POLYMER OXIDATION AND ITS IMPACT ON MATERIALS PERFORMANCE AND LIFETIME PREDICTION: AN OVERVIEW

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This presentation offers an overview on the various aspects of oxidative degradation and lifetime prediction of polymers. We intend to address this topic in a broad manner, allowing us to provide some guidance and a generational perspective for new researchers. We also hope to successfully link applied and fundamental research trends that we have witnessed developing over the years with some ongoing activities in this area. It is not possible to condense all of "oxidative polymer degradation" into a 40 minute talk due to the broadness of the field as well as the depth of many excellent researchers who contribute to this area, as seen by countless original papers. Instead, we will focus initially on a few key trends that could provide a framework for the type of physical polymer chemistry approaches that have made a significant difference in our collective understanding of oxidatively-driven polymer degradation. This will be documented with highlights from the behavior of a few specific materials.

Oxygen will degrade polymers; it is just an issue of time, our performance expectations and how individual properties may change, that determines whether we should care about it or whether it may even be favorable. In some intances, for example accelerated environmental degradation, oxidative degradation is a desirable material breakdown avenue. Regardless of material requirements we must understand the interaction between oxygen and polymers. We will therefore review the following key aspects: Our basic understanding of thermo-oxidative degradation principles and potential countermeasures, approaches towards the measurement of oxidation rates, benefits of degradation kinetic modeling and how oxidation reactions depend on temperature. Examples will show how knowledge of oxidation sensitivity and its temperature dependence can be translated into a basic framework for oxidation extent with time. When coupled with concurrent material performance demands, and hence what matters from an application point of view, this may then yield

guidance for material lifetimes. It is important to establish useful material property correlations with the underlying level of degradation. This is one of the most challenging tasks in comprehensive aging assessments, as reliable and predictable ‘aging’ cannot be expected to occur simply in matter of a few weeks (consider the example of wine). Relevant thermo-oxidative aging for lifetime prediction requires patience (i.e. sustained research funding) and an angle on temperature effects and mechanistic variations in the development of bulk property degradation. Ideally, multiple temperatures should be studied with extended aging times at low temperatures and comprehensive ‘aged-oxidized’ material characterization, together with a clear definition of performance criteria.

From a material point of view, this discussion will provide a perspective on generic behaviors in the thermal oxidative degradation of elastomers in comparison with polyolefins and then focus on epoxy and composite materials. This allows for an opportunity to touch on some of our latest trends in the oxidative aging of thermo-set materials. It offers an excellent example how the interplay between comprehensive experimental approaches, degradation modeling and data extraction using numerical methods can yield an understanding of highly complex material behaviors; initially at least with a perspective of polymer oxidation. We will review the current trends in experimental requirements and modeling approaches to gain a solid understanding of the underlying processes in such challenging polymers followed by a few comments on how this could be used for lifetime prediction and establishing performance limits.

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