
SERVICE LIFE PREDICTION
OF POLYMERIC MATERIALS
REACHING
NEW
HEIGHTS
MARCH 18-24, 2018 - BOULDER, CO
www.nist.gov/el/building_materials/slp_2018.cfm
Q-LAB
NIST
National Institute of
Standards and Technology
U.S. Department of Commerce
UL

Service Life Prediction: Reaching New Heights
March 18-23, 2018
Hyatt Place
Boulder, Colorado

On behalf of the technical organizing committee and the sponsors from **UL**, **Q-Lab**, and the **National Institute of Standards and Technology**, I would like to welcome you all to ***Service Life Prediction: Reaching New Heights.*** This conference features a strong technical program of cutting edge research in service life prediction, including presentations from across the globe with a diverse mix of industrial, academic and government perspectives and moderated panel discussions.

The organizing committee has designed this meeting to address two areas of Service Life Prediction: science and standards. In the *scientific area*, benchmarking the current state of the art is an important desired outcome of this meeting. Additionally, the discussion sections will focus on identifying areas where additional research is required. For the *standards area*, the focus will be on identifying the opportunities for including the state-of-the-art science into industry consensus standards. These discussions will also be used to identify areas where additional scientific results would speed up the adoption of proposed standards. These standards-focused sessions will be held between lunch and dinner.

The meeting has an active social/networking component. This starts Sunday night with an informal gathering where we will find a social dinner. The week will start with a continental breakfast (hotel) and a series of moderated talks and discussion. After a provided lunch (M-Th), the standards session will focus on feedback from the Standards Technical Panel on a current standards effort. In the evening there will be a light reception (Monday) followed by two talks and more discussion. This pattern remains similar with Tuesday having a dinner at Carellis restaurant (https://carellis.com/) and Wednesday banquet at the Boulder Chophouse (http://www.boulderchophouse.com/). A poster session at the hotel with a reception will be held on Thursday. The conference wraps up on Friday at noon.

Following this meeting, all presenters are encouraged to submit a paper for publication in a peer-reviewed volume edited by C. White and J. Pickett to be published by Elsevier. Previous volumes of the conference proceedings have been highly sought-after technical references. Everyone with a full registration for this meeting will be mailed a copy of this volume. The paper submission deadline is September 1, 2018.

Many thanks to all of the authors, session chairs, organizers, and participants for making this conference possible. Wishing you all an enjoyable and productive time in Boulder, Colorado.

Dr. Christopher C. White
Polymeric Materials Group
Engineering Laboratory
National Institute of Standards and Technology

Picture view of 2018 program

Time	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
7:00		Breakfast				
7:30						
8:00		J. Pickett	K. White	M. Celina	A. Pintar	M. Ito
8:30			K. Wood	E. Linde	L.Sung	J. Huang
9:00		M. Reitman	E. Sapper	K-A Weiß	D. Li	M. Kraus
9:30		Coffee Break	Coffee Break	Coffee Break	Coffee Break	Coffee Break
10:00		K. White	O. Rosseler	L. Glascoe	H. Sharma	M. Botz
10:30		M. Nichols	J. Pickett	D. Vermillion	D. Miller	R. Heinzmann
11:00		J-F Masson	O. Kuvshinnokc	M. McGreer	I. Alig	G. Siebert
11:30		Discussion				
11:45						
12:30		Lunch				
1:00						SLP
1:30						sealants
2:00		UL	UL &PSI	UL	Roadmap	meeting
2:30					rollup.	
3:00						
3:30						
4:00						
4:30						
5:00		Reception	Dinner Bus to		Poster	
5:30			Carellis		Session	
6:00	Informal			Banquet	Reception	
6:30	Dinner.	H. Chiang	J. David	Dinner	P. Morel	
7:00		B. Roduit	M. Nichols	Chophouse	C Juarez	
7:30		Discussion	Discussion		Discussion	
8:00						

List view of 2018 program

Monday Morning: General Overview of Service Life Prediction
Discussion Leaders: Matt McGreer, Mat Celina, Oliver Rosseler

Time	Presenter	Title
7:00 AM-8:00 AM		Continental Breakfast.
8:00 AM-8:30 AM	Jim Pickett	Why is SLP so hard?
8:30 AM-9:00 AM		
9:00 AM-9:30 AM	Maureen Reitman	Failure Mode Analysis
9:30 AM-10:00 AM	Coffee Break	
10:00 AM-10:30 AM	Ken White	Accelerated Weathering
10:30 AM-11:00 AM	Mark Nichols	Service Life Prediction from and End User Perspective
11:00 AM-11:30 AM	Jean-Francois Masson	Structural Insulated Panels for Housing Construction: Development of Guidelines to Assess Composite Durability for a Fifty-year Service in the Canadian Climate.
11:30 AM-12:30 PM		Panel Discussion
12:30 PM-2:00 PM	LUNCH	

Monday Afternoon: UL 746 Process

Time	Title
2:00 PM-5:00 PM	Tom Fabian 2000HR Program working draft and proposal: This is a working session for members of the UL 746B LTTA Forum and it is open to SLP attendees interested in participating. The objective of this session is to develop a final draft of a UL 746 Standard Technical Panel (STP) proposal that can be ready to be submitted for ballot by the end of the session.

Reception

Time	Title
5:00 PM-6:30 PM	Reception

Monday Evening: Successful Thermal Implementations of SLP
Discussion Leaders: Mark Nichols, Tom Fabian, Andy Francis

Time	Presenter	Title
6:30 PM- 7:00 PM	Helena Chiang	UL Roadmap for Long-Term Thermal Aging Program
7:00 PM - 7:30 PM	Bertrand Roduit	Prediction of shelf life of materials from forced degradation studies based on different analytical techniques by using advanced kinetic and statistical analysis
7:30 PM – 8:30 PM		Panel Discussion and (7:30 PM-8:30 PM)

Tuesday Morning: Service Life Prediction, Specific Issues.
Discussion Leaders: Erica Redline, Jim Pickett, Graham Duthie

Time	Presenter	Title
7:00 AM- 8:00 AM		Continental Breakfast.
8:00 AM- 8:30 AM	Ken White	Unraveling Reaction Pathways to Predict Degradation Rates in PET
8:30 AM- 9:00 AM	Kurt Wood	Use of Color Component Analysis to predict the color service life of fluoropolymer-based architectural coatings
9:00 AM- 9:30 AM	Erik Sapper	In Life, Death: Service Life Prediction and the Automated Design of New Polymeric Materials
9:30 AM- 10:00 AM	Coffee Break	
10:00 AM- 10:30 AM	Olivier Rosseler	How long should I run my weathering test to reproduce 1 year of outdoor aging?
10:30 AM- 11:00 AM	James Pickett	Accelerated weathering parameters for aromatic polymers
11:00 AM- 11:30 AM	Olga Kuvshinnikova ,	Outdoor and xenon arc weathering of aromatic engineering thermoplastics
11:30 AM- 12:30 PM		Panel Discussion
12:30 PM- 2:00 PM	LUNCH	

Tuesday Afternoon: UL 746 Process

Time	Title

2:00 PM- 5:30 PM	Jun Haruhara, and Dr. Thom Fabian IEC 60216-7: Applicability & next round robin plans. This is a working session to discuss the potential applicability of newly published IEC Technical Specification (TS) 60216-7-1 and IEC Test Report (TR) 60216-7-2 for the determination of Relative Thermal Indices (RTIs). Plans for additional round robins incorporating different materials will be discussed.

Meet at 4:45 PM Bus at 5:00 PM Tuesday Evening: Bus will take us to Carellis restaurant (Italian) and return us for the Tuesday evening talks.

Tuesday Evening: SLP concerns for Automotive Industry
Discussion Leaders: LiPiin Sung, Erik Sapper, Ingo Alig

Time	Presenter	Title
6:30 PM- 7:00 PM	Jennifer David	An Analysis of Thermal and Humidity Cycling Stresses in Automotive Hard Coatings
7:00 PM - 7:30 PM	Mark Nichols	Stone Chip Performance of Automotive Paint Systems
7:30 PM – 8:30 PM		Panel Discussion (7:30 PM-8:30 PM)

Wednesday Morning: Specific Exposure Issues with SLP: Water and Light
Discussion Leaders: Ken White, Libby Glascoe, Michael Kempe

Time	Presenter	Title
7:00 AM-8:00 AM		Continental Breakfast.
8:00 AM-8:30 AM	Mat Celina	Rapid IR Flow-Through Method for Volatile Quantification in Thermoset Ageing used for Lifetime Predictions
8:30 AM-9:00 AM	Erik Linde	Water Diffusion in Thermoset Amorphous Materials - Influence of the Glass Transition Temperature
9:00 AM-9:30 AM	Karl-Anders Weiß	Interaction of Permeats During the Measurement of Permeation Coefficients of Dense Polymer Films Under Realistic Conditions
9:30 AM-10:00 AM	Coffee Break	
10:00 AM-10:30 AM	Glascoe	Predicting chemical compatibility and aging of materials in a system a combined experimental and modelling approach
10:30 AM-11:00 AM	Doug Vermillion	Introduction to Metal Halide Weathering Chamber for Accelerated Material Testing
11:00 AM-11:30 AM	Matt McGreer	The Importance of Specimen Surface Temperature for The Understanding Of Correlation And Service Life Prediction
11:30 AM-12:30 PM		Panel Discussion
12:30 PM-2:00 PM	LUNCH	

Wednesday Afternoon: UL 746 Process

Time	Title
2:00 PM-4:30 PM	Helena Chiang, Dr. Chris White, Dr. Tom Fabian Roadmap for SLP into UL, IEC, and other standards. This is a working session to discuss how to continue to incorporate lessons from SLP meetings into the development of standards used to determine temperature ratings. A white paper outline is the goal from this session.

Banquet Dinner: at the
Boulder ChopHouse & Tavern
921 Walnut Street
Boulder , CO 80302
303-443-1188

This dinner will start at 6:00 PM. To get there is a pleasant 40 minute (1.8 m) walk which will take you through the heart of the Boulder shopping and recreation district (Pearl St. pedestrian mall). Directions are to walk down Pearl Street 1.8 miles, then left on 10th street for one block south, then turn on Walnut street for one block.

Another possibility is the use the excellent HOP bus service. http://www3.rtd-denver.com/Hop.shtml this circular bus service has a stop right outside the hotel (Pearl St & 30th St, right outside the Barnes and Noble bookstore) and drives directly down Pearl St. It will drop you off very near the restaurant (Walnut St & 11th St). This bus runs every 8 min. It will cost $5.20 for a round trip ticket. Tickets can be bought on the bus (cash only) or on the RTD app http://www.rtd-denver.com/mobileticket.shtml

Taxies, Uber and Lyft are also possibilities.

