# Durability of Polymeric Materials for Solar Hot Water Collectors

Gary J. Jorgensen, Kent M. Terwilliger, Carl E. Bingham
National Renewable Energy Laboratory (NREL), Golden, CO, gary_jorgensen@nrel.gov

## ABSTRACT

The cost of solar collectors can be reduced by using polymeric glazing and absorber materials, but the durability of their optical and mechanical properties must be demonstrated. A number of new candidate polymeric glazing constructions were tested that exhibited ultraviolet (UV) stability in terms of optical durability. The impact strength of several candidate glazing materials was measured as a function of UV exposure time. Measurable losses in impact resistance for non-UV-screened constructions were found. Mechanical creep was also measured as a function of temperature and applied stress for two candidate absorber materials. These creep data suggest that such absorber materials are adequate for solar applications.

## 1. Objectives

Improved polymeric glazing and absorber materials are required to increase the reliability of cost-effective solar collectors. As discussed in the DOE 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. Both passive solar water heating and active cold-climate solar water heating technologies require polymeric glazings and absorbers to survive in harsh operating environments.

To address these needs, the objectives of this research are to: (1) identify alternative polymeric materials/constructions that will allow design trade-offs that can help reduce the costs associated with solar water heating (SWH) systems, and (2) perform materials testing to demonstrate whether such candidate polymers will meet the durability requirements for real systems. This task complements and supports the Low-Cost Systems Development/Low-Cost Polymers activities. Materials are evaluated and recommended to private-sector partners for use with their prototype systems. We also test materials that are of interest to the project's subcontractors.

## 2. Technical Approach

The primary property of interest for candidate polymeric materials is the ability to avoid optical and/or mechanical degradation (yellowing and embrittlement) during exposure to elevated temperatures 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 laboratory-controlled accelerated-weathering chambers, and at NREL's unique UV-concentrator facility. Optical transmittance and mechanical impact strength are measured as a function of exposure time and conditions.

To assess the mechanical stability of candidate polymeric absorber materials, creep is measured as a function of temperature and applied stress.

## 3. Results and Accomplishments

The optical and mechanical durability of a number of candidate glazing materials was quantified. A creep-compliance master curve was generated for two candidate polymeric absorbers of interest to a private-sector company planning to manufacture collector systems using these materials.

### *3.1 Glazing Materials*

We have previously found that polycarbonate (PC) laminated to an acrylic UV-screening film (Korad®, a product of Polymer Extruded Products) can be UV weatherable.[1] 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.

Interactions were held with material suppliers to identify several new types of polymeric glazing materials. Two major polymer manufacturers 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.

Prospective solar manufacturers are also considering non-PC glazing materials, including impact-modified acrylic (IMA) and fiberglass-reinforced polyester (FRP). Solar-weighted transmittances for some of these more recent samples are shown in Fig. 1. Most of these materials are maintaining optical performance after a cumulative UV dose equivalent to about 5 years outdoor exposure in Miami, FL. Longer-term exposure testing of these materials is ongoing.

The impact strength of several candidate glazing materials has also been measured and found to degrade as a function of exposure time in our XR-260 WOM. The impact strength of PC is substantially greater than for IMA. The initial impact strength for 2.3-mm-thick PC is 32.1 ± 0.25 J, whereas the unweathered value for 2.2-mm-thick IMA is 0.17 ± 0.03 J. Furthermore, IMA lost ~25% impact strength in less than 1-year equivalent outdoor exposure. The behavior on impact of these two glazing materials is also quite different. The PC generally fails by cracking around the perimeter of permanently deformed dimples, whereas the IMA typically cracks or shatters at the impact site without any plastic yield.

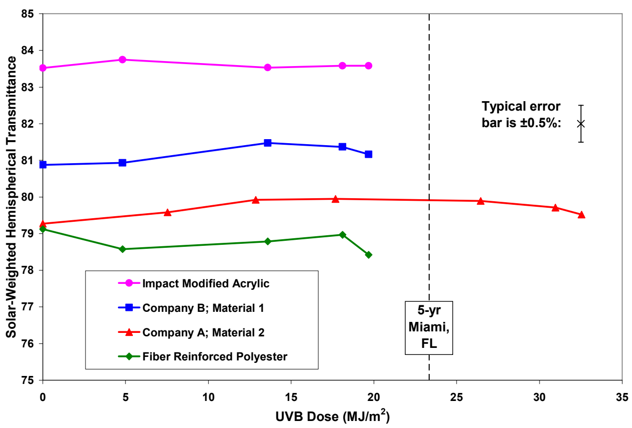


Fig. 1. Solar transmittance as a function of UVB dose for candidate glazing polymeric materials exposed at NREL's UV concentrator at 70°C.

*3.2 Absorber Materials*

Industry partners have identified two absorber materials that we have tested, namely, polypropylene (PP), including PP random copolymer (PPR), and metallocene-based multi-density polyethylene (MBMDPE). Creep is an important concern for absorber materials. Severe deformations can result in elevated stress concentrations that can result in cracking. If absorber bulges reach the glazing, then thermal performance is catastrophically compromised.

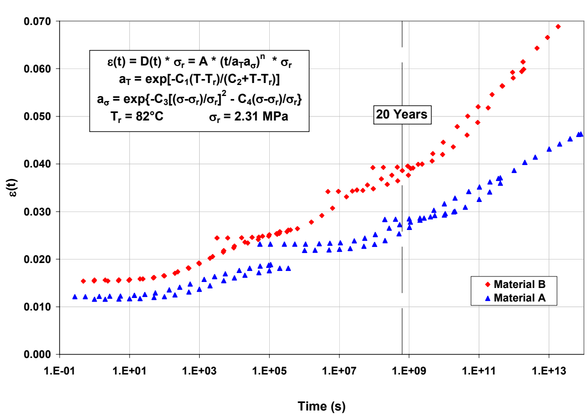


Fig. 2. Strain for PPR obtained from creep compliance master curve for reference conditions of 82°C and 2.3 MPa.

Creep has been measured for both MBMDPE and PPR. Results for MBMDPE were previously reported.[2] For PPR, samples of two materials (A and B) were tested at 82°C / 2.3 MPa (the reference conditions), 100°C / 2.3 MPa, 100°C / 3.4 MPa, 75°C / 3.4 MPa, and 110°C / 2.8 MPa. The data sets were then used to derive transformation equations to allow extrapolation to extended times at the reference conditions, as shown in Fig. 2. The resulting strain values after 20-years service are about 2.7% for material A and 3.8% for material B at the design reference conditions. Significant surface oxidation was also visible for material B during the creep measurements.

## 4. Conclusions

Several new constructions of glazing material have demonstrated optical durability for ~5-years equivalent exposure in Miami, FL. These constructions include UV-screening clear-coats applied to polycarbonate as provided by two industry collaborators. An impact-modified acrylic and an improved fiber-reinforced polyester glazing have also shown similar optical durability, although the impact resistance (both initially and after weathering) may not be adequate.

The mechanical creep properties of MBMDPE and PP absorber materials were measured as a function of temperature and applied stress. These creep results suggest that such absorber materials are adequate for solar applications.

Based on this work, our future efforts will include continued testing of UV stability of new candidate polymeric glazing constructions including thin films, providing support for development of standards for hail testing of evacuated tube collectors, and continued long-term testing and evaluation of candidate polymeric absorber materials.

## ACKNOWLEDGEMENTS

Jay Burch of NREL provided support and many useful discussions. This work was performed under DOE contract DE-AC36-99-GO10337.

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