Thermal Systems Group: CSP Capabilities

Advanced Reflector and Absorber Materials

The National Renewable Energy Laboratory (NREL) can test and develop optical materials—mirrors and receiver tube coatings—which are the major components of the solar field of concentrating solar power (CSP) systems. In evaluating the performance of these materials, we can help to improve the overall efficiency of CSP plants. Because the solar field accounts for nearly half the total plant construction cost, an increase in optical efficiency can be a significant step toward making CSP competitive with fossil fuels as a utility-scale energy source.

Ideally, we want reflector materials in a CSP plant to last 20 to 30 years and cost less than $2.50 per square foot (or $25 per square meter) to manufacture. Highly specular mirrors should have better than 95% reflectance into a 4-milliradian full-cone angle and should resist soiling in all outdoor conditions. NREL focuses on achieving these goals by creating and applying testing procedures that accurately predict the performance and lifetime of materials. Some testing is relatively brief, lasting several weeks, whereas other processes may take several months or even years.

We evaluate the potential of reflector (mirror) and absorber (receiver) materials in the three areas described below, working with our industry partners to develop technologies that will move CSP toward economic parity with electricity generated by coal and natural gas.

Evaluating Performance

NREL evaluates the performance of mirrors, solar-selective coatings, glazings, lenses, and glass by measuring reflectance, transmittance, and absorptance. We also test for tensile strength, adhesion, permeability, and scratch resistance. In many cases, our partners submit samples for testing as a step in developing a new product.

For mirrors, we measure both hemispherical and specular reflectance, using ultraviolet-visible-near infrared (UV-Vis-NIR) spectrophometers and specular reflectometers. In 2010, NREL will add the capability to measure the specular reflectance of mirrors in a variety of cone angles across the entire solar spectrum. This added capability will enable us to rapidly measure the solar-weighted specular reflectance to determine how much light is being scattered from a mirror's surface for all CSP technologies.

For solar-selective coatings, we measure the following parameters: solar absorptance (with a goal of greater than 96%); thermal emittance (with a goal of less than 7%); and oxidation resistance at high temperatures (with a goal of 650ºC operating temperature). We use the UV-Vis-NIR spectrophotometer to measure solar absorptance and an infrared spectrophotometer to measure emittance between 2.5 and 50 micrometers. Using hand-held instruments, our researchers can measure emittance at ambient temperature and determine emittance by fitting to the blackbody temperature of interest.

PIX 16817; NREL

Working at NREL, visiting scientist Florian Sutter of the German Aerospace Center (DLR) builds a space-resolved specular reflectometer, which can be used to measure the amount of light scattered from a mirror's surface in a CSP plant.

NREL will also be adding the capability of measuring absorption and emittance of curved surfaces at operating temperatures. This will allow our partners to understand the optical properties of their receiver tubes at real-world operating temperatures.

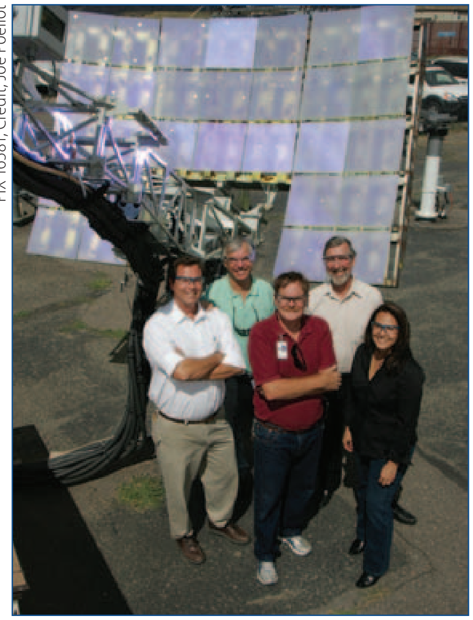
Determining Degradation Rate and Lifetime

We expose samples to a variety of natural outdoor and accelerated exposure tests to determine their rate of degradation and to estimate lifetime. Typically, we measure samples until they have degraded by 10% of their initial value. The samples are measured at regular intervals over a period of months and years, which helps to ensure that a new product meets desired optical requirements and avoids failure in the field.

NREL has developed a Service Lifetime Prediction methodology that allows us to predict the lifetime of a sample with as little as 12 to 18 months of accelerated exposure testing. Our exposure chambers simulate a variety of conditions, including sunlight, various temperature and humidity levels, rain, freeze/thaw, hail, and salt spray. Chambers use xenon arc light that accelerates light exposure by a factor of 7.5.

The testing chambers run 24 hours a day, seven days a week, replicating specified conditions on an ongoing basis. The newest weatherometers simulate the freeze/thaw cycle and rain with light exposure. Some testing may accelerate outdoor weathering by a factor of 30, helping to identify potential long-term problems. Scientists can then determine failure mechanisms and develop strategies to mitigate possible product failures.

To ensure that accelerated exposure testing replicates the failure mechanisms observed, leading to the most accurate results possible, we test samples outdoors at three testing facilities that represent different environmental conditions: Atlas Weathering Service DSET Laboratories (Phoenix, Arizona); NREL (Golden, Colorado); and Atlas Weathering Service South Florida Test Service (Miami, Florida).



PIX 16581; Credit, Joe Poellot

NREL and Atlas Material Testing Technology researchers stand before the Ultra-Accelerated Weathering System, an ultraviolet solar concentrator that won an R&D 100 Award for innovation in 2009. The system replicates the effects of years of outdoor weathering in very abbreviated timeframes.

PIX 17034; Credit, Pat Corkery

Researchers in NREL's Thin Film Deposition Laboratory develop mirror and solar-selective coatings to improve the efficiency of CSP systems. Here, Senior Scientist Cheryl Kennedy is holding a sample in the evaporation chamber of the three-chamber deposition system.

Candidate samples are submitted to all three sites for exposure, and a standard series of accelerated tests is performed in parallel to outdoor testing. NREL can currently expose solar-selective coatings at high temperatures in an inert gas environment. In 2010, we will add the capability of exposing solar-selective materials at operating temperatures in a vacuum, enabling our partners to determine the reliability of their receiver tubes at real-world operating temperatures.

Developing New Coatings

In NREL's Thin Film Deposition Laboratory, we develop new mirror and solar-selective coatings and determine if they will provide improved optical performance and durability. We use a three-chamber system:

- First, we place a sample in a load-lock chamber, where it is pumped down to a vacuum before it moves into the deposition chambers.
- Second, the sample is coated, using pulsed direct-current sputtering in another chamber. For example, an aluminum target can be bombarded with heavy argon molecules, which sputter off aluminum and coat the substrate with the metal.
- Third, an electron beam in a final chamber evaporates molecules, and an ion gun is used to compact them in the coating, thus creating a dense "hard coat."

This process helps to develop new coatings that cost less than current ones and have better optical qualities and to produce mirrors and receivers that are easier to install and maintain. One new solar-selective coating developed in the laboratory was recently commercialized, based on its excellent properties of high absorption, low emittance, and resistance to oxidation.

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