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Polymeric Glazings

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POLYMERIC GLAZINGS

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Polymeric glazings are used as coatings to protect silver mirrors and as free-standing films to protect other solar system elements. Experiments are in progress to evaluate and improve films for these applications.

Introduction

Polymer-glazed mirrors may provide lower-cost alternatives to current glass mirror designs. The glass mirror fields account for about half of the cost of a central receiver power system, and it is estimated that central receiver system costs need to be halved to be economically viable. Polymer-coated aluminum mirrors have been used in field tests that indicate life spans of at least several years. The (solar-weighted) reflectance of aluminum mirrors is limited to about 85% by the aluminum, while polymer-coated silver mirrors can have reflectances of 96%. System studies suggest that the difference in reflectances can have an important cost impact that probably will exclude the use of aluminum. Polymer-protected silver mirrors that can withstand outdoor use with sufficient lifespans are not yet developed. This study was undertaken to evaluate polymer-coated silver mirrors with reflectances greater than 90% that can approach a lifespan of five years.

Results

Evaluation of silver mirrors has been initiated and is continuing, using real-time outdoor screening tests along with accelerated weathering devices

(Weather-Ometer* and QUV**). Mechanistic studies of degradation processes are also in progress [1,2]. The experimental approach is multifaceted. Metallized films currently available from industrial sources are tested, commercially available polymeric films are silvered and tested, and polymeric films are formed (solution cast or plasma polymerized) onto silver films, which are deposited on a glass substrate for testing.

The metallized films from industrial sources are identified in Table 1 (series 107, 207, 507, 407). The first film (FEK 244) is the only aluminized film documented in this study. It is used as a standard comparison material because long-term outdoor data for FEK 244 exist. The solar-weighted, hemispherical reflectances are listed before degradative exposure, after four weeks exposure in the Weather-Ometer, and, for other samples, after six-weeks outdoor exposure. Similarly, values are listed for the coated silver mirrors: polycarbonate (PC), acrylic/polyester (YS94), and Teflon (FEP). Polycarbonate mirrors discolored significantly, and their testing was discontinued. The other materials are essentially unchanged during these initial, short-term tests. As noted earlier, the reflectance of aluminized mirrors is limited to about 85% while silver mirrors yield about 95%. The materials of Table 1 are being supplemented by other commercial polymeric films [Teflon, polymethylmethacrylate (PMMA), polyacrylonitrile (PAN)] that are silvered using vacuum sputtering and then coated with a protective backing (sputtered aluminum or Inconel, FEK 244, Scotch tape, PMMA, PAN).

Empirical evidence has shown that PMMA is stable during long-term outdoor exposure [3] and the field experience with FEK 244 demonstrates that PMMA can protect aluminum. We are emphasizing PMMA coatings, recognizing that pure PMMA probably will not provide sufficient protection for silver [4]. Table 1 also lists a series of PMMA and PAN films solution-cast onto silver films that were deposited on glass (Corning 7809). The silver films for these samples were formed on glass using the wet chemical process (series 607, 707, 807,

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*Weather-Ometer is a registered trademark of the Atlas Electric Devices Company, Chicago, Ill.

**OUV is a registered trademark of the Q-Panel Company, Cleveland, Ohio.

Table 1. Exposure Results

Series	Product	Company	Solar-Weighted Averages (Hemispherical Reflectance) Weather-Ometer Initial	Weather-Ometer 4 Weeks	Outdoors 6 Weeks
107	Acrylic/AL (FEK 244)	3M	85.5	85.5	85.5
207	PC/AG/Mylar	Sheldahl	92.3	84.0	84.9
507	PEst/AG (YS94)	3M	96.3	96.0	94.0
407	Teflon/AG/Inconel (FEP)	Sheldahl	95.6	94.6	95.1
607	PMMA/AG/7809 (1% National Starch)	SERI	87.0	78.9	84.3
707	PMMA/AG/7809 (1% Uvinol 400)	SERI	88.0	67.3	87.0
807	PMMA/AG/7809 (1% Tinuvin P)	SERI	87.3	87.9	86.4
907	PMMA/AG/7809	SERI	87.9	77.9	86.2
117	PAN/AG/7809	DU	87.9	88.4	88.0
	PMMA/AG_{SP}/7809	SERI	93.6	--	--

907, 117). The reflectances for these samples are only about 88% compared to the last entry of Table 1 where the reflectance is about 94%. The latter sample is different in that the silver is vacuum-sputtered onto the glass, and we have observed the same improvement in reflectance with PAN film on vacuum-sputtered silver compared to wet-processed silver.