Thursday Morning: Service Life Prediction Modelling

Discussion Leaders: Bertand Roduit, Adam Pintar, Kurt Wood

Time	Presenter	Title
7:00 AM- 8:00 AM		Continental Breakfast.
8:00 AM- 8:30 AM	Adam L. Pintar	Building Hierarchical Bayesian Models for Sealant Data from the NIST Solar Sphere
8:30 AM- 9:00 AM	Li-Piin Sung	Predicting outdoor weathering of PE using NIST SPHERE methods
9:00 AM- 9:30 AM	Donghui Li	Multivariate Multiple Regression Models of the Waterborne Acrylic Coating Degradation under Multi-Factor Accelerated Weathering Exposures or Degradation of Waterborne Acrylic Coatings under Accelerated Weathering Exposures
9:30 AM- 10:00 AM	Coffee Break	
10:00 AM- 10:30 AM	Hom Sharma	An experimental and triple-mode sorption modelling of sorption and diffusion in polymeric materials
10:30 AM- 11:00 AM	David Miller	Degradation in PV encpasulant transmittance: Results of the first PVQAT TG5 study
11:00 AM- 11:30 AM	Ingo Alig	Accelerated Thermal Aging of Thermoplastic Materials: Combination of material characterization and cyclic fatigue testing
11:30 AM- 12:30 PM		Panel Discussion
12:30 PM- 2:00 PM	LUNCH	

Thursday Poster session: 5:00 PM -6:30 PM Poster Session and Reception

Poster	Presenter	Title
1	Kaushal Gandhi	Acceleration Parameters for Polycarbonate under Blue LED Light
2	Barbara Siebert	All Glass Pavilion
3	Tom Fabian	Overview of the 746 processes.
4	Larry Judovits,	Determination of Activation Energy using High Resolution TGA coupled with Modulated TGA.
5	Chris White,	Predicting Field Panel Temperature

Thursday Evening: Issues Relating Indoor Exposure to Outdoor Exposure
Discussion Leaders: Sean Fowler, Jim Pickett, David Miller

Time	Presenter	Title
6:30 PM-7:00 PM	Pierre Morel	Development of a combined testing technique to characterize coatings performance
7:00 PM-7:30 PM	Carlos Juarez-Garcia	Accelerated and Outdoor Weathering of non-PET aromatic polyesters and Polystyrene. Evaluation of the weathering Test Method ASTM D7869 to Simulate Miami Florida Outdoor Exposure
7:30 PM-8:30 PM		Panel Discussion (7:30-8:30)

Friday Morning: Elastomer Issues Related to Service Life Prediction
Discussion Leaders: Geralt Siebert, Jessica Vargas, Ralf Heinzmann

Time	Presenter	Title
8:00 AM-8:30 AM	Masayuki Ito	Methodology study of time accelerated γ ray irradiation to elastomer
8:30 AM-9:00 AM	Jing Huang	Thermo oxidation of polydicyclopentadiene : determination the initiation rate constants and termination rate constants of kinetic model
9:00 AM-9:30 AM	Michael A. Kraus	Experimental and numerical investigations on the load bearing behavior of unaged and weathered polymeric interlayers in Laminated Glass
9:30 AM-10:00 AM	Coffee Break	
10:00 AM-10:30 AM	Martin Botz	Towards the Influence of Chemical Ageing on The Constitutive Behaviour of Polymeric Interlayers in Laminated Glass Applications
10:30 AM-11:00 AM	Ralf Heinzmann	Comparison of cyclic movement testing according to ISO 19862 and two-year outdoor weathering with cyclic movement with different types of sealants and polymer bases
11:00 AM-11:30 AM	Geralt Siebert	Experimental and numerical investigations on the influence of chemical ageing on the load bearing behaviour of a U-type silicone façade sealing
11:30 AM-12:30 PM		Panel Discussion and wrap up.

Table of Contents

Monday Morning: General Overview

The Monday morning session is a general overview of service life prediction. In this section the talks will present the general state of service life prediction from many different perspectives. By the end of this session we all should be able to understand in broad terms the challenges and opportunities associated with predicting the in-service performance of polymers exposed to outdoor weathering.

Monday Morning: General Overview of Service Life Prediction
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Why is Service Life Prediction So Hard?

Jim Pickett

SABIC Innovative Plastics

Abstract
Service life prediction in general and weathering lifetime in particular have been persistent problems despite nearly a century of work. Part of the problem has been a gap between the work of scientists studying material degradation and the practices, needs, and desires of engineers who make the specifications and standards that drive most testing. In this talk, we describe why this gap exists and propose a way to close it using the methodology of service life prediction to develop predictive test conditions for specific classes of materials.

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Service Life and Practical Risk: Incorporating Failure Modes and Predictive Tools in Product Development

Maureen TF Reitman, ScD, Exponent

From building products to batteries, an understanding of relevant failure modes is important to managing risk and predicting the functional lifetime of a product. In this talk, we will review common frameworks for assessing risk and lifetime, and their applicability to industrially relevant systems. Examples will include products with relatively straightforward degradation mechanisms (e.g., lithium ion batteries) as well as products in which more than one mechanism maybe relevant (e.g., sealants and coatings). We will review and compare theoretical frameworks, practical assumptions and simplifications, consensus standards and other empirical approaches in the context of product development, risk management, and customer expectations for various industries. This talk provides a foundation for scientists and engineers to address service life and use the associated tools to avoid premature failure and mitigate risk.

Maureen Reitman
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Ex|50 Celebrating 50 Years

Accelerated Weathering

Ken White

Abstract:
This tutorial teaches the principles of accelerated weathering and discusses the methods and instrumentation that are employed to conduct exposure tests. The effects of elevating the levels of stress from light, heat, and water are considered and rates of material degradation caused by them are assessed and assembled into a model that is useful for service-life prediction.

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Service Life Prediction from an End-User Perspective

Mark Nichols Ford Motor Company

Abstract
The Service Life Prediction methodology is difficult to implement from an end-user perspective due to manufacturing noise, system interactions, and a diverse supply base. Traditional durability testing has involved subjecting materials and components to accelerated tests, of dubious correlation, and assessing their performance after a specified test duration. Comparisons to acceptance criteria are made either quantitatively via hard metrics, or qualitatively via subjective evaluations or a panel of experts. Materials or components are often subjected to outdoor testing to provide higher fidelity data, but at the price of longer time scales. This often proves problematic, as the more trustworthy (natural weathering) tests take longer, and can fail to capture all failure modes. In addition, the service environment for many products can be diverse. As outdoor exposure is typically done in harsh climates, the translation of those results to other geographic regions can be challenging and may miss certain failure modes. The manufacturer of complex products is forced to choose between risk, cost, and product development time. Examples and implications of these constraints will be discussed.

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Structural Insulated Panels for Housing Construction: Development of Guidelines to Assess Composite Durability for a Fifty-year Service in the Canadian Climate

Masson*, **J-F.; Collins**, **P.; Banister**, **C.;** Makar , **J.; Di Lenardo**, **B**.

National Research Council of Canada, Construction Research Centre

Abstract:
Housing construction is an important driver of the world economy. In terms of gross-domestic production (GDP), it represents in most countries about 14% of GDP, and it is second in size only to food production. With sustained growth in global population, there is a continued need for more housing. New dwellings should be designed and constructed to be more energy efficient to reduce as much as possible energy consumption and greenhouse gas emissions. Greater air-tightness and better insulated building envelopes in new housing are important contributors to this need.

Structural insulated panels (SIPs) are used increasingly to build energy efficient building envelopes. SIPs consist of stress-bearing skin panels on either side of a rigid insulation panel. Starting in the 1950's, Buckminster Fuller produced SIPs with metallic panels and polyurethane cores. However, to this day, only a small percentage of new dwellings is produced with SIPs, with most of it consisting of SIPs with skins of oriented-strand board (OSB). The lack of knowledge of SIPs amongst home builders and the lack of data on engineering properties and durability currently limits engineers and architects from specifying SIPs in housing construction. To address this need, the National Research Council of Canada and the Canadian Construction Material Centre have recently addressed issues related to the durability of SIPs for Canadian construction as part of a program to demonstrate compliance of these products with the National Building Code of Canada.

This paper details aspects of a program to assess the durability of SIPs in conditions that simulate service-life in Canadian climatic conditions. In service, SIPs are exposed to physical and chemical aging. The physical processes include cyclic weathering conditions, whereas the chemical processes include oxidation and hydrolysis. The results of testing indicate that all SIP components are subject to aging deterioration under a simulated 50-year service life, and that aging deterioration can begin relatively early during service. This has been demonstrated by means of tensile testing of SIP coupons, and Fourier-transform infrared spectroscopy and dynamic mechanical analysis of SIP components. The outgrowth from this program was a guideline to assess acceptable performance of SIPs over a service life of fifty years.

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Monday Evening: Successful Thermal implementations of SLP

Monday Evening session following the reception will present two different industries that have had success with service life prediction based on a thermal degradation of the polymer systems. We should learn from these two examples the elements of the service life prediction that allowed the models to successfully predict thermal aging.

Discussion Leaders: Nark Nichols, Tom Fabian

Time	Presenter	Title
6:30 PM- 7:00 PM	Helena Chiang	UL Roadmap for Long-Term Thermal Aging Program
7:00 PM - 7:30 PM	Bertrand Roduit	Prediction of shelf life of materials from forced degradation studies based on different analytical techniques by using advanced kinetic and statistical analysis
7:30 PM – 8:30 PM		Panel Discussion and (7:30 PM-8:30 PM)

UL Roadmap for Long-Term Thermal Aging Program

Helena Chiang, **Thomas Fabian**, **George Fechtmann**, **Prasad Shankarappa UL LLC**

Abstract:
UL 746B is the standard describing the procedures to evaluate the long-term properties of polymeric materials that are intended to be used as parts for specific applications in end products. The defined temperature rating in the standard, the Relative Thermal Index (RTI), is a measure of a material's thermal endurance indicating its ability to retain a particular property (electrical, mechanical, etc.) after exposure to an elevated temperature for an extended period of time. For those applications concerned with the long-term thermal aging of polymeric materials, the relevant product standard may specify the particular part fulfilling RTI requirements to ensure that the critical property may not be unacceptably compromised through thermal degradation over its service life.

In UL 746B, the RTI rating(s) of a polymeric material can be assigned via two approaches: (1) a generic rating based on historical records of certain chemical structures, and (2) an elevated RTI determined through a long-term thermal aging (LTTA) program of conventional heat aging tests. UL's LTTA program adopts a comparative approach to compare the thermal-aging characteristics of one material with another reference material whose service experience or performance has been established. In this process, the Arrhenius equation is applied as life expectancy model to establish time-temperature relationship (life-line) of materials. Then the RTI value of the material under investigation can be determined by extrapolation to the life of the correlating reference material. In case the reference data is absent, an extrapolated life of 100,000 hours is used to assign a RTI. Since the 1950s, thousands of materials have been evaluated for elevated RTI ratings via this program. Nowadays the industry relies on the represented RTIs for benchmark or selecting suitable materials.

Although RTI ratings have been widely accepted, the industry and UL continue looking for methods to enhance the LTTA program. One of the main reasons is the heat aging tests generally take several months to more than a year to complete. In some cases the analysis results are not as expected and there is no clear guidance defined in UL746B. Additionally, there are new methodologies and alternative approaches proposed to assess thermal endurance within the program. Thus how to accelerate the process and enable more accurate estimation of life expectancy are important drivers for change.

In order to deal with these challenges and strengthen the integrity of RTI measurements while coordinating the necessary supporting research, the development of a roadmap for UL's LTTA program was initiated. The objectives of this roadmap cover different aspects: ensure the data quality of testing, introduce new techniques to advance the evaluation process, and include alternative temperature ratings to accommodate the need in product design. The project ideas and strategic plan are also proposed to drive the results in this work. Now the LTTA roadmap is under final refinement stage and will be implemented in the near future.

