ATLAS
MATERIAL TESTING SOLUTIONS

SunSpots®

Material Testing Product and Technology News

Volume 38
Issue 83

Fall 2008

In This Issue

Accelerated UV Test Methods and Selection Criteria for Encapsulants of Photovoltaic Modules

By Michael D. Kempe
National Renewable Energy Laboratory, 1617 Cole Blvd., Golden, CO 80401

Abstract

Photovoltaic modules are exposed to extremely harsh conditions of heat, humidity, high voltage, mechanical stress, thermal cycling, and ultraviolet (UV) radiation. The current qualification tests (e.g., IEC 61215) do not require UV exposure high enough to evaluate a lifespan of 20 years or more. Methods to quickly test the UV durability of photovoltaic materials are needed. The initial performance and material cost of encapsulant materials must be taken into account, but equally important is their ability to maintain adhesion and transmissivity under UV exposure. This can be evaluated under highly accelerated conditions with light from a xenon arc lamp using glass that transmits more UV radiation than standard cerium doped glass. The use of highly transmissive glass results in a UV dose that is about 3.8 times higher with regard to adhesion. With this configuration the effect of 20 years of exposure can be obtained in just over 6 months using standard commercial accelerated stress chambers.

Introduction

Polymeric encapsulant materials are used in photovoltaic (PV) modules to provide electrical insulation, protect modules from mechanical damage and environmental corrosion, and to optically couple the PV cells to the front-sheet material. PV module qualification tests (such as IEC 61215) are designed to provide minimum standards for module durability and to demonstrate a degree of safety in the use of modules in the production of electricity. The specific effects of these highly accelerated

Continued on page 4

AtlasClient Education

Atlas Client Education helps clients learn to design durability test programs to understand how weathering affects materials. Our education and training solutions will help you and your staff effectively master the skills and knowledge needed to develop long-lived products in shortened development cycles. Our programs are designed for all levels to ensure that everyone develops the skills required to understand the fundamentals of weathering and how to operate our instruments. For the latest schedules and locations, check the Atlas website, www.atlas-mts.com, or e-mail info@atlas-mts.com.

2008

Fundamentals of Weathering I

November 4
Kassel, Germany

November 4
Kolding, Denmark

November 27
Horb, Germany

December 4
Paris, France

Fundamentals of Weathering II

November 5
Kassel, Germany

November 5
Kolding, Denmark

December 5
Paris, France

Weather-Ometer® Workshop

November 25–26
Linsengericht, Germany

Webinars

Weathering Design of Experiments
(Weathering DOEs)

November 5, 09:00
US$95/€70 excl. taxes

All times listed in -06:00 GMT.

NEW» **Understanding the Relation of Reliability, Durability & Weatherability**

November 11, 09:00
Free

Photodegradation and Stabilization Mechanisms of Polymers

November 19, 09:00
US$95/€70 excl. taxes

Industry Standards: Learn How They Apply to Your Weathering Testing

December 9, 09:00
Free

2009

Fundamentals of Weathering I

February 3
Borås, Sweden

Fundamentals of Weathering II

February 4
Borås, Sweden

Xenotest® Workshop

March 17–18
Linsengericht, Germany

September 29–30
Linsengericht, Germany

SUNTEST® Workshop

March 20
Linsengericht, Germany

October 2
Linsengericht, Germany

AtlasShows

Learn about the latest weathering developments and how Atlas can help advance your testing program. Visit our booth at the following shows, and one of our representatives will be happy to talk with you about your goals and needs.

2008

ITME 2008
November 15–22
Bangalore, India

China Coat
November 18–20
Guangzhou, China

For the latest on Atlas shows and presentations, visit ***www.atlas-mts.com.***

2009

Forced Degradation Studies Conference
January 27–28
Brussels, Belgium

Plast India 2009
February 4–9
New Delhi, India

European Coatings Show 2009
March 30–April 2
Nuremberg, Germany

NPE 2009
June 22–26
McCormick Place
Chicago, IL, USA
Booth #10054

AtlasSpeaks

2008

Advances in Coatings Technology ACT '08
November 25–27 • Warsaw, Poland

"Saving Time and Money by Optimized Weathering Testing"
Mr. Andreas Riedl

2009

SKZ-Symposium
March 4–5 • Würzburg, Germany

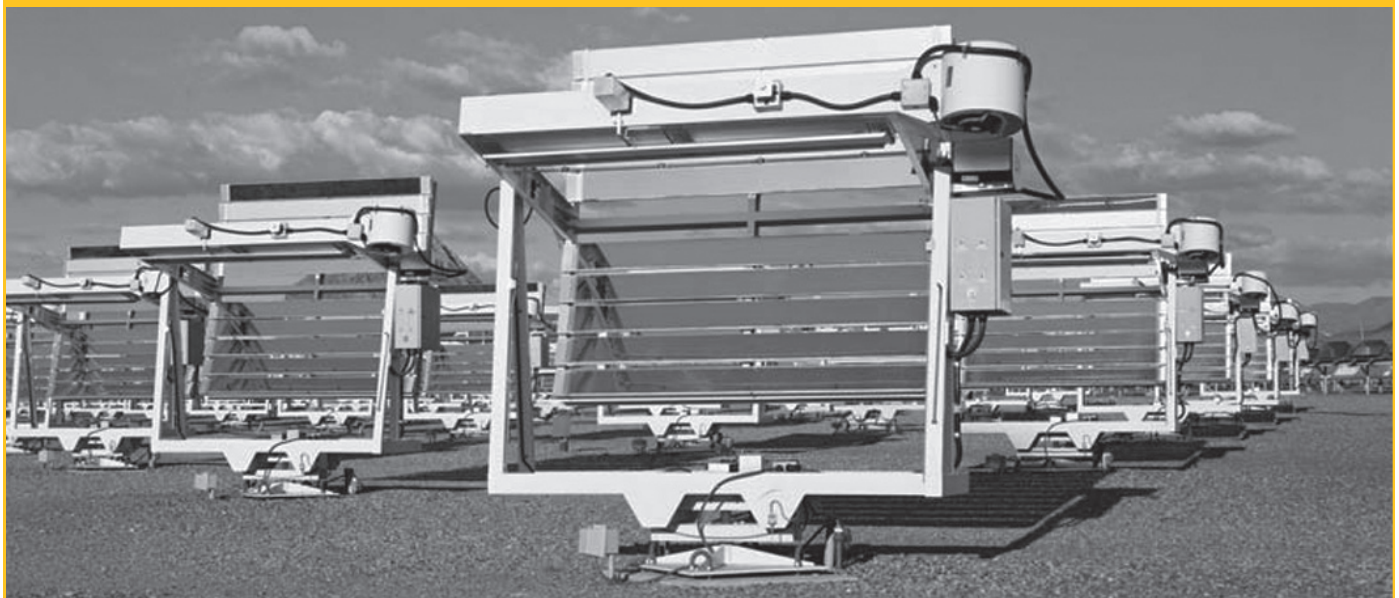
"State of Weathering Standards for Polymers and Requirements for Sensor Technology"
Dr. Artur Schönlein

