Technical Situation

Accurate prediction of the time to failure (service life prediction) for polymeric materials is needed to support precise life cycle costs and sustainability assessments. Unfortunately, typical test methods have been deemed inadequate for determining Service Life Prediction (SLP) of this material. Thermal is currently the most understood mechanism for polymeric failure, and UV is a strong catalyst to enhancing this failure and Relative Humidity (RH%). Other variables include mechanical strain and water action. The development of reliable performance data requires accelerated weathering exposure equipment capable of conducting controlled, repeatable and precise accelerated aging experiments. These experiments are essential to developing performance models for service life and durability.

The test methods that exist for accelerated aging with UV irradiation typically include factors of high relative humidity and elevated temperatures in a controlled test chamber. The problem is that equipment technology does not provide the desired control of all three variables independently nor does it assure uniform exposure of the UV irradiation on the samples. Results for many weathering systems do not show good agreement with actual real-world conditions when high UV irradiance is considered. Better quality empirical data and predictive models are needed, but the limitation has been with test equipment technology to provide precise control of these three critical variables.

This creates liability issues and replacement costs to the tune of several billion dollars per year, which is the current value of warranty replacement on worldwide products.

Business Challenge

SPHERE – NIST’S Technology for SLP with UV Irradiance

In 2000, NIST (National Institute of Standards and Technology) addressed the need for better SLP models and test technology by developing and instituting a novel approach to material weathering with their test device S.P.H.E.R.E (Simulated Photodegradation by High Energy Radiant Energy). The design uses a 2 m diameter Spectralon® sphere with 32 ports for testing chambers, each with individual control of temperature, humidity, and ultra-violet irradiation. The UV irradiation is very uniform and at an intensity 10 to 20 times the sun (per ASTM G173). Since its inception SPHERE has been in continuous use with a queue of materials waiting for time inside a test chamber.
NIST has published this research and developed predictive models for accelerated service life prediction and created a database over the last 15 years that correlates well with long-term aging in field locations like Florida and Arizona. In fact, with SPHERE, specific regional conditions can be programmed into the testing scheme and achieve very good prediction capability. These tests represent a significant advancement in the predictive power of SLP models and testing technology. This knowledge directly benefits many groups and results in tangible financial profitability because it helps polymer companies develop better materials, shortens times to market new products, and establishes better product warranties.

The objective (or challenge) is to provide weathering data that will become standard test methods available for public referencing. In addition, NIST is moving forward with replicating the SPHERE technology into 2 new platforms,

1) The 6-port MUUSIC (Multi-port Uniform Ultraviolet Solar Irradiance Chamber) system and
2) the NIST strain SPHERE (MUUSIC Tensile Tester (TT))

Both systems represent design improvements from the original SPHERE technology which will facilitate transfer of technology to stakeholders and, during in-out years, support round robin testing.

After installation of the MUUSIC system, the project will focus on developing the validation protocols to confirm its performance against the current 2 m SPHERE.

There are several established weathering standards based on results of SPHERE.

<table>
<thead>
<tr>
<th>Test Specification</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>UL 746</td>
<td>Polymer Thermal/RH Aging</td>
</tr>
<tr>
<td>UL 1703</td>
<td>Flat-Plate Photovoltaic Modules and Panels</td>
</tr>
<tr>
<td>ASTM C719</td>
<td>Sealants</td>
</tr>
<tr>
<td>ASTM G03.02</td>
<td>Natural and Environment Exposure Tests</td>
</tr>
<tr>
<td>ASTM G03.03</td>
<td>Simulated and Controlled Exposure Tests</td>
</tr>
<tr>
<td>ASTM G03.08</td>
<td>Service Life Prediction</td>
</tr>
<tr>
<td>IEC</td>
<td>60068-2-78 PV Cells</td>
</tr>
</tbody>
</table>

A senior polymer scientist at a fortune 500 company has called SPHERE technology “The greatest contribution to polymer science and a game changer for the industry.”
**Labsphere Solution**

Labsphere’s Uniform Source Systems are based on proven integrating sphere technology, providing a source of collimated ultraviolet (UV) radiation in the 290 nm to 400 nm region of the light spectrum. Visible and infrared components of the input radiation are largely removed by dichroic mirrors or filters. The physics of integrating spheres ensures that the uniformity of the UV radiation emitted from a sphere exit aperture is 95%. By coupling the integrating sphere with a high intensity UV light source, irradiance levels equivalent to 60 or more “suns” can be achieved at the sphere exit apertures. This allows researchers to program specific regional weather conditions into their testing scheme to achieve accurate service life prediction.