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Helena.Chiang@ul.com, Thomas.Fabian@ul.com, George.J.Fechtmann@ul.com, Prasad.Shankarappa@ul.com

Prediction of shelf life of materials from forced degradation studies based on different analytical techniques by using advanced kinetic and statistical analysis

Roduit B1, Hartmann M 1, Folly P2, Sarbach A2, Dejeaifve A3, Dobson R3

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3PB Clermont EURENCO Group, Rue de Clermont, 176 - 4480 Engis, Belgium

Abstract
One of the most important goals of the investigation of the kinetics of the thermal behavior of materials is the possibility of the application of the computed kinetic parameters for the prediction of materials' properties at temperatures higher or lower than those used during the data collection. The applications of the kinetic approaches for the extrapolation of materials' behaviors at lower or higher temperatures are well known, however, they are generally based on continuous data collection when plenty of experimental points are available for kinetic analysis. This study presents the possibility of a correct kinetic determination based on a limited amount of experimental points, which is a common situation for those working with e.g. stabilizers, ingredients, pharmaceuticals, biotherapeutics, vaccines, polymers, when very often only few experimental points can be collected in acceptable periods of time. In such situations, the kinetic analysis, based on scarce data, is impossible using the commonly applied isoconversional analysis [1] and requires another kinetic approach.
In this study, we apply a specific kinetic based method [2] which is required in the case where available data are in the form of only sparse experimental points collected in discontinuous mode. We illustrate our method by the results of the elaboration of approximately 15-30 data points only and present the kinetic and model selection procedures allowing the evaluation of kinetic parameters and rational prediction of the reaction course. The proposed method delivers prediction bands (e.g. with 95% confidence) showing scattering of the data and allows considering the uncertainty of the best-fit curve being particularly valuable for thermal aging predictions. The proposed method is can be applied for any data reporting the changes of the properties for all kinds of materials. In the present study, the approach is illustrated for determining the chemical and ballistic stability of propellants. The evaluation of the kinetic parameters from only a few points is based on data collected by (i) Heat Flow Calorimetry (HFC), (ii) High Performance Liquid Chromatography (HPLC) for stabilizer depletion, (iii) Vacuum Stability
Test (VST) and (iv) ballistic firings (pressure peaks during the combustion process). Using the proposed method, it is possible to verify the selection of the best kinetic model and computed kinetic parameters by the experimental points collected after several days or even years by checking if they are laying inside the prediction bands. The results clearly indicate that the data collected during few weeks at higher temperatures of 70, 80 and 90°C can be used for the correct prediction of the reaction course even during 7 years at 50°C. After successful validation of the kinetic analysis with experimental data, it was possible to uncover the differences of the reaction course for the various propellant properties in different climates and storage conditions.

1. Roduit B, Hartmann M, Folly P, Sarbach A, Brodard P, Baltensperger R. Determination of thermal hazard from DSC measurements. Investigation of Self Accelerating Decomposition Temperature (SADT) of AIBN. J. Therm. Anal. Calorim. 2014;117: 1017-1026.
2. Roduit B, Hartmann M, Folly P, Sarbach A, Baltensperger R. Prediction of thermal stability of materials
by modified kinetic and model selection approaches based on limited amount of experimental points. Thermochim. Acta. 2014;579: 31-39.

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Tuesday Morning: Service Life Prediction, Specific issues.

Tuesday morning presentations delve into specific general issues related to service life prediction. From understanding the degradation mechanism, color component analysis, estimate the climatic conditions, to progress on a series of polymer materials, these talks detail how to construct a service life prediction method. By the end of this session, we should be able to define the components of a successful service life prediction method.

Discussion Leaders: Erica Redline, Jim Pickett, Graham Duthie

Time	Presenter	Title
7:00 AM- 8:00 AM		Continental Breakfast.
8:00 AM- 8:30 AM	K. White	Unraveling Reaction Pathways to Predict Degradation Rates in PET
8:30 AM- 9:00 AM	Kurt Wood	Use of Color Component Analysis to predict the color service life of fluoropolymer-based architectural coatings
9:00 AM- 9:30 AM	Erik Sapper	In Life, Death: Service Life Prediction and the Automated Design of New Polymeric Materials
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10:30 AM- 11:00 AM	James Pickett	Accelerated weathering parameters for aromatic polymers
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11:30 AM- 12:30 PM		Panel Discussion
12:30 PM- 2:00 PM	LUNCH	

Unraveling Reaction Pathways to Predict Degradation Rates in PET

Ken White, 3M

Application of accelerated laboratory weathering to predict service life in an outdoor environment has been demonstrated previously for color fade in a dyed polymer film. Extending the same experimental protocol to degradation in a neat polymer film poses significant challenges because of the potential for multiple reaction mechanisms that can exhibit complex interactions and failure modes. Although such interactions have been discovered in weathering studies of unstabilized poly(ethylene terephthalate) films (PET), it was possible to focus on one reaction pathway to model the degradation rate as a function of irradiance and sample temperature. Using climate data in the model yielded a prediction for degradation at an outdoor site which was assessed relative to natural weathering observed for PET exposed at the site.

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Use of Color Component Analysis to predict the color service life of fluoropolymer-based architectural coatings

Kurt Wood, **Arkema, Inc**.

Abstract
For premium architectural coatings in regions of the color palette requiring the use of organic pigments, it can be difficult to estimate the color service lifetime, since common accelerated weathering cycles often do not accurately reproduce the details of observed Florida color changes in a reasonable time. In this paper we examine Florida and accelerated data for polyvinylidene fluoride (PVDF)-based coatings with organic pigments from several color families. By connecting with a generalized weathering model for PVDF coatings, color component analysis is used to gain mechanistic insights about the relative rates of different weathering processes. Using color data from pigment volume concentration ladder formulations, observed weathering changes in the chroma (C*) color component can be converted quantitatively into changes in the effective concentration of the organic pigment. We consider the implications for developing coatings with color lifetimes of 20 years or more, in "exotic" regions of color space.

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In Life, Death: Service Life Prediction and the Automated Design of New Polymeric Materials

Erik Sapper, **California Polytechnic State University.**

Abstract:
Traditional material design methodologies focus on performance. While these methods are capable of producing new materials with interesting functionalities, the serviceable life of these materials is usually an afterthought. Service life prediction methodologies can be successful in estimating performance over time, but are usually exercised in the domain of the end-user, after the material design cycle is completed. Advances in applied artificial intelligence and machine learning methods are enabling a new class of material design methodologies. These approaches utilize genetic algorithms and evolutionary programming, along with principles of autonomous science, in order to automatically and efficiently design new materials that fulfill specified performance functions. However, these methods still focus on initial, optimal, or "time zero" performance, and do not incorporate knowledge of service life, outdoor exposure, or performance deterioration with time. This work proposed a new methodology, which incorporates service life prediction concepts into autonomous material design cycles. The objective is to create computer programs that can design new, functional polymeric materials that can also meet rigorous serviceable life requirements common to many industrial applications. Emphasis will be placed on how present understanding of failure modes can be translated to autonomous materials discovery algorithms currently being developed.

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How long should I run my weathering test to reproduce 1 year of outdoor aging?

Olivier Rosseler, **Saint-Gobain**

Abstract:
Isn't it funny how sometimes the simplest questions can have the most complex answers? The most frequently asked question when it comes to aging tests probably is "How long should I run this accelerated test to reproduce 1 year of aging?". It is a simple question that our community has been investigating for years and years which only has one good answer: "Well… it depends". However, that answer is not good enough.
The field of service life prediction is becoming increasingly adept at generating predictive equations for various materials, based on experimental data and degradation kinetics. These equations calculate the amount of property change as a function of time and stressors' intensity. Climate data are used as inputs. Therefore, in addition to predictive equations, we seek ways to better estimate the climatic conditions samples are exposed to in any given location to more accurately answer our initial question. This presentation will cover our efforts in an ASTM working group within theG03 committee on weathering to standardize UV calculations to estimate how much UV radiant dose a product receives over the course of a year as a function of location, tilt angle and orientation.

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Accelerated weathering parameters for aromatic polymers

James Pickett[2], **Olga Kuvshinnikova**[1], and **Li-Piin Sung**[3]

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The NIST SPHERE was used to investigate reciprocity, activation energy, relative humidity, and wavelength effects on the yellowing and gloss loss of four engineering thermoplastics: BPA polycarbonate (PC), poly(butylene terephthalate) (PBT), a PC/PBT blend, and poly(styrene-coacrylonitrile) (SAN), all pigmented white with coated, rutile TiO2. All four materials exhibited excellent reciprocity, that is, the yellowing and gloss loss scaled with radiant exposure independent of the irradiance. Reciprocity was demonstrated at 35, 55, and 70 °C at four irradiance levels. Arrhenius plots of the data gave activation energies in the range of 4-5 kcal/mol (17-21 kJ/mol) for yellowing and 2-4 kcal/mol (8-17 kJ/mol) for gloss loss. The only effect of humidity on yellowing was for 0-10% RH SAN; all other materials exhibited little or no humidity effect. The effect of humidity on gloss loss was larger for PBT and SAN, but was complicated by the lack of water spray. Overall, it appeared that a moderate level of relative humidity was sufficient to reproduce outdoor effects. Exposures through band pass filters showed rates due to UV centered at 306, 326, and 354 nm. The wavelength information is useful for full weathering models, but is not essential if weathering is done with light sources that closely match sunlight. Xenon arc weathering data obtained using state of the art filters were interpreted using these findings, giving excellent predictions of Miami, Florida performance for these four materials. Gloss loss of black samples was predicted less successfully, indicating a need for better reproduction of the effects of rain in accelerated weathering devices.

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Outdoor and xenon arc weathering of aromatic engineering thermoplastics

Olga Kuvshinnikova, Gert Boven, James Pickett, SABIC Innovative Plastics

Abstract:
A series of 31 aromatic engineering thermoplastic formulations was exposed to weathering at three outdoor sites: Miami, Florida; Phoenix, Arizona; and Riyadh, Saudi Arabia as well as in a modified ISO4892-2 xenon arc protocol (Right Light™ filters, 0.75 W/m2 irradiance). Color shifts, 60° gloss, haze and transmission for transparent samples, erosion, tensile properties, and Charpy impact were measured and compared. After 18 months of outdoor weathering, most materials were significantly degraded or had reached a steady state. There was little difference noted for most properties among the outdoor sites when the data were evaluated as functions of radiant exposure. Erosion was slower for a number of samples at the very dry Riyadh site. Color shift, erosion, transmission of transparent samples, tensile elongation at break, and Charpy impact mode were generally well-predicted by the xenon arc protocol using a rational correlation factor. Gloss loss of white samples also was well-predicted, but gloss loss of black samples and haze of transparent samples were not reliably predicted, probably due to poor simulation of the effects of rain (and/or wind) in the accelerated weathering device. This indicates that using proper xenon arc lamp filters and making reasonable temperature corrections allow prediction of many properties after weathering, including mechanical properties. Reproducing the washing effects of rain remains a challenge.

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Tuesday Evening: SLP concerns for Automotive Industry

Tuesday evening, following our dinner at Carrillis restaurant, we have two talks focused on issues related to the automotive industry. Both talks are focused on issues related specifically related automotive coatings.

Discussion Leaders: LiPiin Sung, Erik Sapper, Ingo Alig

Time	Presenter	Title
6:30 PM- 7:00 PM	Jennifer David	An Analysis of Thermal and Humidity Cycling Stresses in Automotive Hard Coatings
7:00 PM - 7:30 PM	Mark Nichols	Stone Chip Performance of Automotive Paint Systems
7:30 PM – 8:30 PM		Panel Discussion (7:30 PM-8:30 PM)

An Analysis of Thermal and Humidity Cycling Stresses in Automotive Hard Coatings

Jennifer David, **Momentive Performance Materials, Inc**.