"Overview of the Main Photodegradation Mechanisms of Polymers"
Dr. Olivier Haillant

European Coatings Congress
March 30–April 1 • Nuremberg, Germany

"Accelerated Weathering Tests of Plastics and Coatings: New Technologies and Standardization"
Dr. Artur Schönlein

EMMAQUA® Winter Exposure Special



In tough economic times, it is even more important that your materials stand the test of time.
Avoid unexpected warranty and recall costs by testing your materials to their full service life.
To help, Atlas is offering discounted pricing for longer duration EMMAQUA test programs if you start today.

The sooner you begin your tests, the sooner you will have the data you need!

Start your testing before December 31, 2008 to receive discounted winter exposure pricing:

- For testing durations of at least 1-year equivalents (> 280 MJUV) = 10% discount
- For testing durations of at least 2-year equivalents (> 560 MJUV) = 15% discount
- For testing durations of at least 5-year equivalents (> 1400 MJUV) = 25% discount

Discounts good for all EMMAQUA and EMMA® applications, as well as our complete range of evaluations.
Contact your client service representative at **+1-800-255-3738** with any questions, or to request a cost estimate.
Mention “Winter EMMAQUA” to receive your discounted price.

ATLAS®
MATERIAL TESTING SOLUTIONS

www.atlas-mts.com

UV Test Methods, from page 1

stress tests vary significantly from manufacturer to manufacturer and even more so among different PV technologies. These tests alone do not necessarily predict the long-term stability of a module design.

Because of the extreme difficulty of exposing production modules to concentrated light sources for long periods of time, the UV exposure required by qualification tests corresponds to a timescale of a few months rather than years. The IEC qualification tests 61215, 61646, and 61730-2 [1, 2, 3] include a "UV Preconditioning Test." Here modules are held at 60 °C ± 5 °C and subjected to 15 kWh/m^2 between 280 nm and 385 nm with at least 5 kWh/m^2 between 280 nm and 320 nm. For comparison, the AM 1.5 spectrum [4] contains 35.3 W/m^2 and 1.52 W/m^2 in these ranges, respectively. To achieve the necessary irradiance for the IEC tests using the AM 1.5 spectrum, it would take 17.7 days for the 280 nm to 385 nm range and 137 days for the 280 to 320 nm range. Considering that AM 1.5 has a total of 1000 W/m^2 and that a more typical outdoor day/night average is about 250 W/m^2, another factor of 4 is necessary to compare chamber exposure to outdoor exposure [5]. Even with this, the equivalent exposure time is still only 71 days for 280 nm to 385 nm and 548 days for the 280 nm to 320 nm range. Similarly, IEC 62108 requires a "UV Conditioning Test" consisting of 50 kWh/m^2 below 400 nm. This is equivalent to 45 days of AM 1.5 or about 181 days outdoors. Thus, these tests do not provide assurance that a PV module will withstand 20 or more years of UV radiation. These tests are only designed to provide minimum standards for PV panel construction.

Obtaining a 20-year UV dose on a full-size module would be expensive and time consuming. Alternatively, one can evaluate small samples of materials and/or minimodules constructed in a similar manner to a full-size module. A method for evaluating the UV stability of PV packaging materials in a relatively short timeframe is necessary to evaluate module reliability. This work discusses methods for quickly evaluating the potential use of polymeric encapsulants in PV modules, including initial screening protocols looking at light transmission and encapsulant cost.

Experimental

UV exposure (60°C/60% RH and 2.5 UV suns) was obtained using an Atlas Ci4000 Weather-Ometer® with a light intensity of 114 W/m^2 between 300 and 400 nm. The Xenon arc lamp light was filtered using a type "S" borosilicate inner and outer filter. The black panel standard temperature was maintained at 100°C ± 7°C, resulting in a temperature of 70°C to 80°C for the transparent glass lap shear samples.

Lap shear tests were conducted as outlined previously by Kempe et. al [6] using an Instron Test Unit (model 1122/5500R). Two ¼"-thick 3" × 3" glass pieces were used for the test specimens. The adhesive was applied to an approximately 19-mm^2 area at a thickness of about 0.5 mm (see Figure 1).

The effective solar photon-weighted absorptivity of polymeric encapsulant materials (integrated between λ=200 nm and 1100 nm) was measured by curing thick sections (1.5 to 5.5 mm) of polymer between two pieces of 3.18-mm thick AFG Krystal Klear glass and measuring the transmission using a Lambda 9 UV-Vis spectrophotometer equipped with an integrating sphere. Percent transmission is relative to the product of the AM 1.5 [4] irradiance in units of W/m^2/nm multiplied by the wavelength to yield values related to the photon density. If one neglects reflection at the polymer glass interfaces, assumes highly transmissive materials, the total transmission can be estimated as

$$T = T_{glass} e^{-(t_p \alpha_p)} \quad \textbf{Equation 1.}$$

Here T_{glass} = 88.94% and is the solar photon weighted transmission through a piece of 6.35 mm-thick plate glass. t_p is the polymer layer thickness, and α_p is the solar weighted photon absorptivity in the polymer.

