and responses in a detailed degradation pathway model which provides a greater insight into degradation occurring in each material variant and stressor condition.
About the Speaker: Dr. Laura S. Bruckman is an Associate Research Professor in Materials Science and Engineering. Her research is focused on a data science approach to material degradation. She is an expert on quantitative spectroscopic techniques and image analysis to understand material degradation in relation to particular stresses. A material data science approach using statistical analytics is used to develop $<stres|mechanism|response>$ pathway (netSEM models) diagrams for material systems. These pathway diagrams elucidate the impact of materials and stressors and their relationship to overall degradation and lifetime performance loss. By encompassing data from both in use and accelerated experiments of the degradation of materials, lifetime predictions can be made for material systems under a wide variety of use conditions. Her area of focus has been on solar packaging materials, building envelope materials, and coatings. She teaches in the Applied Data Science Minor program at CWRU with a focus on data science projects and communicating results to various stakeholders.