Abstract:

In designing a hard coat system to protect exterior plastic components found in automobile applications (headlamps, sunroofs, pillars), a critical consideration is the lifetime of these hard coats in the field. It is necessary to predict the expected lifetime of the coating, before cracking and delamination compromise the optical quality of the part or the integrity of the plastic component it protects. Numerous test protocols exist that accelerate real world conditions (temperature, humidity, and ultraviolet exposure) in order to develop a predictive look at the coating performance within a reasonable development timeframe. In the case of cracking, the failure of a coating may be anticipated when the instantaneous stress the coating experiences exceeds some threshold determined by the properties of the coating as initially prepared, and taking into account any changes in those properties due to weathering exposure. In this study, a stress meter is used to measure the instantaneous stress of siloxane resin type coatings (ca. 5-10 micron thickness) when subjected to the temperature and humidity cycling conditions found in accelerated tests that are typical for automotive qualifications. A comparison is made of the relative importance of humidity and temperature as contributors to coating stress and ultimate cracking failure.

Stone Chip Performance of Automotive Paint Systems

Tony Misovski and Mark Nichols Ford Motor Company

Abstract

A single projectile impactor was designed to quantify the stone chip resistance of automotive paint systems. As paint's damage mechanisms during stone impact are not well understood, the impactor was used to quantify the effects of projectile speed, shape, kinetic energy, and edge geometry, as well as temperature, basecoat color, film build, and intercoat adhesion. High speed photography and non-contacting profilometry were used to quantify the volume of material removed during chipping and the details of the removal process. Impactor speed, paint system chemistry/process, basecoat color, and impactor angle were all shown to significantly affect the amount of material removed during impact. The data from single impactor experiments was compared to traditional gravelometer experiments, instrumented components from proving ground experiments, as well as data from customer vehicles. The potential sources of energy dissipation during chipping as well as potential mechanisms to improve stone chip performance will be discussed

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Wednesday Morning: Specific Exposure issues with SLP: Water and Light

The Wednesday morning session is focused on how specific weathering factors can be included in a successful service life prediction program. Specifically, the issues related to water, (in its many forms) light, and temperature (specifically sample temperature) will be discussed. By the of this session we should have a healthy appreciation for the complexities of these three weathering factors.

Discussion Leaders: Ken White, Libby Glascoe, Michael Kempe

Time	Presenter	Title
7:00 AM-8:00 AM		Continental Breakfast.
8:00 AM-8:30 AM	Mat Celina	Rapid IR Flow-Through Method for Volatile Quantification in Thermoset Ageing used for Lifetime Predictions
8:30 AM-9:00 AM	Erik Linde	Water Diffusion in Thermoset Amorphous Materials - Influence of the Glass Transition Temperature
9:00 AM-9:30 AM	Karl-Anders Weiß	Interaction of Permeats During the Measurement of Permeation Coefficients of Dense Polymer Films Under Realistic Conditions
9:30 AM-10:00 AM	Coffee Break	
10:00 AM-10:30 AM	Glascoe	Predicting chemical compatibility and aging of materials in a system a combined experimental and modelling approach
10:30 AM-11:00 AM	Doug Vermillion	Introduction to Metal Halide Weathering Chamber for Accelerated Material Testing
11:00 AM-11:30 AM	Matt McGreer	The Importance of Specimen Surface Temperature for The Understanding Of Correlation And Service Life Prediction
11:30 AM-12:30 PM		Panel Discussion
12:30 PM-2:00 PM	LUNCH	

Rapid IR Flow-Through Method for Volatile Quantification in Thermoset Ageing used for Lifetime Predictions

Mathew Celina, Nick Giron Sandia National Laboratory

Abstract:

Accelerated aging of polymers at elevated temperatures often involves the generation of low molecular weight volatiles. These can be formed as the products of oxidative degradation reactions or intrinsic pyrolytic decomposition as part of polymer scission reactions and thermally induced polymer degradation. We are therefore interested in a simple analytical method for the quantification of water, CO_2, and CO as fundamental signatures of degradation kinetics and the magnitude of degradation chemistry. We present a new analytical framework and rapid mid-IR based gas analysis methodology to quantify volatiles that are contained in small ampoules after aging exposures. The approach requires identification of unique spectral signatures, systematic calibration with known concentrations of volatiles, and a rapid acquisition FTIR spectrometer for time resolved successive spectra. The volatiles are flushed out from aging ampoules with dry N_2 carrier gas and are then quantified through spectral and time integration. This method is sufficiently sensitive to determine absolute yields of ~ 50 µg water or CO_2, which relates to probing mass losses of less than 0.01% for a 1 gram sample, i.e. the early stages in the degradation process. Such quantitative gas analysis is not easily achieved with other approaches.

This approach enables a method to quantitatively monitor volatile evolution as an avenue to better understand polymer degradation kinetics and its dependence on time and temperature, all in the context of lifetime prediction based on degradation chemistry as presented for accelerated aging of an epoxy material.

Key words: Accelerated aging and predictions, thermo-sets, thermal stability, IR gas spectroscopy, volatile analysis, off-gassing quantification, degradation chemistry kinetics.

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Water Diffusion in Thermoset Amorphous Materials – Influence of the Glass Transition Temperature

Erik Linde, Mathew Celina Sandia National Laboratory

Abstract:
Polymer components in service are often exposed to water, as either humidity or liquid water, which can affect the degradation behavior and stability of the polymer. The water diffusion properties are thus important as they influence the water distribution within the material. However, the diffusion process is temperature dependent, and the diffusion behavior must be known in order to predict the distribution of water at elevated temperatures for accelerated aging and weathering. This presentation will discuss experimental and computational methods (1D to 3D) to determine water diffusivity, as well as show comprehensive diffusivity data, determined from TGA and NIR measurements, for a range of amorphous epoxy systems over a wide temperature range. The epoxy materials were chosen to have varying glass transition temperatures (*Tg*), from below room temperature up to 240°C, in order to determine the influence of *Tg* on the diffusion process. Computational models and experimental data are then used to illustrate the impact of geometry and temperature on diffusion kinetics, and drying or sorption behavior of thermoset materials. Diffusivities for a range of epoxy-amine systems with different Tg as a function of temperature

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Interaction of Permeats During the Measurement of Permeation Coefficients of Dense Polymer Films Under Realistic Conditions

Karl-Anders Weiß, Andreas Piekarczyk, Fraunhofer ISE

Abstract:
The permeability of polymer film is not only an important issue for many applications. Especially in electronic devices the presence of humidity and oxygen leads to chemical reactions and can cause failures of components. This requires the knowledge of the permeation coefficients to compare different materials for defined applications. Small permeation coefficients are required if a thin polymer film has to maintain a barrier for many years. Adequate measurement devices are limited in terms of applicability and precision. In this study measurements of polymer films, which are used in photovoltaic modules (PV), are analyzed. Experimental Setup and Procedure In order to mimic realistic conditions measurements are performed using ambient air with a variable relative humidity as permeate mixture. The experimental setup consists of gas transmission cells, a climate chamber and a mass spectrometer as detector. The inside of the gas transmission cell (GTC) is separated from the climate chamber by the specimen. Prior to the measurement the partial pressure of all measured permeates in the GTC is reduced. For the measurement the GTC is closed off and the concentration and the total pressure is monitored in regular intervals. During the measurement the relative humidity is increased. Data/Results and discussion from the concentration recorded in the GTC over time the partial pressure inside and outside the GTC has been calculated. The permeation coefficients for oxygen show a remarkable variation over the course of the measurement. They have constant, but different values, before and after the increase of the humidity. Both show a slight decrease over time. Short after the increase of the relative humidity there is a strong increase in the values. This variation of the permeation coefficient indicates not only that the concentration of the two permeates water vapor and oxygen has an influence on the determined value but also that the permeation process is influenced by the rapid changes conditions with increasing humidity. This can be seen as an indication for the competition of different permeation processes. Depending on the permeation model this effect can be explained by a change of the chemical potential of the polymer film at different humidity levels resulting in different absorption and desorption rates of the other permeates. Using a molecular diffusion approach based on diffusion channel's inside the polymer film this effect can be mostly explained by different temperature-dependent channels diameters and different mass and volume dependent diffusion rates for individual gasses. Both explanations are expected to be strongly influenced by the specific material which requires further measurements for validation. Conclusions
The data shows that the permeation of permeates cannot be treated individually, which should be also reflected in the measurement methodology. Therefor the values obtained with single permeate measurements have limited significance for real applications. Further it has been identified that a variation of the environmental conditions can lead to changes in the coefficients. Based on the interpretation model cyclic changing conditions, like a periodical change of the relative humidity, may lead to much higher coefficients than measured under stationary conditions.

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Predicting chemical compatibility and aging of materials in a system: a combined experimental and modelling approach

Elizabeth A. Glascoe, Hom Sharma, and Yunwei Sun, Lawrence Livermore National Laboratory

Abstract

Predicting the aging and compatibility of materials in a system or sub-system is important to establishing the lifetimes and viability of current assembly and screening new materials for future designs. In addition to traditional screening methods and analytical tools for investigating material compatibility and aging, LLNL is developing a novel tool to predict the compatibility using reactive transport modeling. The challenge with multi-material assemblies is that the degradation products of one material may initiate a chain-reaction that could not be simulated with binary combinations of materials. Experiments on multi-material assemblies are critical to establishing compatibility on a system level. However, it is often difficult to establish the problem material or materials because of the complexity of the system.

We are developing a reactive transport modeling capability to address these kinds of issues. Our model includes (1) a triple-mode sorption model that includes absorption, adsorption, and pooling of species, (2) molecular diffusion, and (3) chemical reaction kinetics. Using a 1D or 3D mesh we can simultaneously simulate the transport and chemical reactions of mobile species through polymeric and organic materials. Recently we have explored the viability of predicting 3D moisture sorption/outgassing experiments with parameters derived from 1D experiments, expanded the capability to gas-sorption and diffusion modeling, and commenced experiments to validate the chemical reaction portion of the model. This talk will discuss our overall approach to compatibility and aging at LLNL, with an emphasis on our modeling approach. We will report on our progress to date, which will include, model development and experimental work using polymeric systems to parameterize and validate the model.

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Introduction to Metal Halide Weathering Chamber for Accelerated Material Testing

Doug Vermillion, **Iwasaki- Applied Optics**

Abstract:
Material testing is a time consuming process that is critical to enhancing product quality. This is particularly true of products that are exposed to outdoor elements. Plastics will crack and paint colors will fade when exposed to sunlight, temperature, humidity and wind.
Manufacturers have used weathering chambers for years to simulate outdoor conditions. New metal -halide lamp material testing equipment are available that allow for highly accelerated environmental testing. This equipment can generate UV irradiance up to 30 times that of natural sunlight, and the user may program varying UV, temperature, humidity and shower cycles. Acceleration factors are more than 10 times those of traditional testing chambers depending on the material type.
This presentation will provide background on the highly accelerated environmental test equipment operation including test result examples that show the correlation between lab testing and outdoor "control" testing. Artificially accelerated testing has the combined benefits of dramatically decreasing testing time while significantly increasing efficiency of R&D, quality control, process control and profitability.

