Outdoor Testing Program Goes International

SunLab's outdoor testing program has recently taken on an international flavor. Working with counterparts in Europe, SunLab researchers have added two new testing sites in Spain and Germany to the outdoor exposure testing network. Also, with an eye toward emerging solar energy markets in the third world, project researchers established a new testing site in Miami, Florida, which emulates the hot, humid conditions found in many developing countries. With these new additions, the outdoor testing program now comprises eight sites in the United States and Europe.

Begun in 1992, the program is determining the effect of prolonged outdoor exposure on the optical performance of solar reflector materials. Researchers will correlate data collected from these sites with data from accelerated laboratory tests, greatly improving their ability to predict the service lifetimes of reflector materials. Similar correlation techniques are used extensively in the automotive industry to predict the deterioration of automobile paint.

A researcher examines samples at the outdoor test site at the National Renewable Energy Laboratory in Golden, Colorado. Setups similar to this are used at the other sites in the United States and Europe.

Optical Materials Research at SunLab

SunLab's optical materials research team develops low-cost, high-performance advanced optical materials for solar-thermal applications. The team conducts basic research and analysis on the fundamental properties that influence material performance; tests, characterizes, and evaluates candidate materials; and collaborates with the solar and materials industries to develop, and test optical materials.

The eight outdoor test sites, listed in the box on page 2, are the backbone of the program. Researchers selected these sites based on input from utilities and the solar industry. Each site has unique geographic, meteorological, and atmospheric characteristics that affect the weathering process. An array of monitoring equipment at each site samples ambient conditions every 10 minutes; this information is downloaded to a central data station at the National Renewable Energy Laboratory (NREL) in Golden, Colorado.

Each site contains two 12-foot-by-4-foot racks on which the reflective material samples and monitoring equipment are mounted. Researchers typically test 4-square-inch samples, but large samples (up to 4 square feet) are also tested to evaluate size-dependent weathering effects.

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Outdoor Testing Program
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Researchers are testing a wide variety of reflector materials, including glass/metal mirrors, metalized polymer reflectors, front-surface reflectors, thin glass mirrors, and other advanced experimental reflectors. Every 6 to 12 months, the samples are sent back to the laboratory where their hemispherical and specular reflectance are measured. After testing, the samples are returned to the field. In this way, researchers are collecting an extensive amount of data on how these reflective materials degrade over time under varying environmental conditions.

The two new European testing sites—at Almería, Spain, and Köln, Germany—are exciting additions to the outdoor testing program. They expand the volume of data available on reflector durability, and they are an encouraging step toward international cooperation within the solar community. The two sites are being monitored by researchers under the auspices of the International Energy Agency.

The newest domestic site in Miami will allow researchers to evaluate how reflector materials perform in a humid, corrosive coastal environment. The data collected from this site will be particularly important to the solar industry, which is interested in expanding into developing countries, many of which have tropical or semitropical climates.

By correlating the outdoor test results with results from indoor accelerated tests, researchers are better able to predict the service lifetimes of reflector materials. Although the formal testing program is less than 3 years old, certain weathering trends are becoming apparent. For example, total ultraviolet exposure is proving to be the single most detrimental influence on sustained reflectance. Temperature also appears to play a role in degrading optical performance; certain samples at the test site in Tempe, Arizona drop below 90% hemispherical reflectance within 18 months, while duplicate samples at the site in Golden, Colorado, have remained above 90% reflectance for more than 4 years.

The outdoor testing program is producing similar results on several different optical materials in a variety of climates. The program is maturing into an important component of the continuing quest for low-cost, high-performance optical materials for solar concentrator applications.

Under One Roof: SunLab Convenes Industry Advisory Panel

It never hurts to get a second opinion. Taking this old adage to heart, researchers within SunLab's optical materials group convened the first meeting of the Optical Materials Industry Advisory Panel last June. The panel comprises representatives from organizations—such as utilities, solar equipment manufacturers, and optical materials manufacturers—that have a direct interest in SunLab’s optical materials research. Organizers believe the panel, which is scheduled to meet annually, will ensure SunLab’s research in optical materials is closely aligned with the needs and long-term goals of related industries.

Recognizing that industry buy-in is critical to the ultimate success of its research endeavors, SunLab established the industry panel to assess research priorities, suggest directions for future research and development, improve communication between researchers and industry, and determine mid- and long-term cost and performance goals. Through such interaction, industry gains a clear understanding of SunLab’s research emphases, and SunLab researchers learn first-hand industry’s perspective on the current and future value of optical materials research.

The panel comprises representatives from the industry and utility sectors, including representatives from Solar Kinetics, Inc.; Industrial Solar Technologies, Inc.; Science Applications International Corporation (SAIC); KJC Operating Company; Arizona Public Service; Cummins Power Generation; and Sheldahl, Inc.

At the inaugural meeting in June, SunLab researchers presented a general overview of their research, explaining their goals for developing marketable advanced reflector materials and describing the in-house and subcontracted R&D. Industry and utility participants presented their respective views.

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Outdoor Test Sites

- Rancho Seco Nuclear Generating Station, Sacramento, California.
- APS Ocotillo STAR Center, Tempe, Arizona.
- Cummins Power Generation Company, Abilene, Texas.
- Solar Two Project, Barstow, California.
- South Florida Test Service, Miami, Florida.
- Plataforma Solar de Almería, Almeria, Spain.
- DLR, Köln, Germany.
Researchers Develop High-Performance Selective Absorber.