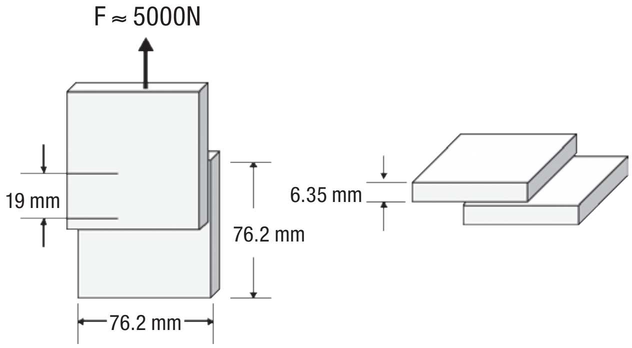


Figure 1. Schematic of lap shear samples.

Results and Discussion

Encapsulant materials used on the front side of a PV device must provide good optical coupling for the maximum transmission of incident photons. A large number of materials were evaluated and the AM 1.5 solar weighted absorptivity was determined (Table 1). The total transmission to a hypothetical cell through a 3.18-mm piece of glass and through 0.45 mm of encapsulant was estimated as

$$T_{cell} = \frac{(100 + T_{glass})}{2} e^{-(t_p \alpha_p)}$$ **Equation 2.**

Here T_{glass} = 88.94% and is the global solar weighted photon transmission through a piece of glass two times as thick. Equation 2 slightly overestimates the light because T_{glass} includes light from multiple reflections; however, the cell-to-polymer interface will also cause multiple reflections, so the net result should still provide a good estimate. The light that reaches the cell will then be absorbed by the cell as governed by the cell optics.

According to Equation 2, a perfectly transparent encapsulant would transmit about 94.5% of the photons between 200 nm and 1100 nm. Because of the thinness of the encapsulant layer, the absorption and scattering in ethylene vinyl acetate (EVA) only account for about a 0.6 ± 0.2% loss in the potential initial power output of a module.

EVA will yellow somewhat after environmental exposure. The optical transmission of thin aged encapsulant samples were obtained as an estimate of the yellowing potential of these encapsulants. Following the same procedures for calculating Table 1, light transmission measurements were made of UV-aged polymer samples behind glass. It was estimated that 0.45 mm-thick sections of EVA and GE RTV 615 placed behind 3.18 mm Krystal Klear glass would transmit 88.7 ± 2% and 93.6 ± 2% after being exposed to 14,364 h and 15,238 h respectively of 60 °C/60% RH/2.5 UV suns. The small 0.9% transmission loss for GE RTV 615 is principally due to minor etching and corrosion of the glass.

For a 15% efficient module, this 4.9% transmission difference between EVA and RTV615 would result in a 7.4W loss. Because this exposure has a far greater UV dose than would be experienced over an expected module lifetime, this should be considered an upper limit for lost irradiance. Taking a lifetime average transmission loss difference of 7.4/2 = 3.7 Wp/m^2, in addition to the initial 0.5 Wp/m^2, as a time average power loss for using EVA instead of a silicone, one would expect an additional 4.2 Wp/m^2 performance loss. The monetary value of 4.2 Wp/m^2 gives an upper limit to the additional cost that might be acceptable for a better performing encapsulant. EVA is the dominant encapsulant used in the PV industry not because it is the best material but because the performance gain from using

Continued on next page

UV Test Methods, from previous page

Encapsulant	AM 1.5 Solar Weighted Absorptivity 200 nm to 1100 nm (1/mm)	Transmission to Cells through 3.18 mm glass and 0.45 mm Encapsulant (%)	Approximate Cost Relative to EVA	Comments
GE RTV615	0.000 ± 0.003	94.5 ± 0.3	4.45	PDMS Addition Cure
Dow Corning Sylgard 184	0.001 ± 0.004	94.4 ± 0.3	6.97	PDMS Addition Cure
Dow Corning 527	0.001 ± 0.003	94.4 ± 0.3	2.33	PDMS Gel Addition Cure
Polyvinyl Butraldehyde	0.014 ± 0.005	93.9 ± 0.4	1.50	
EVA	0.014 ± 0.005	93.9 ± 0.4	1.00	
NREL Experimental	0.025 ± 0.006	93.4 ± 0.4	1.28	
Thermoplastic Polyurethane	0.027 ± 0.004	93.3 ± 0.3	2.00	
Thermoplastic Ionomer #1	0.052 ± 0.007	92.3 ± 0.4	1.00	Co-polymer of Ethylene and Methacrylic Acid
DC700	0.067 ± 0.004	91.7 ± 0.3	0.94	PDMS Acetic Acid Condensation Cure
Theroplastic Ionomer #2	0.147 ± 0.007	88.4 ± 0.4	2.00	Co-polymer of Ethylene and Methacrylic Acid

Table 1: AM 1.5 [4] Solar photon weighted optical density determined from transmission measurements through polymer samples of various thickness (1 to 5 mm) sandwiched between two pieces of 3.18 mm-thick Krystal Klear glass. Only the solar spectrum below 1100 nm was used for transmission measurements. The approximate cost factor relative to EVA is based on costs quoted by the manufacturer where no effort was made to negotiate a better price. The true cost factor could easily be different by a factor of two.

other encapsulants is not very large. While this higher transmission alone probably does not justify the additional expense of silicones, it may justify the additional cost of better EVA formulations and/or other alternative resins.