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The Importance of Specimen Surface Temperature for The Understanding of Correlation And Service Life Prediction

Matt McGreer, Dr. Florian Feil, Atlas Material Testing Technology

Abstract
The surface temperature of a material exposed to solar radiation or to artificial xenon-arc radiation is critical for its degradation behavior. However, due to the lack of practicable measurement techniques, the surface temperature is usually only estimated based on reference thermometers, such as insulated (black standard thermometers) or uninsulated black panels (black panel thermometers), which may, but not always, represent the hottest temperature a surface can achieve in a specific environment. However, small variances in the estimates can lead to significant different lifetime predictions. Surface temperatures of individual samples can be performed with thermo-elements or platinum resistance elements in outdoor exposures and in laboratory weathering using data-loggers. A recently developed technology allows determining the surface temperature of multiple individual specimens during the exposure in an operating xenon-arc weathering instrument using an IR-pyrometer (Specific Sample Surface Temperature/S³T Technology). Knowing the exact surface temperature facilitates the comparison between different weathering experiments, such as accelerated laboratory and outdoor weathering, or between differently colored samples. This data can also help weathering experimenters to refine the test parameters of artificial weathering cycles towards the sample properties, such as the glass transition temperature or other destructive processes. It can also assist in the development of customized testing cycles to provide better replication of end-use service environment conditions, potentially improving correlation to those natural outdoor exposures. In this paper, examples of real surface temperatures measured under a variety of test conditions and the resulting impact on understanding the details of degradation behavior will be discussed. Data collected with the S³T technology will be presented for a variety of materials (polymers, coatings, textiles). In addition, we present how contact-less surface temperature measurements during artificial weathering can be used to determine the activation energies of photochemical degradation processes, such as photo-yellowing or photo-fading. It will be shown how significant the consideration of temperature can be and how it can be used to improve life time and correlation studies. Since the knowledge of the temperature helps to understand and predict degradation processes in weathering, it can also be used to improve reliability and reproducibility of accelerated testing.

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Thursday Morning: Service Life Prediction Modelling

Thursday morning session will present the progress on modelling service life prediction. Specifically linking multiple environmental variables together and then predicting the in-service performance of those materials. Combinations of moisture, UV light and temperature, UV light, temperature and strain, ASTM methods, and other procedures to produce the degradation will be used create predictions for the in-service performance of polymer materials. This session should illustrate the current state-of-the-art in modelling related to these environmental exposures.

Discussion Leaders: Bertand Roduit, Adam Pintar, Kurt Wood

Time	Presenter	Title
7:00 AM-8:00 AM		Continental Breakfast.
8:00 AM-8:30 AM	Adam L. Pintar	Building Hierarchical Bayesian Models for Sealant Data from the NIST Solar Sphere
8:30 AM-9:00 AM	Li-Piin Sung	Predicting outdoor weathering of PE using NIST SPHERE methods
9:00 AM-9:30 AM	Donghui Li	Multivariate Multiple Regression Models of the Waterborne Acrylic Coating Degradation under Multi-Factor Accelerated Weathering Exposures or Degradation of Waterborne Acrylic Coatings under Accelerated Weathering Exposures
9:30 AM-10:00 AM	Coffee Break	
10:00 AM-10:30 AM	Hom Sharma	An experimental and triple-mode sorption modelling of sorption and diffusion in polymeric materials
10:30 AM-11:00 AM	David Miller	Degradation in PV encpasulant transmittance: Results of the first PVQAT TG5 study
11:00 AM-11:30 AM	Ingo Alig	Accelerated Thermal Aging of Thermoplastic Materials: Combination of material characterization and cyclic fatigue testing
11:30 AM-12:30 PM		Panel Discussion
12:30 PM-2:00 PM	LUNCH	

Building Hierarchical Bayesian Models for Sealant Data from the NIST Solar Sphere

Adam L. Pintar[1], **Christopher C. White**[2], **Donald L. Hunston**[3], **and James J. Filliben**[1]
National Institute of Standards and Technology

Abstract
The NIST SPHERE accelerates the degradation of sealant materials by continuously exposing the samples to UV radiation. Other factors or weathering conditions thought to affect degradation such as temperature, humidity, and mechanical strain are also part of the exposure conditions on the NIST SPHERE. In generic terms, the data resulting from a sealant SPHERE exposure experiment is a history of degradation, or inversely, reliability, at fixed values of the weathering conditions. Combining data from multiple experiments yields a collection of histories across multiple weathering conditions. A Bayesian hierarchical model is a natural fit for such data. At the lowest level, the individual histories are modeled. At the second rung, we imagine a model that forms a continuous bridge between the models for the individual histories. In some cases, a third level may be desired to control the bias-variance tradeoff of the interpolation occurring at the second level. At each step, modeling assumptions are made that affect the eventual predictions of the model. In this talk, strategies for choosing assumptions at each level, and the effect of those assumptions on predictions are discussed. The importance of cross validation for evaluating model assumptions is discussed too. Recent SPHERE experiments for the Sealant A material will provide context.

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Predicting outdoor weathering of PE using NIST SPHERE methods

Li-Piin Sung, **Hsiang-Chun Hsueh**, **Lakesha Perry**, **Deborah Jacobs**, **Jae-Hyun Kim**, **Andrew Fairbrother**, **Chen-Yuan Lu**, **Donald Hunston**, **David Goodwin**, **Stephanie Watson**, **Adam Pintar**,
and Christopher White National Institute of Standards and Technology.

Abstract
Accelerated weathering methods have been widely implemented to rapidly evaluate the durability of thermoplastics used in the outdoor applications. Several questions remain: (1) if the degradation mode and mechanism of the polymer is the same under accelerated and the outdoor natural weathering; (2) if accelerated weathering results allow prediction of service life of the material. In this study, high-density polyethylene (HDPE) specimens were exposed both outdoor conditions (in Florida, USA) and on the NIST
SPHERE (Simulated Photodegradation via High Energy Radiant Exposure) at different temperatures and ultraviolet (UV) intensities (irradiance dose). The mechanical behavior of PE (via tensile testing) was measured and results followed similar trends in both outdoor and accelerating weathering conditions. Particularly, ductile behavior changed, then rapidly transited into brittle mechanical failure with increased exposure to both conditions. Accelerated weathering data (such as elongation at break values) collected on the NIST SPHERE were used to investigate reciprocity, kinetics of degradation (Arrhenius relationship and activation energy), and served as input for statistical modeling of the polymer degradation. In addition to mechanical properties, chemical and physical properties were also measured to evaluate the degradation mechanism of the PE on the NIST SPHERE compared with that for outdoor weathering.

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Multivariate Multiple Regression Models of the Waterborne Acrylic Coating Degradation under Multi-Factor Accelerated Weathering Exposures

Donghui Li*, **Noah Tietsor**t*, **Yiyang Sheng** §, **Adam Joselson**, **Roger French***‡, **and Laura Bruckman*** **Case Western Reserve University**

Abstract:

The service life of waterborne acrylic coatings is essential to exterior coating applications. In this study, the effect of photoreactivity of titanium dioxide (TiO_2) pigments on the durability and lifetime of acrylic waterborne coatings was investigated via accelerated studies. Two grades of acrylic waterborne coatings with low and high concentrations of anatase TiO_2 were exposed in accelerated exposures prescribed by ASTM G154 and G155. Longitudinal multilevel gloss and yellowness index data was modeled in a predictive <Stress | Response> framework by multivariate multiple regression (MMR). The MMR model takes advantage of correlations between the response variables to improve predictive accuracy for sevice life prediction. The quantitative <Stress | Response> framework is potential for the cross-correlation of accelerated and real-world exposures.

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An experimental and triple-mode sorption modelling of sorption and diffusion in polymeric materials

Hom N. Sharma, **Yunwei Sun, and Elizabeth A. Glascoe, Lawrence Livermore National Laboratory**

Abstract:

Sorption and diffusion in polymeric materials is of great interest in wide range of applications (e.g. electronic components to microfluidics).(1-3) To many application, moisture sorption and diffusion can be catastrophic due to the change in chemical and mechanical properties of materials over time. The uptake and outgassing of moisture is also associated with aging and compatibility issues in a system, which can directly alter the lifetimes and viability of system assemblies and screening new materials for future designs. The process is dynamic and consists of different sorption modes and varies dramatically in different materials. Therefore, a detailed understating of the moisture uptake and diffusion is crucial.

In this study, we investigate the moisture sorption and diffusion phenomena using a combined experimental and modeling approach. Polymeric materials (for example: KaptonH and Kapton HN) are investigated over a wide range of temperatures and relative humidities (RH) to quantify the moisture transport mechanism as shown in the figure 1 below. Gravimetric type dynamic vapor sorption (DVS) experiments were employed to measure the moisture uptake and used for the modeling. A reactive transport model is used which includes a triple-mode sorption model(3) that includes absorption, adsorption, and pooling of species, molecular diffusion, and chemical reaction kinetics. Our sorption experiments and modeling results quantify the differences between the two example materials and demonstrate a substantially larger adsorption capacity and moisture affinity for Kapton HN compared with Kapton H. A distinct pooling mode can be seen above 70% RH in both materials, however the pooling mode is larger in Kapton HN. We also show a simultaneous simulation of the transport and chemical reactions of moisture through those example materials. Density functional theory calculations are performed to investigate the impacts on moisture uptake due to $CaHPO_4$ filler, which is present only in Kapton HN.

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

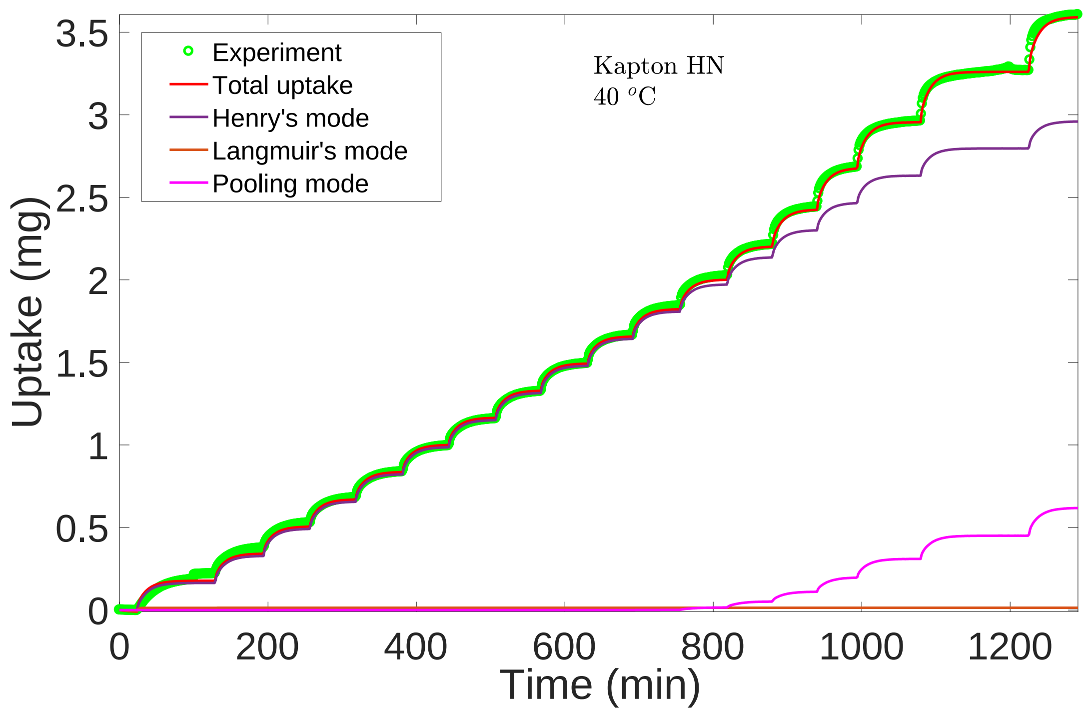

Fig 1: Experiments and modeling results of dynamic moisture uptake by Kapton HN at a range of relative humidities at 40°C.