A series of experiments demonstrates that the diminution of reflectance using wet-processed silver is not a chemical effect. For example, wet-processed silver has a reflectance of about 96% before being coated by PMMA, although after coating, the reflectance drops to 88%. When the PMMA film is redissolved with the same type solvent, the reflectance of the silver returns to its original value, 96%, and transmittance measurements of the redissolved polymer compared to the original polymer solution are also unchanged. Polymer coated onto wet-processed silver has a slight yellow hue that is not present when vacuum-sputtered silver is used. The yellowing phenomenon is observed for different polymer types or even when a drop of solvent (toluene) is deposited on bare silver. We conjecture that the surface of wet-processed silver is rougher than that of vacuum-sputtered silver, resulting in the loss of reflectance. The effect on reflectance is illustrated in Figure 1 where the initial reflectance of PAN/Ag/7809 (series 117, Table 1) is shown as a function of wavelength. The dip in reflectance at 0.4 μm is absent when sputtered silver is used.

Table 1 illustrates that, in general, Weather-Ometer tests are harsher than outdoor exposures for PMMA samples. Three ultraviolet screens are included in this initial test set, and the Tinuvin P/PMMA (series 807) sample demonstrates an improved stability. Similarly, pure PAN film is unchanged in the Weather-Ometer tests; however, outdoors it partially delaminated. Where the PAN film had not delaminated, its reflectance was unchanged (series 117, Table 1). For PAN the outdoor tests were harsher than the Weather-Ometer. Laboratory experiments at the University of Denver, Colo., have shown that the adhesion of PAN to silver can be improved, and tests are in progress to determine if adhesion is also improved for outdoor exposures.

Mechanistic studies of photodegradation of PMMA/Ag mirrors have corroborated the empirical observation that PMMA is stable in sunlight [1]. PMMA-coated