Lap shear samples of EVA were made using low Fe glass both with (6.35 mm thick Krystal Klear) and without Cerium (1990s vintage 5.61 mm-thick PPG Starphire [7]) to evaluate the effect of enhanced UV transmission on the adhesion of EVA [8, 9, 10]. The transmission of UV light through some sample glasses is shown in Figure 1 before and after solarization at 2.5 UV suns in an Atlas Ci4000 Weather-Ometer® [11] (see Figure 2). The UV-B region extends from 290 to 320 nm and is the region of the solar spectrum typically causing the most damage to hydrocarbon-based polymeric materials. Here we see that the addition of minute amounts of Ce to the glass dramatically reduces the transmission of UV-B radiation and that solarization of the glass extends this absorption to even longer wavelengths.

The effect of increased UV-B transmission on the adhesion of EVA was evaluated using glass lap shear samples exposed to 2.5 UV suns. The fit lines in Figure 3 are exponential decay curves offset from each other on the time axis by a factor of 8. This fit is empirical in nature and valid only for the initial changes in adhesion. The degradation of adhesion for the Ce-doped glass initially dropped to values between 2 MPa and 4 MPa, where it remained for about 10,000 h. Once the adhesive strength began to drop, failure was typically around 80% to 90% on the side facing the UV lamp, indicating that the UV light was responsible for the loss in adhesion.

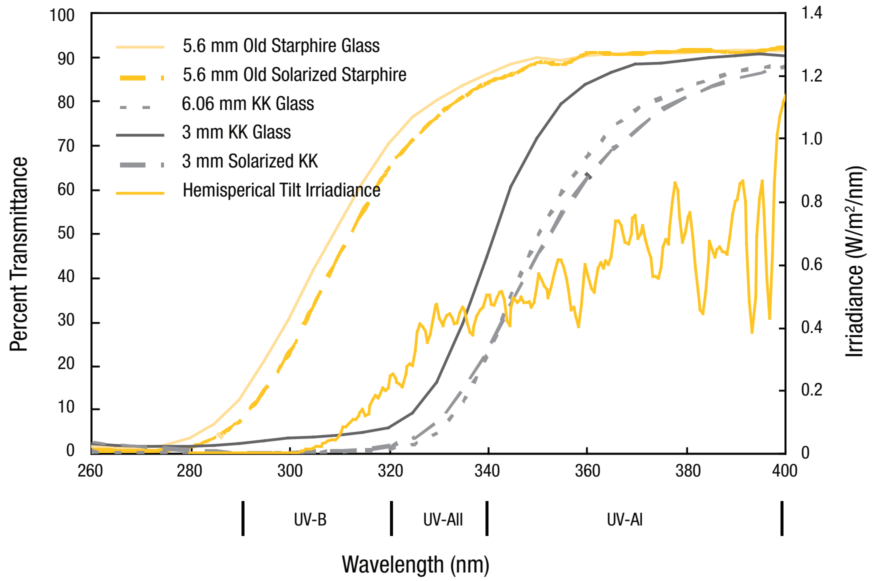


Figure 2. UV light transmission through a variety of glass samples plotted along with the AM 1.5 spectrum for comparision. Samples labeled "solarized" had been exposed to 114 W/m² (300 nm to 400 nm) in a Ci4000 Weather-Ometer® at 60°C and 60% RH.

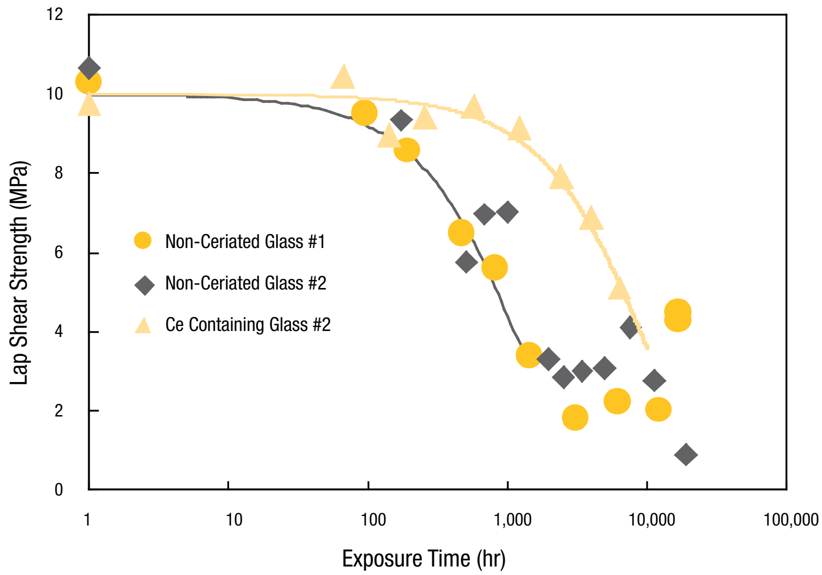


Figure 3: Lap shear strength of EVA after exposure to 60 °C/60% RH/2.5 UV suns.

When EVA is formulated for use in PV applications, a UV absorber is added to reduce degradation. Exposure to UV radiation causes deadhesion preferentially on the side facing the light source because this interface receives a full dose of the light transmitted through the glass. For the lap shear samples in this work, the refractive index difference between the glass and the polymer is small, so the reflection at this interface is negligible. Therefore, the

Continued on next page

UV Test Methods, from previous page

amount of UV radiation reaching this interface, $I(\lambda)$, is equal to the lamp irradiance, I_{Lamp}, reduced by reflection at the glass-to-air interface and by the absorption from a single pass through the glass to the polymer/glass interface:

$$I(\lambda)+I_{Lamp}\frac{(n_1-n_2)^2+k^2}{(n_1+n_2)^2+k^2}e^{\frac{4\pi k}{\lambda}t} \qquad \textbf{Equation 3.}$$

Values for AM 1.5 were used as an approximation for I_{Lamp} because the Weather-Ometer was set up to duplicate natural sunlight. According to Rubin [12], the real component of the refractive index for typical soda lime glasses can be approximated within ±1% by

$$n = 1.5130 - 0.003169\lambda^2 + \frac{0.003962}{\lambda^2} \qquad \textbf{Equation 4.}$$

With these estimates for n and the transmission of light through a sheet of glass, after solarization, values for k were estimated on a wavelength by wavelength (solved numerically using Excel™) and accounting for multiple reflections. From this, the irradiance at the glass-to-polymer interface (see Figure 4) of the lap shear samples using the different glasses was estimated using Equation 3.