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Degradation in PV Encpasulant Transmittance: Results of the first PVQAT TG5 study

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:
Abstract Title:

Abstract
Reduced optical transmittance of encapsulants resulting from ultraviolet (UV) degradation has frequently been identified as a cause of decreased PV module performance through the life of service in the field. The present module safety and qualification standards, however, apply short UV doses only capable of examining design robustness or "infant mortality" failures. The latest versions of the safety and qualification apply ~40-~160 days cumulative dose of the AM1.5G total UV radiation. Essential information that might be used to screen encapsulation through product lifetime also remains unknown. For example, the relative efficacy of xenon-arc and UVA-340 fluorescent sources or the typical range of activation energy for degradation is not quantified. We have conducted an interlaboratory experiment to provide the understanding that will be used towards developing a higher fidelity, more rigorous UV weathering test. Five representative, known formulations of EVA were studied in addition to one TPU material. Replicate laminated silica/polymer/silica specimens were examined at 10 institutions using a variety of indoor chambers (including Xenon, UVA-340, and high-pressure mercury light sources). Specimens were artificially weathered for 180 cumulative days at pre-designated accelerated test conditions. The solar-weighted transmittance, yellowness index, and the UV cut-off wavelength, determined from the measured hemispherical transmittance, are examined to provide understanding and guidance for the UV light source (lamp type) and temperature used in accelerated UV aging tests.

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Accelerated Thermal Aging of Thermoplastic Materials: Combination of material characterization and cyclic fatigue testing

Ingo Alig[*,1], **Harald Oehler**[1], **Dirk Lellinger**[1], **Karsten Rode**, **Frank Malz**[1], **Lena Mavie Herkenrath**[1], **and Jee young Youn**[2]

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Abstract:
In its service life plastic parts close to the automotive engine are exposed to both the weather conditions and the thermal load in the engine compartment. Because of new turbo charger systems or improved space-saving arrangements of the components the service temperature in the engine compartment is increasing. On the other hand there is an increasing demand to use plastic components for lightweight vehicles. For selection of proper materials, for improving the reliability of the plastic parts and to shorten the validation time by accelerated test methods, there is therefore a need for better models for estimation of durability and life-time of polymeric materials. In this study, physical and chemical characterization methods for thermoplastic materials and cyclic fatigue testing were combined to study changes in polymeric chain structure, molecular mobility and morphology as well as material properties during thermal aging. As a test material a commercial polyamide 6,6 with glass fibers (PA 66-GF) containing a typical additive package was studied. The specimens were aged at different temperatures in dry air. The mean times to failure (MTTF) and the related stress-number (S/N) curves were determined from stress controlled fatigue tests on specimens after different times of thermal aging. It was found that the MTTF decreases with aging time. Changes of mechanical properties were studied during and after thermal aging by tensile tests and dynamic-mechanical analysis (DMA). Changes in the thermo-physical properties such as melting and glass transition temperature or crystalline structure were studied by thermal analysis. For detection of changes in the molecular structure of the polymer chains gel permeation chromatography (GPC), time-of-flight matrix-assisted laser desorption/ionization (MALDI-TOF), nuclear magnetic resonance spectroscopy (NMR) and infrared spectroscopy (IR) were performed. Changes in morphology at the surface due to thermal aging and decomposition of the polymer matrix were studied by optical and scanning acoustic microscopy (SAM). Combining different characterization methods allows differentiating between aging mechanisms in semi-crystalline thermoplastic polymers such as thermo-oxidative degradation by chain scission, cross-linking and changes in the crystalline structure. Using chemical analysis allows discussing the property changes in relation to chemical reactions. The molar mass shows an initial increase followed by a decrease for longer aging times. The changes in elongation to break support the interpretation based on the GPC results. The mechanical moduli derived from DMA and tensile tests show a similar decrease with aging time. The results were used to derive input data for thermal aging models (e.g. Arrhenius law, effective aging time or temperature).

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Poster Session and Reception 5:00 PM -6:30 PM

Poster	Presenter	Title
1	Kaushal Gandhi	Acceleration Parameters for Polycarbonate under Blue LED Light
2	Barbara Siebert	All Glass Pavilion
3	Tin Fabian	Overview of the 746 processes.
4	Larry. Judovits,	Determination of Activation Energy using High Resolution TGA coupled with Modulated TGA.
5	Chris White,	Predicting Field Panel Temperature

Acceleration Parameters for Polycarbonate under Blue LED Light

Kaushal Gandhi, Christopher Hein, Rieko van Heerbeek, James Pickett. SABIC Innovative Plastics

Abstract:
Polycarbonate (PC) is used in LED lighting applications where it is known to discolor upon being exposed
to high intensity blue light at elevated temperatures. Testing and service life prediction are important considerations. We have tested several formulations of PC with a blue LED source emitting light at 450 nm in a commercially-available elevated temperature irradiance chamber (ETIC, Orb Optronics, Kirkland,
WA). Lifetime prediction requires knowing the effect of temperature (Arrhenius activation energy) and how degradation scales with light intensity or irradiance (reciprocity). The discoloration follows a linear/exponential curve, eventually entering a thermal runaway when the sample begins absorbing significant amounts of high intensity blue light. Data could be analyzed either by using the slope of the pseudo-linear portion of the curve for low levels of degradation or by using the shift factor/superposition method for higher levels of degradation. The activation energy ranged from 30 kJ/mol for unstabilized PC to ~46 kJ/mol for stabilized PC. This is significantly different from the 17-21 kJ/mol activation energy for outdoor weathering that is independent of stabilization and implies a different photodegradation mech+anism with blue light. The rate of discoloration was found to be linear with irradiance. The results indicate that there may be a more simplified means to calculate failure time, given the time of failure under known test conditions and the effective temperature and irradiance under other testing or use conditions.

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All Glass Pavilion

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The structural system consists on one hand of a glazed steel frame with four stanchions rigidly fixed to the base plate and connected by four transoms at the top and on the other hand of two laterally glass attachments. These are made of vertical load-bearing glass walls and a horizontal glass roof, which are connected among each other by structural sealants. The glass elements are also acting as bracing elements. Specifications of the building authorities called for a structural concept of the pavilion's glass attachments for different states of destruction. In addition, extensive requirements had to be fulfilled to obtain a special building permit for the structural sealants. In this construction, two types of structural bonding can be distinguished, also with regard to place of manufacture: Edge seal of insulating glass units: Factory bonding Assembling of the different IGUs: On site bonding In the IGU factory bonding of the individual layers in the glass edge seal took place using a structural silicon. Because the top and vertical edges of the glass walls are not braced by pressure plates, the sealant is stressed by wind suction and pressure differences between air space and atmosphere. Because the individual layers were supported vertically on the bottom edge by plastic blocks, no shear forces have to be considered from the dead load. First, the glass walls were erected and aligned on site. Thereafter, the ring anchors and roof panels were placed. The joints between ring anchors and glass were sealed with structural two-component silicon too. The joints were designed for the resultant of wind suction and dead weight of the roof panel according to ETAG 002. The project is an outstanding example for the possibilities in constructing with glass and sealants. It combines the structural features of a load bearing all glass building with state-of-the-art joint techniques.

Keywords: All glass building, Structural sealant

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Determination of Activation Energy Using High Resolution TGA coupled with Modulated TGA

L. Judovits[1],H. Chiang[2], & D. Francke[3] [1] Arkema, [2] UL LLC, [3] BASF SE

Abstract:
The UL Standard for Safety for Polymeric Materials – Long Term Property Evaluations, UL 746B, is a testing procedure that assigns a relative thermal index (RTI) that indicates an upper use temperature over a reasonable product lifetime. A UL product certification provides an important marketing tool that means your product has met conditions set by a UL standard for product safety. If a minor change is made to a formulation an alternative recertification could be requested to advance the RTI evaluation with possibly taking up to two years. So other accelerated lifetime techniques for recertification are being investigated such as Thermogravimetric Analysis (TGA) kinetic methods to determine an activation energy (E_a). The UL LTTA working group is exploring new methodologies to determine a quicker polymer lifetime prediction protocol to enhance existing accelerating lifetime prediction programs that are already in place. Multi-rate TGA kinetics (using the Flynn/Wall/Ozawa method) is currently being investigated [1]; however, the activation energy (E_a) determined by this method was found to vary with conversion as well as demonstrating a large lab to lab variation [2]. A question was raised if other TGA techniques may be helpful such as a combined modulated TGA (MTGA), which provides a direct calculation of E_a, with a high resolution algorithm. The high resolution mode is where the heating rate is continuously adjusted to changes in the rate of mass loss in order to achieve close to an isothermal temperature, which is hoped to provide a condition where a consistent E_a can be determined. A plateau region was determined in this mode making the determination of a consistent and readily identified E_a possible.

1. See for example ASTM E1641 or ISO 11358-2.
2. H. Chiang, private communication.

Predicting Field Panel Temperature

Chris White[1], **Eric Byrd**[1], **William Thomas**[2], **Cyril Clerici**[1], and **Larry Kaetzel**[1] **National Institute of Standards and Technology**

Abstract:

This work presents the development of accurate model predictions for panel temperature of model coatings. The model predictions are favorably compared with experimentally obtained field data. The panel temperature model is an analytical solution of first order differential equation aggregated-capacity thermal model expressions. Predictions for both white and black panel temperature are presented. The development of these two models allows for accurate prediction of the actual sample temperature and sample moisture content.

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Thursday Evening: Issues Relating Indoor Exposure to Outdoor Exposure

Thursday evening presents two talks focused on linking the laboratory produced exposure to outdoor exposure. This session will help illustrate some of the issues relating to trying to produce this linkage. By the end of this session we should be able to understand some of the complexities in relating these two sources of exposure data.

Discussion Leaders: Sean Fowler, Jim Pickett, David Miller

Time	Presenter	Title
6:30 PM-7:00 PM	Pierre Morel	Development of a combined testing technique to characterize coatings performance
7:00 PM-7:30 PM	Carlos Juarez-Garcia	Accelerated and Outdoor Weathering of non-PET aromatic polyesters and Polystyrene. Evaluation of the weathering Test Method ASTM D7869 to Simulate Miami Florida Outdoor Exposure
7:30 PM-8:30 PM		Panel Discussion (7:30-8:30)

Development of a Combined Testing Technique to Characterize Coatings Performance

Pierre Morel [a], Linqian Feng [b], Chen-Yuan Lu [c], Li Piin Sung [c], Andrew T Detwiler [b], Leslie T Baker [b], Deepanjan Bhattacharya [b]

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Abstract: A combined approach using Instrumented indentation and Scratch testing was proposed to characterize polymer films and specifically automotive coatings. The instrumented indentation yields the viscoelastic properties of the materials while the scratch testing assesses their resistance to surface damage. This combined technique allows a more quantitative and repeatable assessment of the coatings.