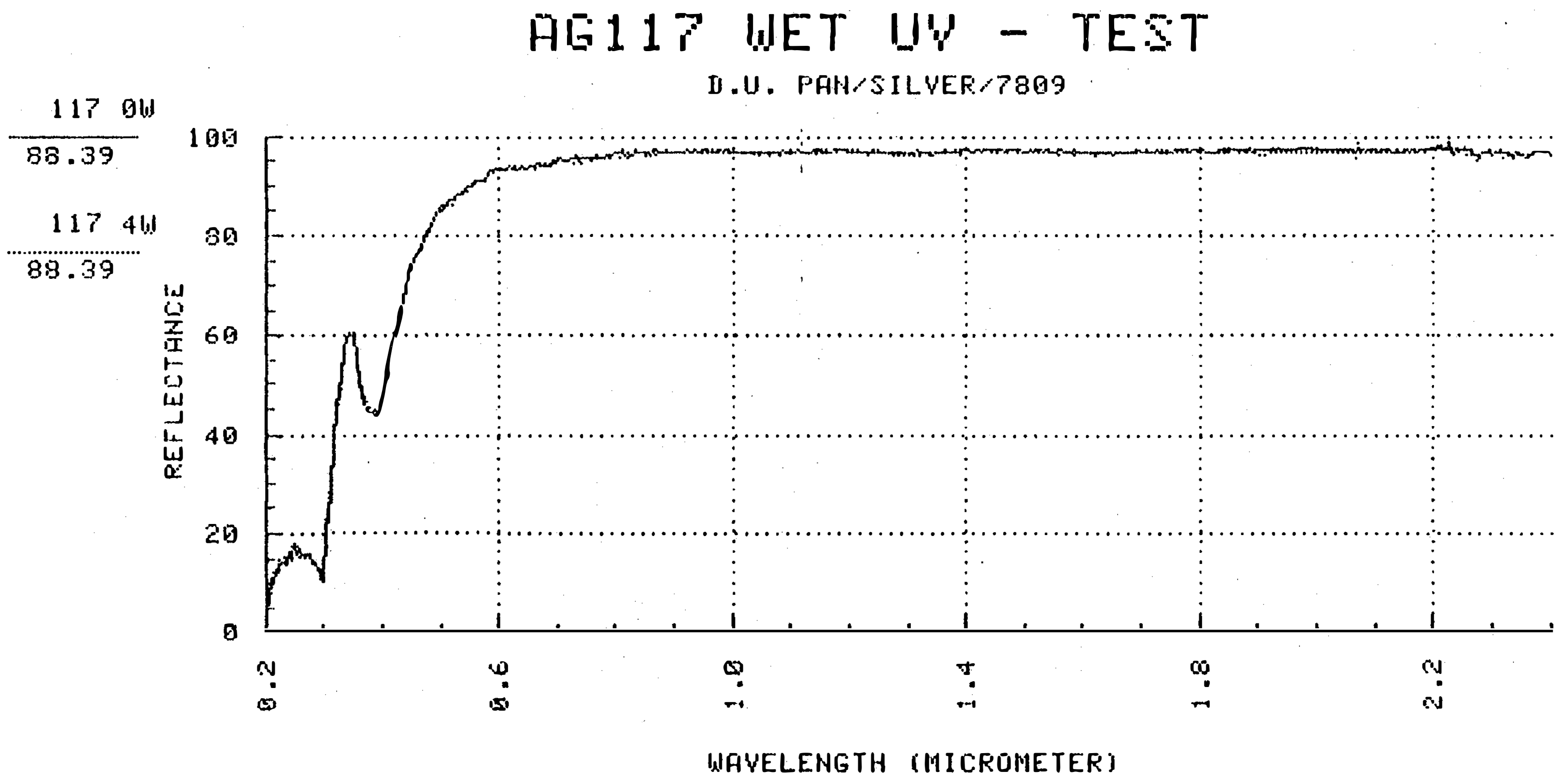

Figure 1. Reflectance Versus Wavelength, 7809 Glass Substrate, Wet-Processed Silver-Cast Polyacrylonitrile

mirrors have been studied in a controlled environment (ultraviolet, temperature, ambient atmosphere, etc.) in a configuration that allows direct observation of the chemical changes using infrared spectroscopy. A comparison of the accelerated degradation of PMMA/Ag mirrors with and without chlorine contamination on the silver is available [1]. Without chlorine no changes are observed in the infrared spectra after exposure to ultraviolet radiation for 3.75 h with a solar wavelength distribution, but with the intensity increased by a factor of 16. If the silver surface is contaminated with chlorine (by exposure to HCl, Cl_2, or by use of AgCl rather than Ag) before PMMA is solution-cast onto the mirror and then the degradation is carried out similarly to the chlorine-free case, changes in the infrared spectra are observed in only one minute. The polymer is now photosensitized to solar radiation. We conjecture that solar photons can produce chlorine radicals that react with the PMMA [5]. Measurements are planned to determine if chlorine sensitization or effects of other atmospheric pollutants are involved in mirror failures during outdoor use.

One approach to lowering mirror costs is to use the stretched membrane concept where the metallized polymeric film is only rim-supported (see companion paper by L. M. Murphy). Other, nonmetallized applications for glazings also require good mechanical properties in addition to the optical properties for polymeric films. One example is the dome concept where a thin polymeric film is air-supported to enclose a polymeric-mirror heliostat. Work on chemically-bound ultraviolet screens to stabilize laminated polymeric films is in progress (see companion paper by R. Liang).

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References

1. Webb, J. D. et al., Polymer Degradation on Reflecting Metal Films: Fourier Transform Infrared (FTIR) Reflection-Absorbance Studies, SERI/TP-255-2054, Golden, CO: Solar Energy Research Institute, 1983.

2. Smith, D. M., private communication, Denver, CO: University of Denver, August 1983.

3. Rainhart, L. G., and Schimmel, W. P. Jr. Solar Energy, Vol. 17, 1975, p. 259.

4. Brauman, S. K., MacBlane, D. B., and Mayo, F. R., Reactivity of Polymers with Mirror Materials, Subcontract No. XP-9-8127-1, Golden, CO: Solar Energy Research Institute, 1982.

5. McNeill, I. C., and Neil, D., Eur. Polymer J., Vol. 6, 1970, pp. 143, 569.