SunLab researchers have developed a non-black, chromium-based solar selective coating that exhibits a solar-averaged absorptive value of approximately 0.96, with a thermal emittance of approximately 0.15 at 100°C. The coating, which can be applied to a substrate in either a batch- or strip-coating process, is stable at 350°C; such high thermal stability may allow the coating to be used in parabolic concentrator systems.

SunLab is negotiating with a solar flat-plate collector manufacturer to jointly commercialize this coating, and project researchers are currently identifying production process control requirements and are scaling up the laboratory strip-coating process.

Under One Roof: SunLab

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on the state of optical materials research and discussed the direction of future research.

The panel reached a consensus on a number of issues, and many of their suggestions have been integrated into fiscal year 1996 activities. The panel believes SunLab research should diversify beyond its current emphasis on silvered-polymer materials, expand research on glass reflectors, and include research on selective absorber surfaces and other optical coatings; they believe diversification is necessary given that different solar applications—such as troughs, dishes, and heliostats—have different optical requirements.

Panel members noted that SunLab’s materials research program is extensive, but outside interests know little about it. They suggest SunLab improve communications with industry by disseminating research papers, placing articles in appropriate journals, and distributing materials describing capabilities and research thrusts.

This newsletter, in fact, is part of our response to the panel’s recommendations.

Although the panel commended SunLab’s current research program, members believed stronger ties with industry are needed. Specific recommendations for achieving this include (1) consulting with industry on systems issues that affect the optical materials R&D process, (2) improving field testing through closer cooperation with industry, and (3) continuing to support industry with standardized optical characterization services. Readers of this newsletter will be kept informed as these recommendations are integrated into the optical materials research program.

Participants considered the inaugural meeting very successful and mutually beneficial. Panel members are planning to meet annually in hopes of strengthening cooperation, mutual understanding, and communication among the optical materials community.

SAIC Tackles Manufacturing Issues and Diamond-Like Coatings

Science Applications International Corporation (SAIC) in McLean, Virginia, and SunLab are jointly investigating methods to manufacture an alumina-coated reflector in high volumes. Participating researchers are using ion-beam-assisted deposition (IBAD) to coat silvered mirrors with a thin layer (0.5-4.0 μ) of alumina (Al₂O₃). This construction, shown above, was selected for study because of its potentially high cost (less than $1 per square foot) and high durability. In addition to determining optimum material configurations, project researchers are identifying the production-specific factors that will influence scaled-up manufacturing. They are also developing cost estimates for low-, intermediate-, and high-volume production based on laboratory and scaled-up test data.

In a different joint project, SAIC in San Diego, California, and SunLab are investigating diamond-like carbon (DLC) coatings to protect metallized polymer reflective materials. The basic material configuration is also shown above. DLC coatings are impermeable and extremely resistant to abrasion, but their brownish hue and high deposition temperatures have precluded use in solar applications. Diamonex, Inc., a subcontractor to SAIC, has developed a proprietary process that overcomes these problems. In early experiments, project researchers have deposited 5.0 μ of DLC onto 8-inch disks of PET film; the samples showed no evidence of thermal damage, exhibited good adhesion between the DLC and the substrate, and contained no performance-degrading tint.

Experimental Reflector Construction Demonstrates Exceptional Optical Durability

SunLab researchers have filed a patent for a new reflector construction that has demonstrated outstanding durability in initial accelerated exposure tests. The reflector’s durability appears to result from a proprietary organized molecular assembly (OMA) layer deposited between the reflecting silver layer and a protective polymethylmethacrylate (PMMA) layer. Researchers believe the OMA layer improves the adhesion between the silver and the PMMA and prevents corrosion at that interface.

After 8 months of accelerated exposure testing, the experimental reflector’s solar-weighted hemispherical reflectance remained.

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unchanged at 95.4%. After 11 months, some optical degradation had occurred, and the average reflectance for three samples dropped to 87%. SunLab researchers are continuing experiment with this OMA-containing reflector, and a new series of durability tests are planned.

Delamination in Dish Reflector Facets Fixed

SunLab researchers recently demonstrated ways to avoid delamination—or “tunneling”—in facets that use tensioned ECP-305+ as the reflector material. ECP-305+ is a promising silvered-polymer material that has excellent reflective properties and can be produced inexpensively. During the summer of 1994, 50% of the ECP-305+ facets used in a Dish-Stirling demonstration project in Abilene, Texas, experienced some tunneling after several severe rain storms.

In the months that followed, SunLab researchers duplicated the tension and bonding conditions existing in the facet design and subjected numerous samples to a series of accelerated weathering tests in the laboratory, including cyclic water immersion and periodic showering. Three factors related to improved adhesion—membrane stress, edge sealing, and heat treatment—were examined during the investigation.

Using a calibrated depth-cutting device that cut through the ECP-305+ film but not through the polyester substrate, researchers relieved the stress on the film where it is mounted to the rim of the facet. They also experimented with two types of edge protection (Silglaz II caulking and Tedler tape), and they heat treated the film both before and after tensioning.

After 137 days of accelerated testing, none of the stress-relieved samples had delaminated. The polymer film used in ECP-305+ is a brittle acrylic, and these tests indicate that this layer is susceptible to cracking, and therefore delamination, when flexed excessively. This experiment also showed that Tedler tape is superior to caulk in sealing the edge of the reflective film. Heat treatment did not affect the ability of the tensioned samples to resist delamination.

Industrial Solar Technologies (IST), a solar concentrator manufacturer that uses ECP-305+ in many of its products, has incorporated these edge-protection strategies in their manufacturing process, and very few delamination failures have subsequently occurred in concentrators that IST has installed in the field.

Publications


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