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Accelerated and Outdoor Weathering of non-PET Aromatic Polyesters and Polystyrene. Evaluation of the Weathering Test Method ASTM D7869 to Simulate Miami Florida Outdoor Exposure

Carlos H. Juarez-Garcia. Eastman Chemical Company

Abstract
Accelerated weathering experiments are often used to test the durability of articles to common simulated environmental stressors such as: sun light, environmental temperatures, water, relative humidity and others. There are many, industry specific, weathering test methods. These methods are intended to expose the specimens under investigation to repeated and controlled cycles of the variables mentioned above. However, these methods are only approximations to the real environmental conditions. Extensive efforts have been taken to fine tune methods to better mimic the stressor levels, their durations and the general conditions experienced by articles when exposed to real life conditions. One of these efforts resulted in the development of a new transportation coatings weathering test method ASTM D7869. Although this method was developed to test the durability of transportation coatings it may well apply to other systems. One of the requirements for an accurate weathering test method is its ability to reproduce the changes (failure modes) experienced by the specimens under investigation when exposed to the outdoor conditions. If the application of accelerated method cannot reproduce these changes then the method may be of poor applicability. This report summarizes the experiments and the results obtained when comparing the behavior of a non-PET aromatic polyester engineering thermoplastic and polystyrene to real outdoor exposure and the conditions of ASTM D7869. This report shows that ASTM D7869 is an excellent method to study the accelerated weathering of non-PET aromatic polyester engineering thermoplastic like materials. The method reproduces very well the observed failure modes. The acceleration factor for yellowing is about ten and the acceleration factor for haze formation is about five

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Friday Morning: Elastomer and Issues Related to Service Life Prediction

Friday morning is devoted to understanding how exposures change the mechanical response of elastomers. This class of materials is primarily useful due to the ability to elastically store and dissipate energy. As these materials degrade this capability is decreased. This session will explore that relationship between aging and mechanical performance. This session should teach us how these important materials change with environmental exposures.

Discussion Leaders: Geralt Siebert, Jessica Vargas, Ralf Heinzmann

Time	Presenter	Title
8:00 AM-8:30 AM	Masayuki Ito	Methodology study of time accelerated γ ray irradiation to elastomer
8:30 AM-9:00 AM	Jing Huang	Thermo oxidation of polydicyclopentadiene : determination the initiation rate constants and termination rate constants of kinetic model
9:00 AM-9:30 AM	Michael A. Kraus	Experimental and numerical investigations on the load bearing behavior of unaged and weathered polymeric interlayers in Laminated Glass
9:30 AM-10:00 AM	Coffee Break	
10:00 AM-10:30 AM	Martin Botz	Towards The Influence Of Chemical Ageing On The Constitutive Behaviour Of Polymeric Interlayers in Laminated Glass Applications
10:30 AM-11:00 AM	Ralf Heinzmann	Comparison of cyclic movement testing according to ISO 19862 and two-year outdoor weathering with cyclic movement with different types of sealants and polymer bases
11:00 AM-11:30 AM	Geralt Siebert	Experimental and numerical investigations on the influence of chemical ageing on the load bearing behaviour of a U-type silicone façade sealing
11:30 AM-12:30 PM		Panel Discussion and wrap up.

Methodology Study of Time Accelerated γ ray Irradiation to Elastomer

Masayuki Ito, **Waseda University**

Abstract
Electric wires and cables used in the containment vessel of nuclear power plants are exposed to low dose rate irradiation during the life time of the plant. The dose is expected to be 500 kGy during 40 years of the life time. The article compared the results obtained by low dose rate irradiation to the result obtained by the high dose rate irradiation to elastomers. The mechanical property was measured by tensile test after irradiation. The ratio of crosslinking and scission which arose during aging was evaluated by modulus-ultimate elongation profile and by the chemical stress relaxation. One of the samples was ethylene-propylene-diene elastomer (EPDM) whose thickness was about 0.5 mm. The reference condition was irradiation of 0.33 kGy/h at room temperature. The maximum dose was 2.0 MGy. The time accelerated irradiation conditions are described below.

1) Irradiation of 4.2 kGy/h in 0.5 MPa oxygen at room temperature.
2) Irradiation of 5.0 kGy/h in air at 70oC.

There was no significant difference between the mechanical property of the sample aged by the reference condition and that of the sample aged by the two short time test. The other sample was acrylic elastomer whose thickness was 0.5 mm. The reference condition was irradiation of 1.0 kGy/h at room temperature. The maximum dose was 3.0MGy. The following condition was chosen for the time accelerated irradiation.

1) Irradiation of 4.0 kGy /h in 0.5 MPa oxygen in room temperature.
2) Irradiation of 3.0 kGy/h at 70oC.

The sample aged by the reference condition and that by the irradiation of 3.0 kGy/h at 70oC brought about the same ratio of crosslinking and scission. On the other hand the ratio of crosslinking and scission decreased when the sample was irradiated above 1.0 MGy of dose in 0.5 MPa oxygen at room temperature.

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Thermo Oxidation of Polydicyclopentadiene : Determination the Initiation Rate Constants and Termination Rate Constants of Kinetic Model

Jing Huang1, Emmanuel Richaud1, Pierre-Yves Le Gac2, Renata Drozdzak3, Gilles Recher3

1 : CNRS, 2 : IFREMER, 3 : TELENE SAS

Abstract
Polydicyclopentadiene (PDCPD) is a thermoset polymer synthetized from Ring Opening Metathesis Polymerization and produced by Reaction Injection Moulding process. Due to its interesting properties, like short processing times (less than 2 minutes) and high tenacity, this polymer is widely used in commercial and industrial applications, including body panels for cars. The final objective of this work is to establish a non-empirical kinetic model for lifetime prediction of PDCPD and for confirmation its non-degradable property at room temperature. For these purposes, the thermal degradation of unstabilized PDCPD in thin film has been investigated in severe conditions (temperatures: 50°C-120 °C; oxygen pressures: 0.02-1 MPa) by IR and DSC. These experiments aim to determine the kinetic parameters.
- The initiation rate constants have been identified specially by means of hydroperoxide decomposition. The thermolysis experiments of oxidized samples in inert atmosphere show a sharp decrease of POOH concentration linked with the great instability of peroxides.
- The termination rate constants have been obtained by specific experiments under various oxygen pressures.
- It was shown that oxidation is confined to a very thin layer (estimated ca 100 µm at room temperature) which can be used as a primer for coatings applications

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Experimental and Numerical Investigations on the Influence of Chemical Ageing on the Load Bearing Behavior of a U-type Silicone Façade Sealing

Geralt Siebert, Michael A. Kraus, Martin Botz

University of German Armed Forces Munich

Structural sealant glazing (SSG) gained a lot of interest in the past. Numerous buildings were erected with SSG façades. The current legal situation is, that only the "Guideline for European Technical Approval for Structural Sealant Glazing kits (SSGK)" (abbr. ETAG002) gives hints on the design of SSG façades. Within the ETAG002 the influence of ageing on the mechanical properties of the structural sealant is considered via prescribing different testing methods for several artificial ageing situations such as exposure to façade cleaning products or acid rain.

Within this presentation, the ETAG002 artificial testing methods are introduced and the practical relevance is discussed. Furthermore, the examination of the effects of the different artificial ageing situations on the residual mechanical strength of a silicone structural sealant are determined experimentally. Different comparative graphs are shown in order to generate an understanding of the influence of different artificial ageing conditions on the residual mechanical behavior. Ð_

The experimentally obtained stress-strain-responses are reproduced within a Finite-Element-Simulation of the test specimen under the test loading. Special focus is thereby laid on the correct consideration of an accurate material description.Ð_

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Towards the Influence of Chemical Ageing on the Constitutive Behaviour of Polymeric Interlayers in Laminated Glass Applications

Martin Botz, Michael A. Kraus, Geralt Siebert

University of German Armed Forces Munich

Abstract:

Recently, the determination of the material characteristics of polymeric interlayers used in laminated glass gained increasing interest. Typically, the thermomechanical behaviour of these polymeric materials is investigated at an unaged (i.e. virgin) stage. Based on already conducted and published small scale test data for different laminated glass interlayers and chemical ageing conditions, this presentation is concerned with the investigation of chemical ageing on the influence of the constitutive laminated glass interlayer properties. The small scale tests were performed using the Dynamical Mechanical Thermal Analysis (DMTA), which exposes small scale test specimen to a steady state oscillation at different frequencies and temperatures. The conducted tests indicate distinctive changes in the material behaviour of the interlayers due to chemical conversion of the base polymers while ageing.

The highly time and temperature dependent viscoelastic material behaviour of the interlayer materials can be described in the context of linear viscoelasticity with the generalized Maxwell model. The constitutive model for a generalized Maxwell model can be formulated by a so-called ‘Prony-Series’. In order to transform a ‘Prony-series’ for a specific temperature to different temperatures of interest the time-temperature correlation can be taken into account by means of the ‘Time-Temperature-Superposition-Principle’ (TTSP). Thereby the shear modulus of the interlayer can be calculated for each time (i.e. load duration) and temperature for the aged and unaged interlayer.

To evaluate the practical relevance of the influence of chemical ageing of the interlayer material on the constitutive behaviour of laminated glass, finite element studies investigate typical glass constructions in the serviceability limit state and the ultimate limit state.

Keywords - Polymeric Interlayer, Chemical Ageing, Laminated Glass, Material modelling.

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Comparison of Cyclic Movement Testing According to ISO 19862 and Two-Year Outdoor Weathering with Cyclic Movement with Different Types of Sealants and Polymer Bases.

Ralf Heinzmann, Sika Services AG

Abstract

Studies concerning the durability of sealants are often made by comparing the different polymer backbones e.g. silicone vs. polyurethane or silane-terminated polymers. At the 2014 ASTM Symposium the author presented a comparison of different sealant types after accelerated weathering according to ISO 19862. In order to establish whether accelerated weathering leads to similar results as real aging, the same tests were repeated with the same products in outdoor weathering with also once-a-week cyclic movement. The tests were carried out in southern Germany in moderate climate conditions. Another goal of these tests was to find out whether movement and weathering according to ISO 19862 gives results comparable to those of outdoor weathering. It was also of special interest to determine whether the addition of adhesion promoters, UV stabilizers, heat stabilizers etc., to various polymer bases has similar effects outdoors as in the UV chamber. Furthermore, the tests showed whether the performance of the final formulation is different in outdoor weathering. In addition to the pass-fail criteria according to ISO 19862 the change in modulus and the elastic recovery were determined regularly in order to get more detailed information about changes of the mechanical properties. These tests were done for outdoor weathering as well as for artificial aging in the UV chamber. On the basis of the tests outlined above, the author will elaborate on the behavior of various formulations and technologies concerning durability as well as aesthetic aspects. The focus is hereby on tests including cyclic movement and the comparison of artificial aging and outdoor weathering processes.

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Geralt Siebert, Michael A. Kraus, Martin Botz

University of German Armed Forces Munich

Abstract:
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The experimentally obtained stress-strain-responses are reproduced within a Finite-Element-Simulation of the test specimen under the test loading. Special focus is thereby laid on the correct consideration of an accurate material description.

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Appendix A: List view of 2018 program.