An action spectrum describes the effectiveness of incoming photons (as a function of wavelength) for producing a specified type of damage. For exposure to a specific distribution of photons, $I(\lambda)$, the activation spectrum describes the relative degradation rate as a function of wavelength. The activation spectrum is thus the result of weighting the action spectrum against a specific wavelength distribution of photons. Unless there are specific absorption bands in the region of interest, the action spectrum of the incoming photons typically varies exponentially [13, 14] with wavelength ($\sim e^{-B\lambda}$). With this approximation the activation spectrum [$E(\lambda)$] is given by

$$E(\lambda) \sim I(\lambda)\lambda e^{-B\lambda} \qquad \textbf{Equation 5.}$$

and the effective UV dose (D) can be estimated as

$$D \sim \int I(\lambda)\lambda e^{-B\lambda}d\lambda \qquad \textbf{Equation 6.}$$

where $I(\lambda)$ is the radiant energy in ($W/m^2/nm$), λ is the wavelength, and B is an empirical constant quantifying the wavelength sensitivity. The effective dose, D, describes the degradation caused by exposure to a polychromatic light source, $I(\lambda)$.

In the Weather-Ometer®, the heat load on the different lap shear samples would be expected to be nearly identical, so temperature differences would not explain the accelerated loss of adhesion. For the ceriated and non-ceriated glass used in the various lap shear samples, the effective dose, D, should differ by a factor of 8. Numerical solution of Equation 6 results in an estimate of the wavelength sensitivity of $B = 0.07$ (1/nm). From this, the activation spectrum for adhesion loss was estimated for a number of front-sheet materials. Using 3.18 mm-thick low Fe, ceriated AFG Krystal Klear as a standard for light transmission, the effective dose acceleration factors were calculated (see Figure 5).

The use of an exponential action spectrum has empirical significance, but in the absence of rigorous evaluation, it is only a first-order estimate. The effect of different action spectra were evaluated to determine the sensitivity to this assumption and to determine the potential range of possible acceleration factors. A linear action spectrum was estimated and the cut-on wavelength λo was adjusted so that the ratio of effective dose for the Ce and non-Ce glass lap shear samples would be 8 (see Figure 6). Using λo = 368 nm, the activation spectra for different front-sheets were calculated and the acceleration factors relative to 3.18 mm-thick Krystal Klear glass were evaluated. A similar analysis was conducted using a step function action spectrum yielding λo = 354.

Although significantly varying action spectra were used, the UV dose acceleration factors did not vary dramatically (see Table 2). The data for the step function were the most different, but it is clear that this result is far from the true action spectrum. Because the differences in the transmission of the various glasses differ the most at shorter wavelengths, action spectra that emphasize this region (exponential function) yield higher acceleration factors than those that emphasize lower wavelengths. Thus, the exponential action spectrum can be regarded as an upper limit. The true acceleration factors are likely to reside somewhere between the linear results and the exponential function results.

Using 3.18 mm Krystal Klear glass as a reference, the low-Fe, non-ceriated PPG Starphire glass transmits UV light that is estimated to cause delamination 3.85 times faster. The environmental chamber irradiates the samples with 2.5 times as much UV radiation as the standard AM 1.5 spectrum. The Weather-Ometer® runs 24 hrs a day this gives a further UV dose acceleration of approximately 4 for a non-tracking system [5]. This yields a total acceleration factor of 3.85 × 2.5 × 4 = 38.5. Therefore, to get a UV dose equivalent to 20 years of exposure, 6.2 to 7 months of exposure is needed in the Weather-Ometer. Without the use of this highly transmissive glass it would take 2 years to get a UV dose equivalent to 20 years.

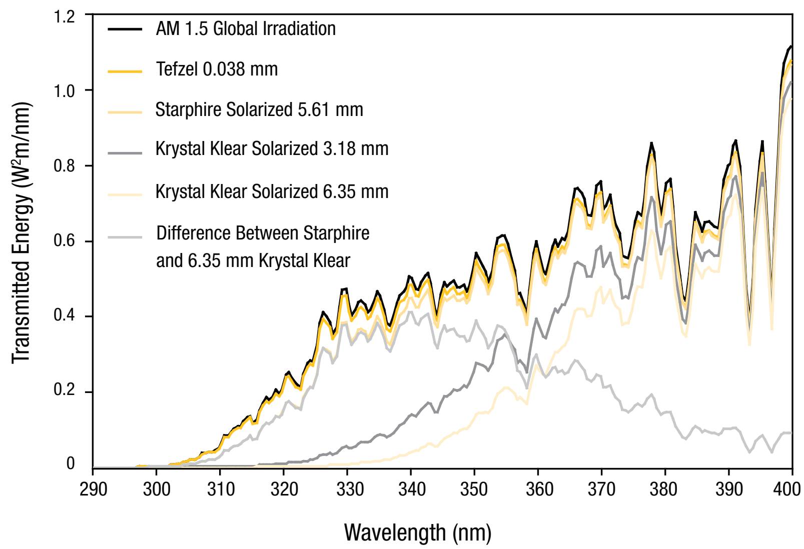


Figure 4. Estimated irradiance at the glass/EVA interface.