**Benefits**

- Provides high uniformity and UV intensity light source needed for accurately predicting service life for polymeric materials
- Flexibility in designing artificial weathering experiments – cycle temperature, humidity
- Allows for mechanical loading to provide stress on the material being aged

**MUUSIC for polymers**

In order to provide a more commercially available SPHERE based system, Labsphere, working in parallel with NIST, created the MUUSIC (Multi-Sample Uniform Ultraviolet Solar Irradiance Chamber) Sphere. MUUSIC extends the SPHERE concept into a floor-standing 6 port version with the same testing chambers for individual control of temperature, humidity, and ultra-violet irradiation. The purpose of MUUSIC is to emulate the NIST system and allow test service companies, polymer manufacturers, and other research organizations to duplicate the NIST methods with their own testing regimen and equipment.

**Key Features of MUUSIC Include:**

- 6 chambers around a 20” Spectralon sphere
- 95% exposure uniformity
- 5.8” diameter irradiance area per chamber
- 6000 - 12000 electrical W of UV Lamps
- Transfer optics to project light onto samples
- Temperature and humidity defined by the chambers
- Produces the equivalent of 30 - 60 suns

**Key Features of SPHERE Include:**

- 36000 electrical W of UV (290 - 400 nm)
- 95% exposure uniformity
- Mostly UV irradiance (VIS and IR removed)
- Temperature control of 0.5°C
- Exposure conditions of chambers individually controlled (UV, T, RH)
- Can do multiple test samples at each port
- Has an optional mechanical stress tester

The exit apertures in the sphere can be connected to specimen chambers, with the specific type of chamber utilized being dependent on the material being tested. These chambers are used to control the independent variables of RH% and temperature for each sample set. Specimen chambers equipped with grips can also apply mechanical loads to specimens while they are undergoing UV exposure.
MUUSIC -TT for Sealants

Another SLP factor for sealant materials is mechanical or strain deformation due to yearly cycles in the weather (expansion + contraction). A critical attribute of an effective sealant is the ability to span and seal gaps between dissimilar building materials. These polymeric materials experience daily (~ ±7%) and yearly cycles (~ ±25%) of strain deformation. As these materials are exposed to the weather, molecular changes occur that eventually prevent the sealant from responding to imposed strains, leading to failure of the sealant. When undetected, this bulk water intrusion and air infiltration leads to significant preventable repair cost and energy loss. Characterizing these molecular changes and attributing them to specific exposure conditions enables the development of models to predict in-service performance.

The unknown accurate service life of these sealants contributes several billion dollars in home repairs.

The MUUSIC TT (Tensile Tester) Sphere's purpose is testing of polymers, such as structural sealants, product development, quality and validation of weathering lifetime. The system should provide independent control of 4 weathering variables with capabilities similar to NIST’s mechanical stressor on SPHERE.

System Specifications and Capabilities
- Eight tensile/compression stations
- 1x to 10x of UV Solar Spectrum per ASTM G173
- Temp range: 30 – 80°C
- Tensile force up to 1,000N
- Stability of Temp, UV, Tensile Load
- Humidity control optional
- 6000 - 12000W of UV Lamps

MUUSIC’s Mechanical Construction – Must Emulate SPHERE

<table>
<thead>
<tr>
<th>Mechanical Specification</th>
<th>SPHERE</th>
<th>MUUSIC</th>
<th>MUUSIC TT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectralon lined diameter interior</td>
<td>2.0 m</td>
<td>0.5 m</td>
<td>0.5 m</td>
</tr>
<tr>
<td>#’s of testing chambers</td>
<td>32</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td># of samples per chamber</td>
<td>17</td>
<td>17</td>
<td>8</td>
</tr>
<tr>
<td>Liner has a Lambertian reflectance of &gt;97%</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Cut-on filter to block light below 300 nm</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Each port uniformly irradiates a 6” dia. area</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Each port has its own shutter</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Spectrometer to measure the irradiance intensity and spectrum or UV enhanced photodetector for intensity</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Can customize filters</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Other bulbs are options</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Dedicated Stress/Strain</td>
<td>Option</td>
<td>Option</td>
<td>✓</td>
</tr>
</tbody>
</table>

Benefits for SLP using Accelerated Weathering

- **SPHERE for Simulated Weathering**
  - Speed formulation for R&D
  - Shorten time-to-market
  - Reduce variable cost of outdoor and simulated weathering testing
  - Correlate to real outdoor testing results in the lab environment
  - Establish warranty periods with good correlation to field test
  - Minimize product risk and liability

- **SPHERE vs. Outdoor Weathering**
  - Fast
  - Repeatable
  - Direct in-house control of experiments
  - Great for early failure tests
  - Great for process control tests
  - Start a test at any season