Monday Morning: General Overview of Service Life Prediction
Discussion Leaders: Matt McGreer, Mat Celina, Oliver Rosseler

Time	Presenter	Title
7:00 AM-8:00 AM		Continental Breakfast.
8:00 AM-8:30 AM	Jim Pickett	Why is SLP so hard?
8:30 AM-9:00 AM		
9:00 AM-9:30 AM	Maureen Reitman	Failure Mode Analysis
9:30 AM-10:00 AM	Coffee Break	
10:00 AM-10:30 AM	Ken White	Accelerated Weathering
10:30 AM-11:00 AM	Mark Nichols	Service Life Prediction from and End User Perspective
11:00 AM-11:30 AM	Jean-Francois Masson	Structural Insulated Panels for Housing Construction: Development of Guidelines to Assess Composite Durability for a Fifty-year Service in the Canadian Climate.
11:30 AM-12:30 PM		Panel Discussion
12:30 PM-2:00 PM	LUNCH	

Monday Afternoon: UL 746 Process

Time	Title
2:00 PM-5:30 PM	Tom Fabian 2000HR Program working draft and proposal: This is a working session for members of the UL 746B LTTA Forum and it is open to SLP attendees interested in participating. The objective of this session is to develop a final draft of a UL 746 Standard Technical Panel (STP) proposal that can be ready to be submitted for ballot by the end of the session.

Reception

Time	Title
5:00 PM-6:30 PM	Reception

Monday Evening: Successful Thermal implementations of SLP
Discussion Leaders: Mark Nichols, Tom Fabian, Andy Francis

Time	Presenter	Title
6:30 PM-7:00 PM	Helena Chiang	UL Roadmap for Long-Term Thermal Aging Program
7:00 PM - 7:30 PM	Bertrand Roduit	Prediction of shelf life of materials from forced degradation studies based on different analytical techniques by using advanced kinetic and statistical analysis
7:30 PM – 8:30 PM		Panel Discussion and (7:30 PM-8:30 PM)

Tuesday Morning: Service Life Prediction, Specific issues.
Discussion Leaders: Erica Redline, Jim Pickett, Graham Duthie

Time	Presenter	Title
7:00 AM-8:00 AM		Continental Breakfast.
8:00 AM-8:30 AM	Ken White	Unraveling Reaction Pathways to Predict Degradation Rates in PET
8:30 AM-9:00 AM	Kurt Wood	Use of Color Component Analysis to predict the color service life of fluoropolymer-based architectural coatings
9:00 AM-9:30 AM	Erik Sapper	In Life, Death: Service Life Prediction and the Automated Design of New Polymeric Materials
9:30 AM-10:00 AM	Coffee Break	
10:00 AM-10:30 AM	Olivier Rosseler	How long should I run my weathering test to reproduce 1 year of outdoor aging?
10:30 AM-11:00 AM	James Pickett	Accelerated weathering parameters for aromatic polymers
11:00 AM-11:30 AM	Olga Kuvshinnikova,	Outdoor and xenon arc weathering of aromatic engineering thermoplastics
11:30 AM-12:30 PM		Panel Discussion
12:30 PM-2:00 PM	LUNCH	

Tuesday Afternoon: UL 746 Process

Time	Title
2:00 PM- 5:00 PM	Jun Haruhara, and Dr. Thom Fabian IEC 60216-7: Applicability & next round robin plans. This is a working session to discuss the potential applicability of newly published IEC Technical Specification (TS) 60216-7-1 and IEC Test Report (TR) 60216-7-2 for the determination of Relative Thermal Indices (RTIs). Plans for additional round robins incorporating different materials will be discussed.

5:00 PM Tuesday Evening: Bus will take us to Carellis restaurant (Italian) and return us for the Tuesday evening talks.

Tuesday Evening: SLP concerns for Automotive Industry
Discussion Leaders: LiPiin Sung, Erik Sapper, Ingo Alig

Time	Presenter	Title
6:30 PM- 7:00 PM	Jennifer David	An Analysis of Thermal and Humidity Cycling Stresses in Automotive Hard Coatings
7:00 PM - 7:30 PM	Mark Nichols	Stone Chip Performance of Automotive Paint Systems
7:30 PM – 8:30 PM		Panel Discussion (7:30 PM-8:30 PM)

Wednesday Morning: Specific Exposure Issues with SLP: Water and Light
Discussion Leaders: Ken White, Libby Glascoe, Michael Kempe

Time	Presenter	Title
7:00 AM-8:00 AM		Continental Breakfast.
8:00 AM-8:30 AM	Mat Celina	Rapid IR Flow-Through Method for Volatile Quantification in Thermoset Ageing used for Lifetime Predictions
8:30 AM-9:00 AM	Erik Linde	Water Diffusion in Thermoset Amorphous Materials - Influence of the Glass Transition Temperature
9:00 AM-9:30 AM	Karl-Anders Weiß	Interaction of Permeats During the Measurement of Permeation Coefficients of Dense Polymer Films Under Realistic Conditions
9:30 AM-10:00 AM	Coffee Break	
10:00 AM-10:30 AM	Glascoe	Predicting chemical compatibility and aging of materials in a system a combined experimental and modelling approach
10:30 AM-11:00 AM	Doug Vermillion	Introduction to Metal Halide Weathering Chamber for Accelerated Material Testing
11:00 AM-11:30 AM	Matt McGreer	The Importance of Specimen Surface Temperature For The Understanding Of Correlation And Service Life Prediction
11:30 AM-12:30 PM		Panel Discussion
12:30 PM-2:00 PM	LUNCH	

Wednesday Afternoon: UL 746 Process

Time	Title
2:00 PM- 4:30 PM	Helena Chiang, Dr. Chris White, Dr. Tom Fabian Roadmap for SLP into UL, IEC, and other standards. This is a working session to discuss how to continue to incorporate lessons from SLP meetings into the development of standards used to determine temperature ratings. A white paper outline is the goal from this session.

Banquet Dinner: at the
Boulder ChopHouse & Tavern
921 Walnut Street
Boulder , CO 80302
303-443-1188

This dinner will start at 6:00 PM. To get there is a pleasant 40 minute (1.8 m) walk which will take you through the heart of the Boulder shopping and recreation district (Pearl St. pedestrian mall). Directions are to walk down Pearl Street 1.8 miles, then left on 10th street for one block south, then turn on Walnut street for one block.

Another possibility is the use the excellent HOP bus service. http://www3.rtd-denver.com/Hop.shtml this circular bus service has a stop right outside the hotel (Pearl St & 30th St, right outside the Barnes and Noble bookstore) and drives directly down Pearl St. It will drop you off very near the restaurant (Walnut St & 11th St). This bus runs every 8 min. It will cost $5.20 for a round trip ticket. Tickets can be bought on the bus (cash only) or on the RTD app http://www.rtd-denver.com/mobileticket.shtml

Taxies, Uber and Lyft are also possibilities.

Thursday Morning: Service Life Prediction Modelling

Discussion Leaders: Bertand Roduit, Adam Pintar, Kurt Wood

Time	Presenter	Title
7:00 AM- 8:00 AM		Continental Breakfast.
8:00 AM- 8:30 AM	Adam L. Pintar	Building Hierarchical Bayesian Models for Sealant Data from the NIST Solar Sphere
8:30 AM- 9:00 AM	Li-Piin Sung	Predicting outdoor weathering of PE using NIST SPHERE methods
9:00 AM- 9:30 AM	Donghui Li	Multivariate Multiple Regression Models of the Waterborne Acrylic Coating Degradation under Multi-Factor Accelerated Weathering Exposures or Degradation of Waterborne Acrylic Coatings under Accelerated Weathering Exposures
9:30 AM- 10:00 AM	Coffee Break	
10:00 AM- 10:30 AM	Hom Sharma	An experimental and triple-mode sorption modelling of sorption and diffusion in polymeric materials
10:30 AM- 11:00 AM	David Miller	Degradation in PV encpasulant transmittance: Results of the first PVQAT TG5 study
11:00 AM- 11:30 AM	Ingo Alig	Accelerated Thermal Aging of Thermoplastic Materials: Combination of material characterization and cyclic fatigue testing
11:30 AM- 12:30 PM		Panel Discussion
12:30 PM- 2:00 PM	LUNCH	

Thursday Poster session: 5:00 PM -6:30 PM Poster Session and Reception

Poster	Presenter	Title
1	Kaushal Gandhi	Acceleration Parameters for Polycarbonate under Blue LED Light
2	Barbara Siebert	All Glass Pavilion
3	Fabian	Overview of the 746 processes.
4	L. Judovits,	Determination of Activation Energy using High Resolution TGA coupled with Modulated TGA.
5	C. White,	Predicting Field Panel Temperature

Thursday Evening: Issues Relating Indoor Exposure to Outdoor Exposure
Discussion Leaders: Sean Fowler, Jim Pickett, David Miller

Time	Presenter	Title
6:30 PM-7:00 PM	Pierre Morel	Development of a combined testing technique to characterize coatings performance
7:00 PM-7:30 PM	Carlos Juarez-Garcia	Accelerated and Outdoor Weathering of non-PET aromatic polyesters and Polystyrene. Evaluation of the weathering Test Method ASTM D7869 to Simulate Miami Florida Outdoor Exposure
7:30 PM-8:30 PM		Panel Discussion (7:30-8:30)

Friday Morning: Elastomer Issues Related to Service Life Prediction
Discussion Leaders: Geralt Siebert, Jessica Vargas, Ralf Heinzmann

Time	Presenter	Title
8:00 AM-8:30 AM	Masayuki Ito	Methodology study of time accelerated γ ray irradiation to elastomer
8:30 AM-9:00 AM	Jing Huang	Thermo oxidation of polydicyclopentadiene : determination the initiation rate constants and termination rate constants of kinetic model
9:00 AM-9:30 AM	Michael A. Kraus	Experimental and numerical investigations on the load bearing behavior of unaged and weathered polymeric interlayers in Laminated Glass
9:30 AM-10:00 AM	Coffee Break	
10:00 AM-10:30 AM	Martin Botz	Towards The Influence Of Chemical Ageing On The Constitutive Behaviour Of Polymeric Interlayers in Laminated Glass Applications
10:30 AM-11:00 AM	Ralf Heinzmann	Comparison of cyclic movement testing according to ISO 19862 and two-year outdoor weathering with cyclic movement with different types of sealants and polymer bases
11:00 AM-11:30 AM	Geralt Siebert	Experimental and numerical investigations on the influence of chemical ageing on the load bearing behaviour of a U-type silicone façade sealing
11:30 AM-12:30 PM		Panel Discussion and wrap up.

Author Index

Time	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday
7:00		Breakfast				
7:30						
8:00		J. Pickett	K. White	M. Celina	A. Pintar	M. Ito
8:30			K. Wood	E. Linde	L.Sung	J. Huang
9:00		M. Reitman	E. Sapper	K-A Weiß	D. Li	M. Kraus
9:30		Coffee Break	Coffee Break	Coffee Break	Coffee Break	Coffee Break
10:00		K. White	O. Rosseler	L. Glascoe	H. Sharma	M. Botz
10:30		M. Nichols	J. Pickett	D. Vermillion	D. Miller	R. Heinzmann
11:00		J-F Masson	O. Kuvshinnokc	M. McGreer	I. Alig	G. Siebert
11:30		Discussion				
11:45						
12:30		Lunch				SLP sealants meeting
1:00						
1:30						
2:00		UL	UL &PSI	UL	Roadmap rollup.	
2:30						
3:00						
3:30						
4:00						
4:30						
5:00		Reception	Dinner Bus to Carellis		Poster Session	
5:30						
6:00	Informal			Banquet Dinner Chophouse	Reception	
6:30	Dinner.	H. Chiang	J. David		P. Morel	
7:00		B. Roduit	M. Nichols		C Juarez	
7:30		Discussion	Discussion		Discussion	
8:00						