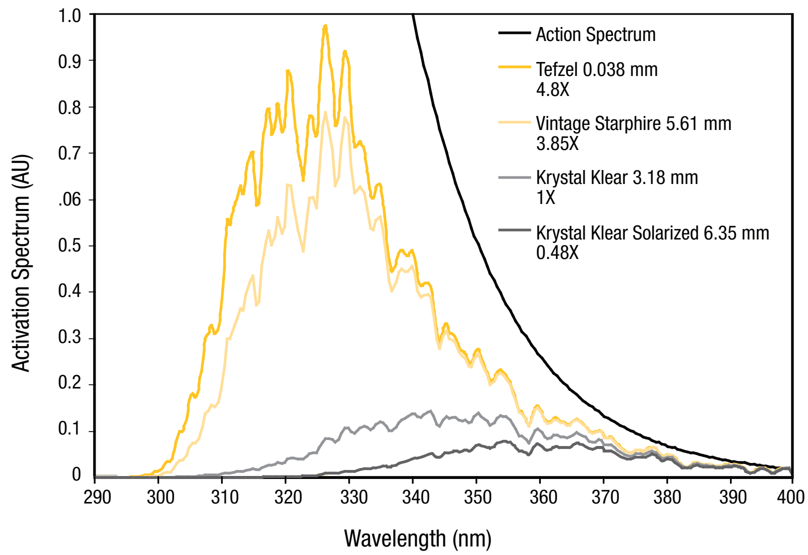


Figure 5. Activation spectrum showing relative damage potential of light transmitted through different front-sheet materials using an exponential action spectrum.

Continued on next page

UV Test Methods, from previous page

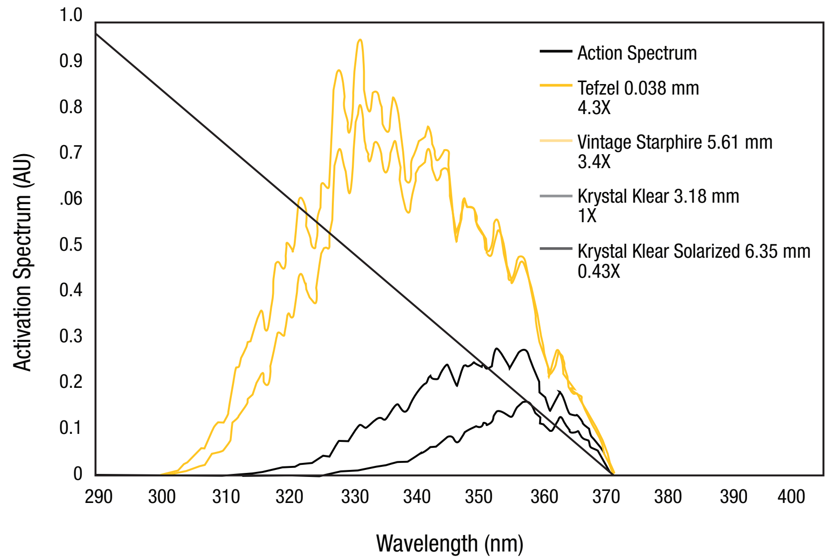


Figure 6. Activation spectrum constructed using a linear action spectrum. $\lambda_0 = 368$ nm.

Action Spectrum		Exponential	Linear	Step
		B = 0.07 (1/nm)	λ_0 = 354 (nm)	λ_0 = 368 (nm)
Tefzel	0.036 mm	4.83	4.30	3.63
Vintage Starphire	5.61 mm	3.85	3.40	3.19
Krystal Klear	3.18 mm	1	1	1
Krystal Klear	6.35 mm	0.48	0.43	0.40

Table 2. Approximate UV dose acceleration factors for different front-sheets.

Conclusions

Materials used for PV encapsulation must be evaluated for their ability to transmit light and to maintain mechanical integrity for extended periods of time under long-term UV exposure. A survey of candidate encapsulants has indicated that, although the absorptivity can vary greatly, the use of thin encapsulant layers makes absorption differences of secondary importance. Similarly, the effects of severe degradation have only a minor effect on light transmission. Current qualification standards do not adequately evaluate the effects of UV radiation, requiring additional tests if one wants to be confident in the longevity of PV modules. Exposure of PV materials to UV radiation in an environmental chamber using highly UV transmissive glass allows UV doses equivalent to 20 years of exposure (as compared to stress behind 3.18 mm-thick Ce-doped glass) in about 6 months. This allows reasonable evaluation of PV materials. Highly accelerated stress tests like this are necessary to evaluate the effect of UV radiation on module performance. This also highlights the potential risks of using non-Ce doped glass in PV applications.

Acknowledgment

This work was carried out under U.S. Departement of Energy contract number DE-AC36-99G010337.

References

[1] IEC 61215, Crystalline Silicon Terrestrial Photovoltaic (PV) Modules – Design Qualification and Type Approval

[2] IEC 61646, Thin-Film Terrestrial Photovoltaic Modules – Design Qualification and Type Approval

[3] IEC 62108, Concentrator Photovoltaic (CPV) Modules and Assemblies – Design Qualification and Type Approval

[4] ASTM G 173-03, "Standard Tables for Reference Solar Spectral Irradiances: Direct Normal and Hemispherical on 37o Tilted Surface"

[5] L. M. Moore, H. N. Post, "Five Years of Operating Experience at a Large Utility-Scale Photovoltaic Generating Plant," *Prog. Photovolt: Res. Appl.* 16, 249-259 (2008)

[6] M.D. Kempe, G.J. Jorgensen, K.M. Terwilliger, T.J. McMahon, C.E. Kennedy, T.T. Borek, "Acetic Acid Production and Glass Transitions Concerns with Ethylene-Vinyl Acetate used in Photovoltaic Devices," *Solar Energy Materials & Solar Cells,* 91, 315-329 (2007)

[7] D. L. King, M. A. Quintana, J. A. Kratochvil, D. E. Ellibee, B. R. Hansen, *Prog. Photovolt. Res. Appl.* "Photovoltaic Module Performance and Durability Following Long-Term Field Exposure," 8, 241-256 (2000)

