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Durability of Polymeric Glazing and Absorber Materials

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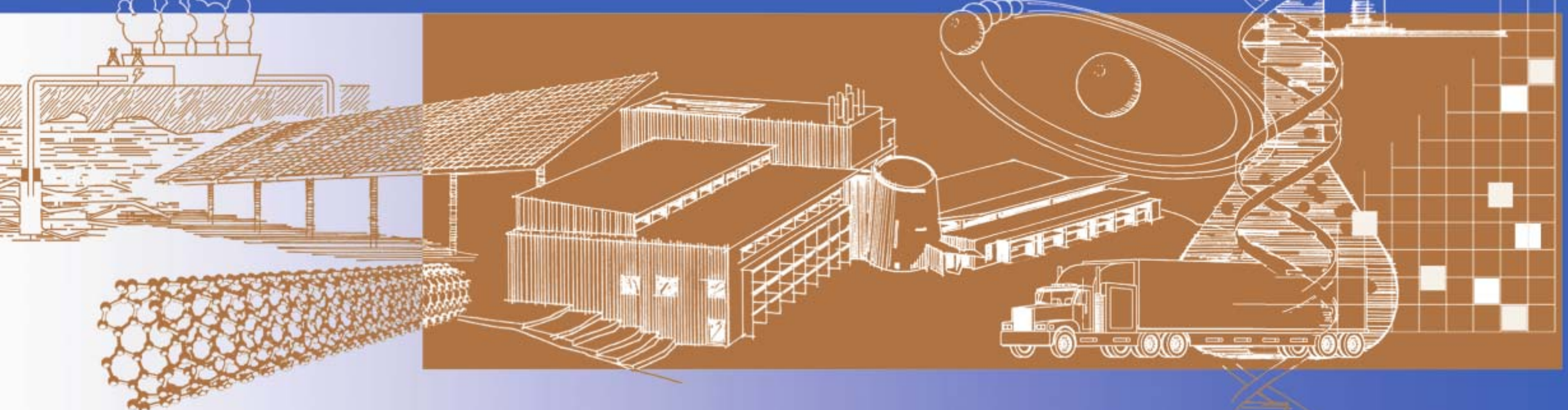

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ABSTRACT

The Solar Heating and Lighting Program has set the goal of reducing the cost of solar water heating systems by at least 50%. An attractive approach to such large cost reduction is to replace glass and metal parts with less-expensive, lighter-weight, more-integrated polymeric components. The key challenge with polymers is to maintain performance and assure requisite durability for extended lifetimes. We have begun evaluation of several new UV-screened polycarbonate sheet glazing constructions. This has involved interactions with several major polymer industry companies to obtain improved candidate samples. Proposed absorber materials were tested for UV resistance, and appear adequate for unglazed ICS absorbers.

1. Objectives

Improved polymeric glazing and absorber materials are required to increase the reliability of cost-effective solar collectors. As discussed in the Solar Program Multi-Year Technical Plan, a major impediment to development of low-cost solar water heating systems is the uncertainty in durability of polymeric components.[1] Both passive solar water heating and active cold-climate solar water heating technologies require polymeric glazings and absorbers to survive in harsh operating environments. The objectives of this research are to identify alternative polymeric materials/constructions that will allow design trade-offs that can help reduce the costs associated with SDHW systems, and to perform materials testing to demonstrate whether such candidate polymers will meet the durability requirements for real systems.

2. Technical Approach

The primary property of interest for candidate polymeric materials is their ability to avoid optical and mechanical degradation (yellowing and embrittlement) during exposure to temperature and UV light. A number of candidate glazing constructions have been subjected to photothermal weathering using three complementary forms of exposure. These include outdoors, in an Atlas Ci5000 accelerated weathering chamber, and at NREL's unique UV-concentrator facility.

To assess the photothermal stability of candidate polymeric absorber materials, mechanical properties (tensile modulus and strength, and % strain at break) were measured as a function of time of Ci5000 exposure to UV light at 60°C.

3. Results and Accomplishments

3.1 Glazing Materials

Based on accelerated screening tests, we have found that fluoropolymers and acrylic are UV weatherable, and all other polymeric glazing materials tested lose transmittance and yellow.[2] However, fluoropolymers are relatively expensive and realistically would be limited to use as thin film glazings. Acrylic tends to be too brittle and exhibits thermal sag concerns as a glazing candidate for solar collector applications. We have also found that polycarbonate (PC) laminated to an acrylic UV-screening film (Korad®, a product of Polymer Extruded Products) can also be UV weatherable. The most promising construction uses a UV-screening film that is adhesively laminated to a PC sheet. Without the additional UV-screening layer, PC products exhibit 3-5% loss in solar-weighted hemispherical transmittance after about 2-3 years equivalent exposure. In addition, severe visual yellowing (an aesthetic concern) occurs in the same timeframe. With the addition of a UV-screening film, significant loss in hemispherical transmittance does not begin until between 10-15 years equivalent outdoor exposure at elevated operating temperatures.

Based on these results, we interacted with industrial vendors to obtain samples in which the UV screening film was thermally bonded to PC sheet in a manner more representative of commercial manufacturing processes. These sheets were subsequently thermoformed into collector glazings and samples of the final construction were subjected to accelerated testing. Glazing constructions in which the UV-screen is thermally bonded to the PC substrate exhibit yellowing much earlier than when adhesives are used. The high temperature of the extruded PC sheet during thermal bonding thins and severely degrades the UV screening layer, resulting in loss of transmittance.