[8] A. Torikai, H. Hasegawa, "Wavelength Effect on the Accelerated Photodegradation of Polymethylmethacrylate," *Polymer Degradation and Stability* 61, 361-364 (1998)

[9] H. Xingzhou, "Wavength Sensitivity of Photo-Oxidation of Polyethylene," *Polymer Degradation and Stability,* 55, 131-134 (1997)

[10] X. Hu, "Wavelength Sensitivity of Photo-Oxidation of Polyamide 6," *Polymer Degradation and Stability* 62, 599-601 (1998)

[11] D. E. King, F. J. Pern, J. R. Pitts, C. E. Bingham, A. W. Czanderna, "Optical Changes in Cerium-Containing Glass as a Result of Accelerated Exposure Testing," *26th IEEE PVSC,* Sept 29-Oct 3, Anaheim, California (1997)

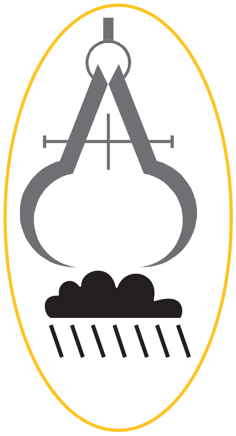
[12] M. Rubin, "Optical Properties of Soda Lime Silica Glasses," *Solar Energy Materials* 12, 275-288 (1985)

[13] A. L. Andrady, "Wavelength Sensitivity in Polymer Photodegradation," *Advances in Polymer Science* 128, 49-94 (1997)

[14] A. L. Andrady, S. H. Hamid, X. Hu, A. Torikai, "Effects of Increased Solar Ultraviolet Radiation on Materials," *Journal of Photochemistry and Photobiology B: Biology* 46, 96-103 (1998)

Atlas' solar exposure site, Phoenix, Arizona.

AtlasCommitment to Growth



Weathering Experimenter's Toolbox: Shainin's Six Pack Test

By Henry K. Hardcastle, Atlas R&D

Many current weathering studies use parametric statistical tools to analyze results. However, researchers should not overlook non-parametric tools for weathering data analysis. Non-parametric analysis can be especially useful in weathering studies involving appearance issues and visual evaluations for acceptability ranking. Also, non-parametric analysis often does not require normally distributed data to be effective.

Dorian Shainin has developed a system of unique techniques for process analysis in manufacturing environments. Shainin developed the concept known as "The Red X" source of variations in manufacturing processes. Shainin's logical approaches to production processes may also represent valuable tools for investigating weathering processes. One such tool includes Shainin's "6-Pack Test." In this test, results are rank ordered. The ranking is then associated with input variables. The probabilities associated with a specific order are then evaluated.

For example, two different lots of automotive paint were obtained from a single supplier with a single formulation. The research question was to see if lot to lot differences could result in different weathering characteristics. Three randomly selected specimens from each lot were exposed side by side, backed in Florida at 5° South for six months. After weathering, the specimens were measured for color. The D b* values were ranked. The ranking and corresponding batch numbers associated with each D b* values were as follows:

Rank Order of Six Specimens	D b* Value after 6 months, Florida, Backed, 5° South	Batch Numbers
1	0.29	881 "C"
2	0.28	881 "C"
3	0.19	881 "C"
4	-0.08	921 "T"
5	-0.18	921 "T"
6	-0.19	921 "T"

There are 20 different equally likely rank orders for these six specimens. Similarly there is only a one in 20 chance that the three "C" specimens would all rank above the "T" specimens. The likelihood of this particular order from chance alone is 1/20 or 0.05. This handy little tool is an effective way to identify vital variations without requiring normality or distribution tables. Readers are strongly encouraged to seek out additional Shainin techniques for weathering processes, as well as manufacturing process solutions.

Atlas® Introduces a New SUNTEST® XLS+

New Features, Enhanced Functionality and Improved Ease-of-Use

Atlas has successfully redesigned the popular SUNTEST XLS+ to improve functionality and ease-of-use. The SUNTEST line comprises state-of-the-art, yet easy-to-use, flat array xenon instruments to meet the needs of screening tests for the plastics, coatings, and packaging industries. In addition to basic lightfastness and weathering testing, the SUNTEST XLS+ is also the perfect instrument for advanced niche markets like the cosmetics and pharmaceutical industries. The new XLS+ will continue to be available in the lab-friendly bench-top model.

Having previously set the benchmark for flat array xenon instruments, the new XLS+ continues to set new standards incorporating advanced optics and new, "smart" accessories. The optics are derived from the high-quality design of the SUNTEST XXL+. Like the XXL+, the new XLS+ uses plug and play lamp cassettes with a rectangular test chamber. A modern, touch screen control board was added to the unit to increase control and simplify navigation. The XLS+ control board will now be available in several languages, including German, English, Chinese, and Japanese.

The new SUNTEST XLS+ sets the standard for bench-top weathering.

Several new accessories have also been developed to expand the functionality of the SUNTEST XLS+, specifically a chiller, an immersion unit and a spray unit. Each of the accessories is designed to be operated as base units for the table-top design with integrated, digital control via the SUNTEST XLS+ touch screen. A complete pharmaceutical kit that includes sample holders, DAQ Software, Lux control/calibration and chiller will be available in 2009 to support the highly competitive ICH Q1B testing market.

For more information regarding the new SUNTEST XLS+, please visit **www.atlas-mts.com** or contact your local sales representative.

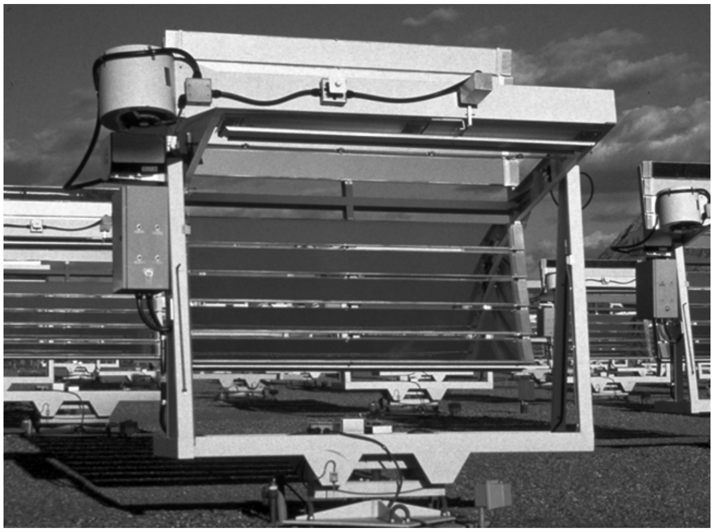
New AAMA Tests Now Reference Temperature Controlled EMMAQUA®

Good for Fiber Reinforced Thermoset Coatings

Atlas is pleased to announce an exciting new test option referencing Temperature Controlled EMMAQUA. Manufacturers of fiber reinforced thermoset profiles for architectural windows, doors, and related building products seeking the American Architectural Manufacturers Association (AAMA) certification now have some new performance requirements at their disposal.

AAMA 624-07, Voluntary Specification, Performance Requirements and Test Procedures for High Performance Organic Coatings on Fiber Reinforced Thermoset Profiles, and **AAMA 625-07,** Voluntary Specification, Performance Requirements and Test Procedures for Superior Performance Organic Coatings on Fiber Reinforced Thermoset Profiles, now specify using concentrated, natural sunlight via Atlas' EMMAQUA testing device. The standards also require control of the black panel temperature. Atlas offers black panel temperature control for EMMA® and EMMAQUA using a patented temperature control system called Temperature Controlled EMMAQUA.

EMMA and EMMAQUA enable manufacturers to expose their thermosets in outdoor accelerated weathering devices with comparable radiant dosages to materials exposed to natural outdoor conditions, but in a fraction of the time. AAMA 624-07 specifies 1450 MJ/m^2 TUVR exposures, both for natural South Florida exposures and EMMAQUA. This radiant dosage is achieved in approximately five years outdoors. However, using the solar concentrating exposure option on the EMMAQUA, this same dosage is achievable in approximately one year and three months. Similarly, AAMA 625-07 requires an exposure of 2900 MJ/m^2, which correlates to approximately 10 years outdoors, but only two and half years in an EMMAQUA.



Some temperature-sensitive materials require rigorous temperature control to minimize specimen temperature during exposures and avoid unrealistic degradation not observed in natural exposures. Using Atlas' Temperature Controlled EMMAQUA or EMMA, the specimen temperature is essentially held constant despite variations in ambient daytime temperature and solar radiation intensity. By calling out the temperature control feature, with the specified light and spray cycles, AAMA is able to offer an accelerated test method that effectively simulates natural exposures, allowing manufacturers to test their materials in significantly less time.

For more information on the new AAMA standards or for information on Temperature Controlled EMMAQUA, please contact your client service representative at **+1-800-255-3738** or at **info@atlas-mts.com.** ■

Atlas Relocates Lab to Create Center of Excellence

Atlas Material Testing Technology is pleased to announce the opening of its weathering "Center of Excellence" at Atlas' world headquarters in Chicago. The new 4,000 ft^2 (375 m^2) facility is stocked with the most advanced weathering equipment that Atlas offers, as well as an evaluations laboratory where our trained technicians can perform a full array of evaluation services (gloss, color, visual assessments, and more). Atlas has been audited by A2LA at our new laboratory. The results of this audit have allowed us to continue our certification to the ISO 17025 requirements.

The new "Center of Excellence" laboratory in Chicago replaces the Atlas accelerated weathering laboratory in Miami, FL. Atlas' reputation as an industry leader in accelerated testing services will now be strengthened by having local support in test program development, on-site engineering for instrument enhancements, and on-site technical service at the U.S. manufacturing headquarters for Atlas instruments. The expanded and enhanced laboratory also provides much-needed space for our continued growth to meet your accelerated weathering test service needs.

Please send all new orders to the following address:

Atlas Material Testing Technology
Attn: Accelerated Lab
4114 North Ravenswood Avenue
Chicago, IL 60613, USA

Please contact your client service representative at **+1-800-255-3738** or at **info@atlas-mts.com** if you have questions or would like more information on our new facility. ■

SunSpots

Visit us at the Forced Degradation Studies Conference, January 27–28, in Brussels!

To receive Sun Spots *electronically, please visit www.atlas-mts.com*

Atlas Material Testing Solutions

Atlas Material Testing Technology LLC
4114 North Ravenswood Avenue
Chicago, Illinois 60613, USA
Phone: +1-773-327-4520
Fax: +1-773-327-5787

Atlas Material Testing Technology GmbH
Vogelsbergstraße 22
D-63589 Linsengericht/Altenhaßlau
Germany
Phone: +49-6051-707-140
Fax: +49-6051-707-149

KHS Germany Office
Gerauer Straße 56a
64546 Mörfelden-Walldorf, Germany
Phone: +49-6105-91286
Fax: +49-6105-912880

Atlas Weathering Services Group
South Florida Test Service
16100 SW 216th Street
Miami, Florida 33170, USA
Phone: +1-305-824-3900
Fax: +1-305-362-6276

DSET Laboratories
45601 North 47th Avenue
Phoenix, Arizona 85087, USA
Phone: +1-623-465-7356
Fax: +1-623-465-9409
Toll Free: 1-800-255-3738

KHS US Office
4114 North Ravenswood Avenue
Chicago, Illinois 60613, USA
Phone: +1-773-327-4520
Fax: +1-773-327-5787

Experience. The Atlas Difference.

www.atlas-mts.com

ATLAS
MATERIAL TESTING SOLUTIONS

ATLAS MATERIAL TESTING TECHNOLOGY LLC
4114 North Ravenswood Avenue
Chicago, Illinois 60613, USA