Another concern has been whether mechanical degradation accompanies optical yellowing. During UV exposure, greater crosslinking can occur which can result in increased stiffness, embrittlement, and consequent lower impact strength. We have used an ARES rheometer to perform dynamic mechanical analysis (DMA) of PC glazing samples. The effect of UV exposure is clearly evident (Fig. 1); 7502 h exposure in an Atlas XR-260 WOM (providing 1.9 years equivalent outdoor exposure) results in an increased modulus, implying increased stiffness and consequent loss in impact strength. Measurements were made at a tortional frequency of 10 rad/s over a wide temperature range (-25 to 75°C).

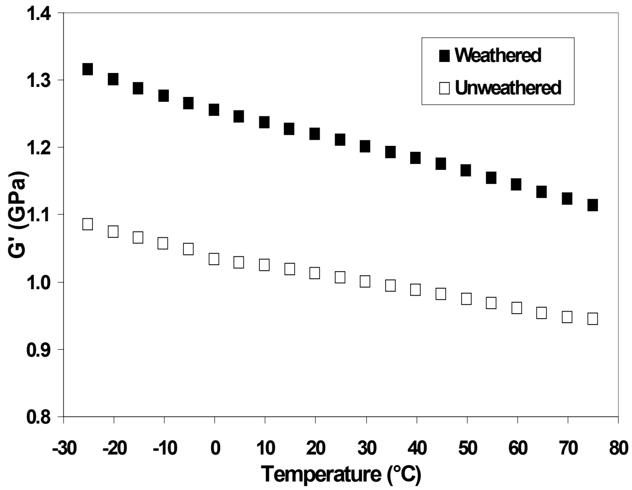

Fig. 1. Shear modulus as a function of temperature for accelerated weathered (1.9 years equivalent outdoor exposure) vs. unweathered thermal-bonded Korad(R)/PC

Further interactions have been held with material suppliers to identify several new types of samples that have the potential to preclude the thermal bonding problem. GE Plastics, a major supplier of PC sheet, is interacting with Polymer Extruded Products to provide thermally-bonded Korad®/PC samples. The UV screening layer is thicker than previously used (0.08-0.15 mm thick rather than 0.05 mm thick), and enhanced screening films (that provide twice as much UV absorption as previously tested) are incorporated into their laminate samples. PPG and Bayer have supplied samples in which UV-absorbing organic clear coats are applied to PC sheet. Such constructions are used in automotive headlamp applications. If a UV-screening film cannot be thermally bonded to PC sheet as it is extruded and/or cannot avoid severe adverse thinning during thermoforming, then clear coats could be applied to thermoformed PC to avoid such damaging effects to the screening agent. Long term testing and evaluation of these new material samples is underway.

3.2 Absorber Materials

Solar manufacturers have recently considered unglazed constructions in which the polymeric absorber is exposed to UV sunlight. Consequently, we have emphasized the effect of UV exposure on mechanical properties of polymer absorbers. One candidate material is metallocene-based multi-density polyethylene (MBMDPE). We have measured mechanical properties of this material as a function of exposure to UV light in our Ci5000 WeatherOmeter. The most sensitive parameter is % strain at break. A three-fold loss in % strain at break is evident after exposure to a cumulative dose of UV irradiance equivalent to 4 years exposure in Miami, FL (Fig. 2). As long as a reasonable residual strain at break is retained (i.e., does not drop to near zero), the absorber material is useable. For the length of time tested, MBMDPE seems suitable as an absorber material. Longer term testing and evaluation of MBMDPE is being continued.

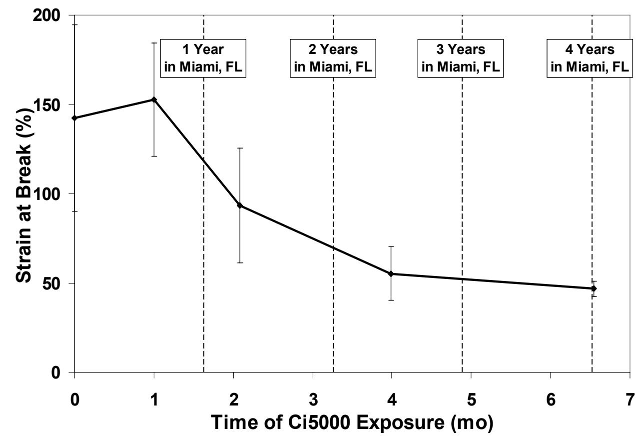

Fig. 2. Strain at break of MBMDPE as a function of Ci5000 exposure

4. Conclusions

We have interacted with several major polymer manufacturers to identify polymeric glazing constructions that can potentially overcome drawbacks associated with previously promising materials. Samples have been prepared and are under test. Loss of mechanical properties have been measured for glazing samples exposed to UV light, providing further impetus to demonstrate stable UV screening constructions. UV weathering of polymeric absorbers also results in loss of mechanical properties. However, if a reasonable residual strain at break is retained, the absorber material is useable. Testing of candidate polymeric absorber materials is continuing.

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